UNIVERSITY OF MARYLAND

COFFMAN ENGINEERS

EPIDEMIC PREPAREDNESS FOR OUR BUILDINGS

University of Maryland Fire Protection Department in Collaboration with Coffman Engineers

July 28, 2020

University of Maryland, Dr. Jim Milke, Ph.D., PE
milke@umd.edu
Coffman Engineers, Traci Hanegan, PE, FASHRAE
traci.hanegan@coffman.com

Administration

AIA Continuing Education

- Course Title:
  - Epidemic Preparedness for Our Buildings
- Course Number:
  - 401104252C18
- Provider Number:
  - 401104252
- Presenters:
  - Dr. Jim Milke
  - Traci Hanegan
- Date:
  - 28 July 2020
- AIA Credit:
  - 1 LU | HSW

Learning Objectives

1. The scientific background of COVID-19 transmission through a building and how this affects design.

2. How the built environment can be modified to mitigate risk of COVID-19 transmission and protect the health and welfare of occupants.

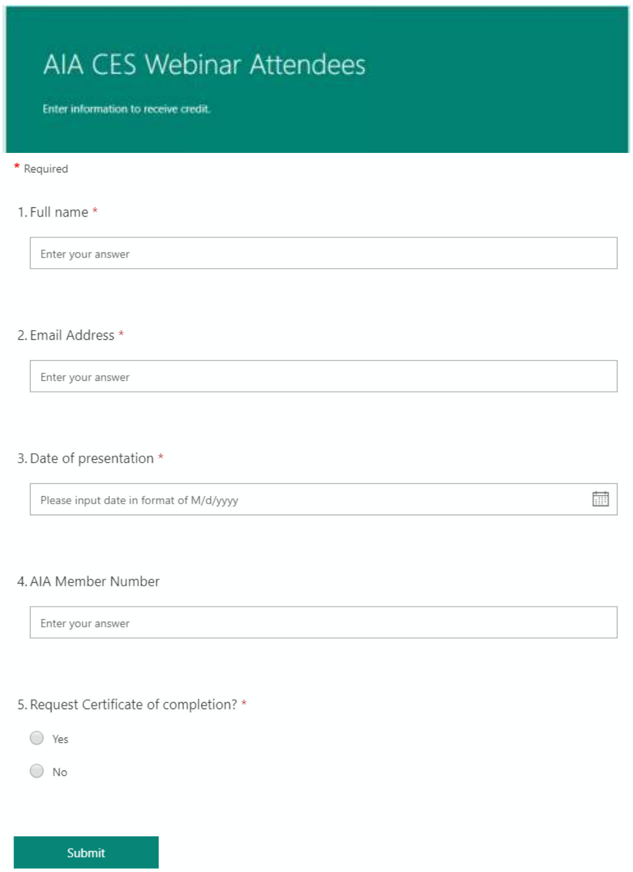
3. Describe impacts of dry indoor air on the human body, the microbiome of the built environment, and the transmission of disease-causing microbes

4. Describe the new research supporting the health benefits of balanced indoor-air hydration.

Administration

AIA Continuing Education

- Online Registration:
  - *Course Link*



AIA CES Webinar Attendees

Enter information to receive credit.

* Required

1. Full name *

Enter your answer

2. Email Address *

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3. Date of presentation *

Please input date in format of M/d/yyyy

4. AIA Member Number

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5. Request Certificate of completion? *

Yes

No

Submit

Introduction

- Introduction
- Transmission Pathways
- Indoor environment impact on our health
- HVAC system resiliency
- Conclusion

Introduction

Jim Milke, PhD, PE, FSFPE

- Professor and Chair
  Fire Protection Engineering, UMD
- Academics
  - BS, Physics, Ursinus College
  - BS, Fire Protection Engineering, UMD
  - MS, Mechanical Engineering, UMD
  - PhD, Aerospace Engineering, UMD
- Specialties
  - Smoke control systems
  - Response of people to fire
  - Advanced fire detection

Introduction

Traci Hanegan, PE, FASHRAE, HFDP, LEED AP

- Principal, Mechanical Engineering
  Coffman Engineers
- Academics
  - BS, Mechanical Engineering, U. of Idaho
  - MS, Mechanical Engineering, U. of Idaho
- Specialties
  - Healthcare and laboratory design
  - Infection control
  - Epidemic preparedness

Re-opening Considerations

Business needs

Risk of transmission

Mitigation efforts

Developing Plans for Reopening

Individual behavior

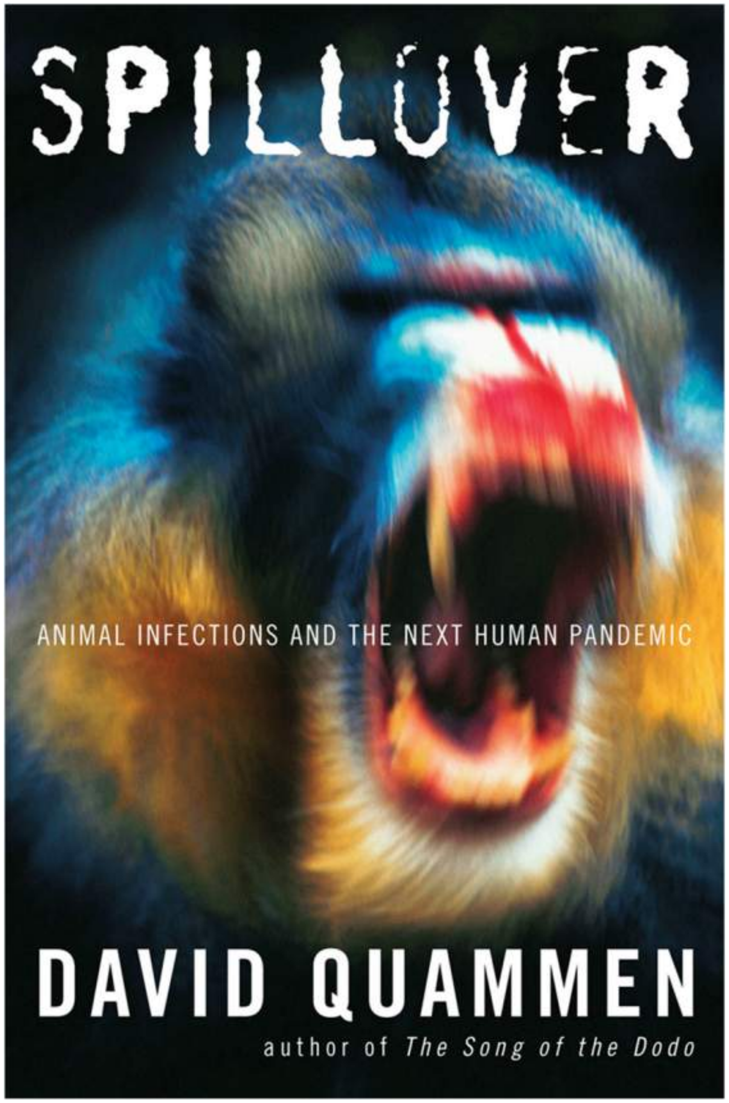
- Health checks
- Face coverings, hand-washing

Physical and Social distancing

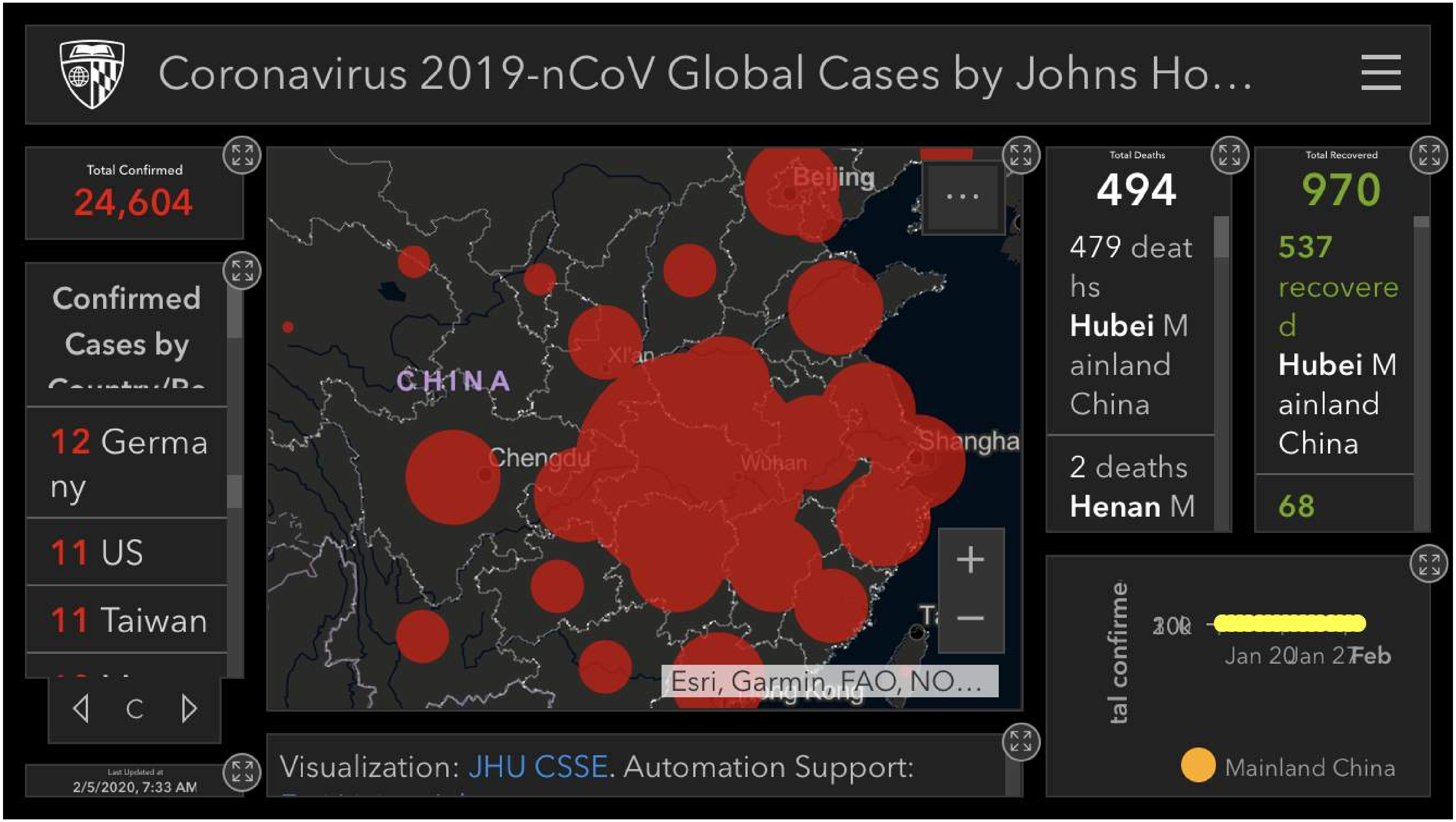
- Pedestrian plans for buildings
- Separation once at desired location within building

Building HVAC system

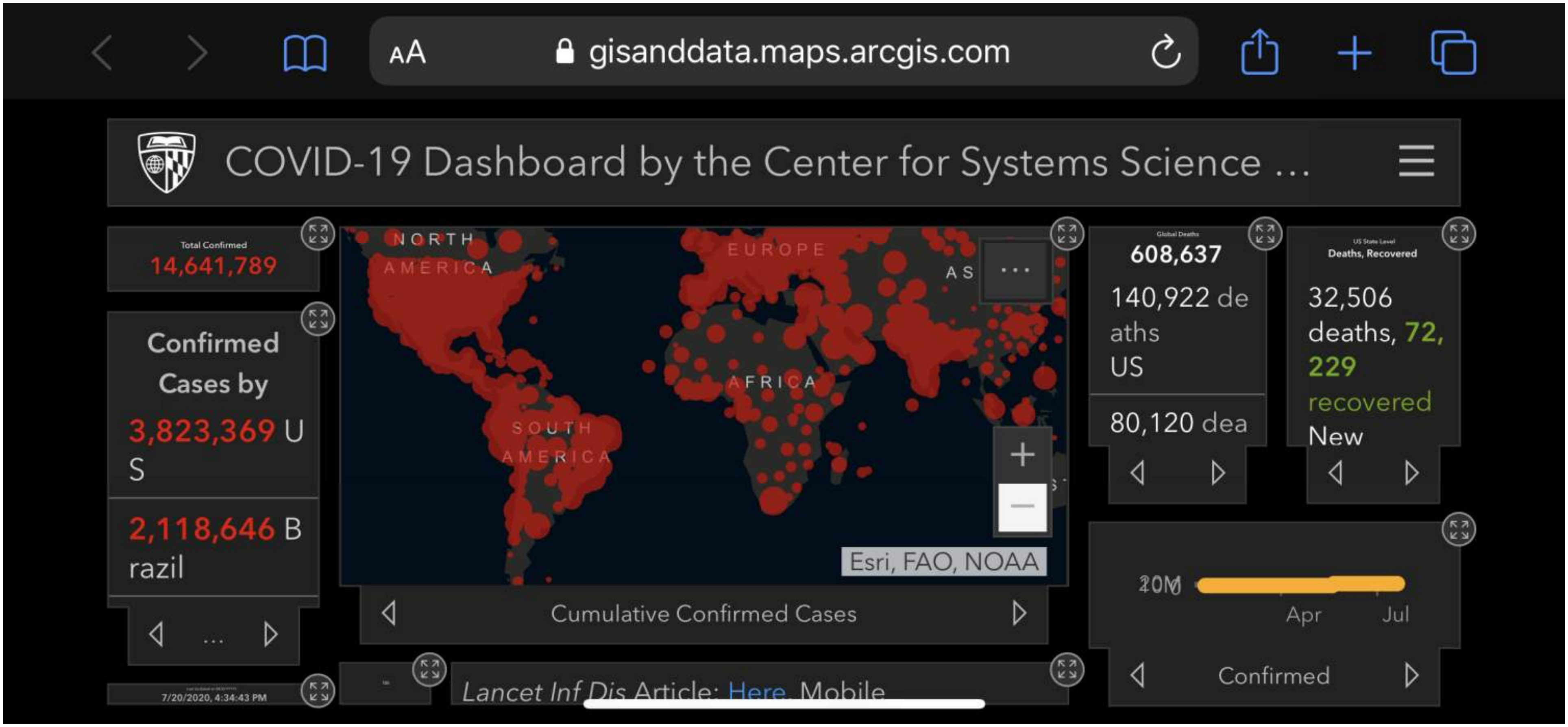
The Enemy is Here!



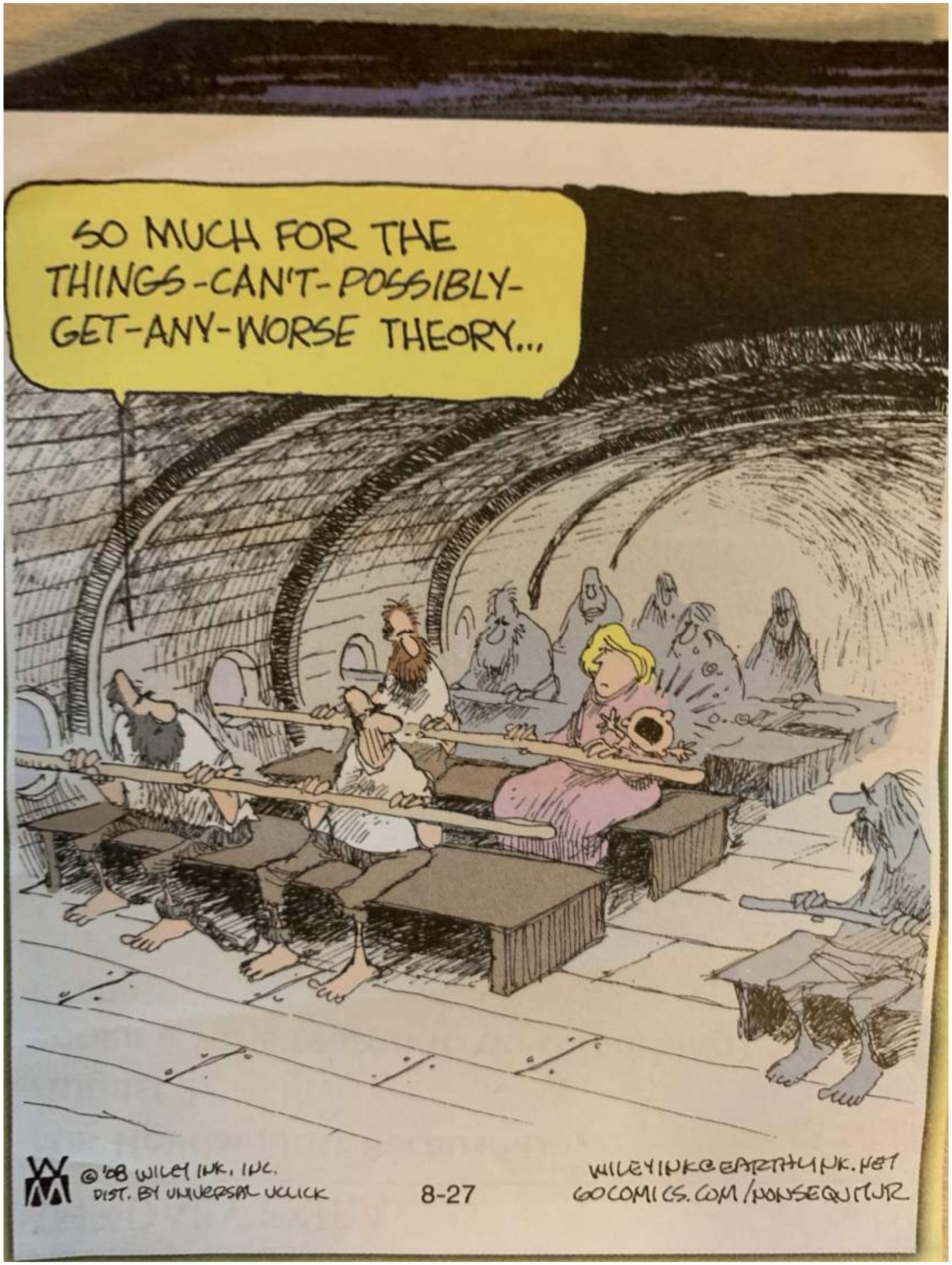
February 5, 2020



July 20, 2020



gisanddata.maps.arcgis.com
COVID-19 Dashboard by the Center for Systems Science ...
Total Confirmed
14,641,789
Confirmed Cases by
3,823,369 US
2,118,646 Brazil
7/20/2020, 4:34:43 PM
NORTH AMERICA
EUROPE
AFRICA
SOUTH AMERICA
Esri, FAO, NOAA
Cumulative Confirmed Cases
Lancet Inf Dis Article: Here. Mobile
Global Deaths
608,637
140,922 deaths US
80,120 dea
US State Level Deaths, Recovered
32,506 deaths, 72,229 recovered New
20M
Apr
Jul
Confirmed


SO MUCH FOR THE THINGS-CAN'T-POSSIBLY-GET-ANY-WORSE THEORY...
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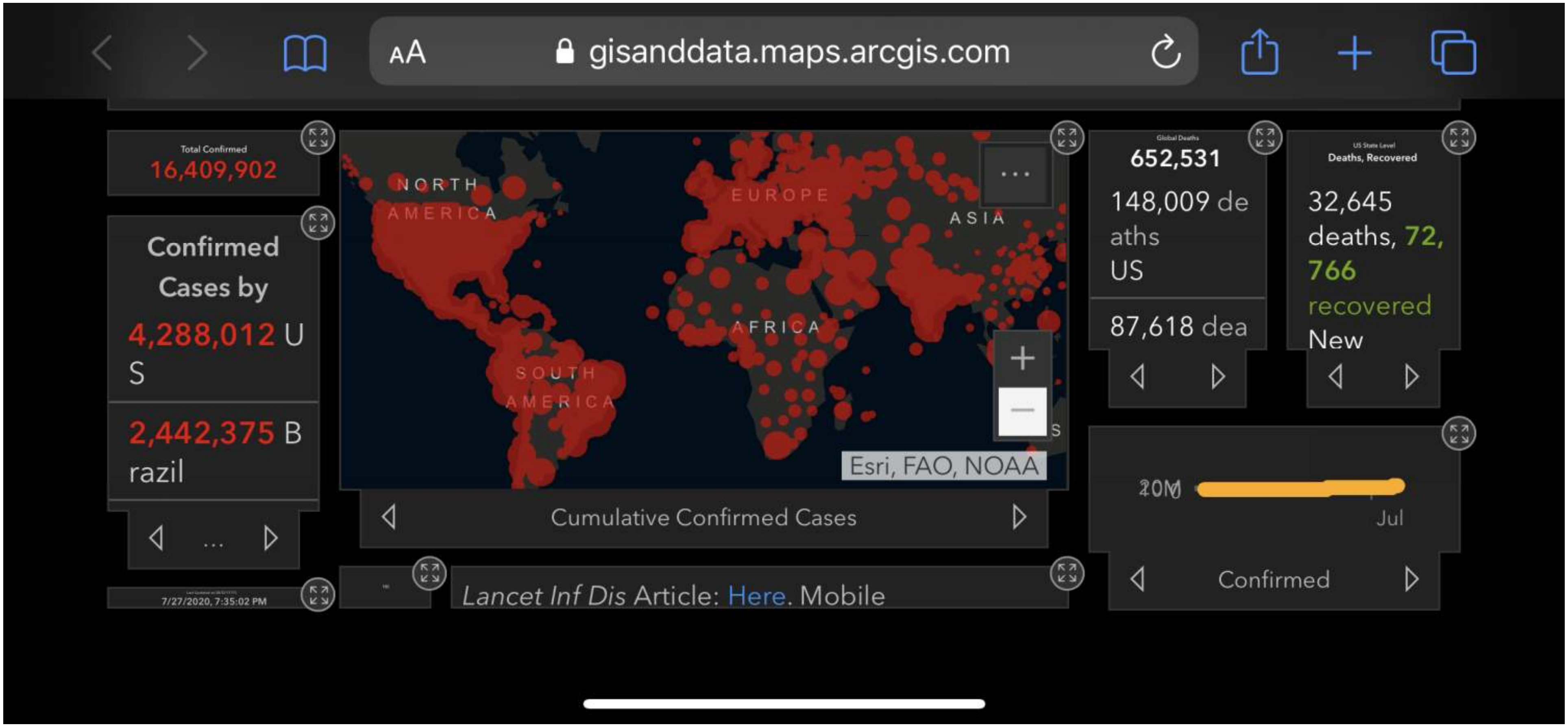
GOCOMICS.COM/NONSEQUITUR

July 27, 2020



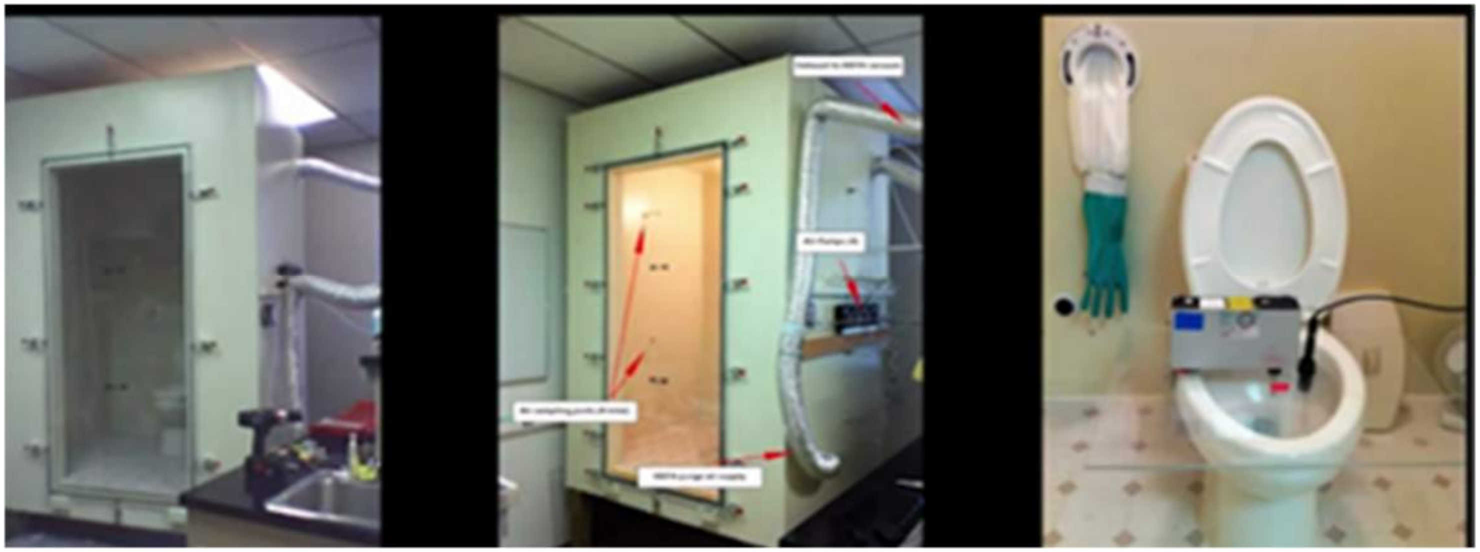
AA
gisanddata.maps.arcgis.com
Total Confirmed
16,409,902
Confirmed Cases by
4,288,012 US
2,442,375 Brazil
NORTH AMERICA
EUROPE
ASIA
AFRICA
SOUTH AMERICA
Esri, FAO, NOAA
Cumulative Confirmed Cases
Global Deaths
652,531
148,009 deaths US
87,618 dea
US State Level Deaths, Recovered
32,645 deaths, 72,766 recovered
New
20M
Jul
Confirmed
7/27/2020, 7:35:02 PM
Lancet Inf Dis Article: Here. Mobile

What We Are Learning

- Size is about 0.12μm, but usually attached to a droplet that's much larger and easier to capture in a filter.
- Super spreader events teach us about transmission
  - Skagit Valley Choir
  - Guangzhou Restaurant
  - Weddings, Funerals, Churches, Fitness Classes
    - https://Quillette.com – 54 Super spreader events studied
- University of Nebraska Medical Center – Viral Shedding
  - Outside patient rooms in corridor
  - On return grilles
  - Under beds
  - Toilet rooms
- Studies are pending, but no evidence yet of viable SARS-CoV-2 on a filter, in a duct, or out a supply diffuser into another room. Stay tuned.

Transmission Through Air in Toilet Rooms

Studies show that toilets can be a risk of generating droplets and residues from plumes in the air that could contribute to transmission of pathogens.



December 2018 – American Journal of Infection Control

- C-Diff seeded in a toilet
- Water samples, settle plates, and air samples
- Spores present after 24 flushes
- Droplet nuclei spore bioaerosol produced over at least 12 flushes

New Calculator

https://www.dhs.gov/science-and-technology/sars-airborne-calculator

Read the Background & Caveats

PANTHR

Estimated Airborne Decay of SARS-CoV-2

Estimated Surface Decay of SARS-CoV-2

Estimated Airborne Decay of SARS-CoV-2 (virus that causes COVID-19)

under a range of temperatures, relative humidity, and UV index

Use the sliders to select the UV index, temperature and relative humidity of interest. Information on how long SARS-CoV-2 would be expected to remain stable in aerosols (airborne) will be displayed in the table below. Users can find the environmental conditions for a specific location by accessing general weather resources online.

SARS-CoV-2 Airborne Decay Calculator

UV Index: 1 – 10; 1

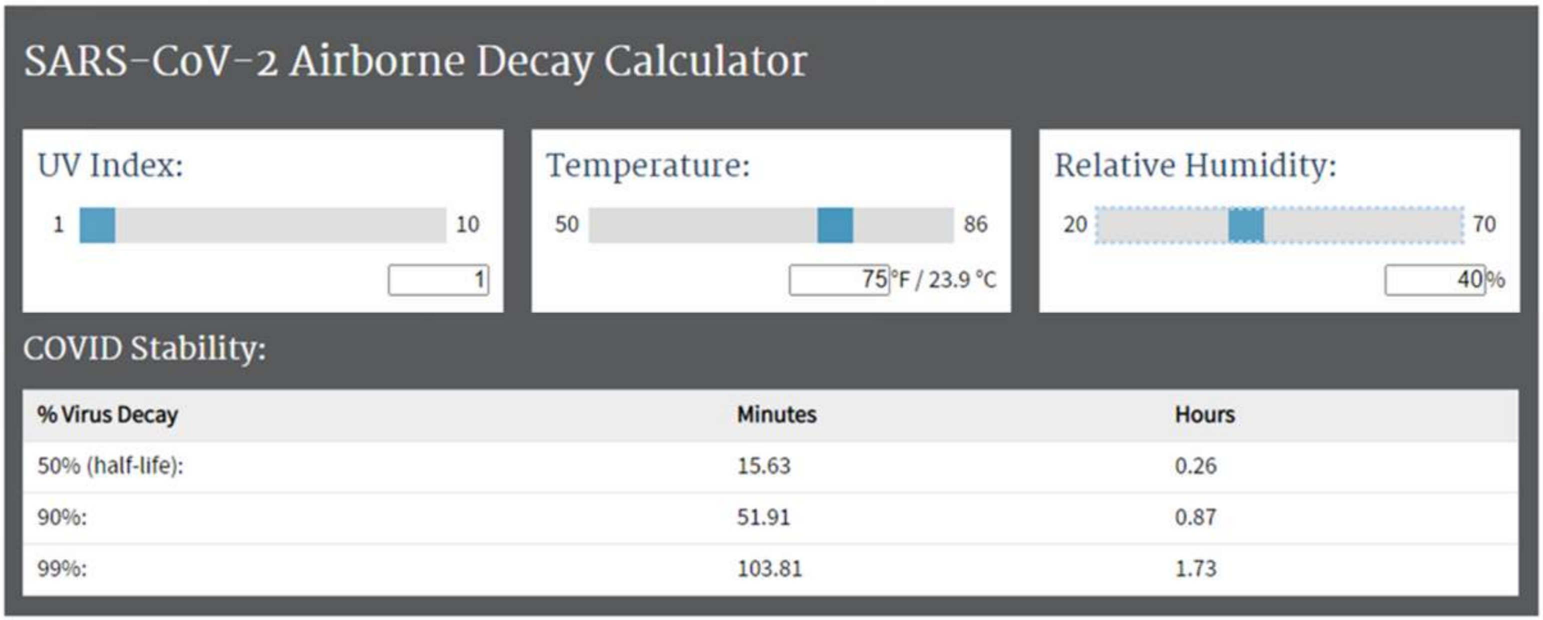
Temperature: 50 – 86; 75 °F / 23.9 °C

Relative Humidity: 20 – 70; 20 %

COVID Stability:

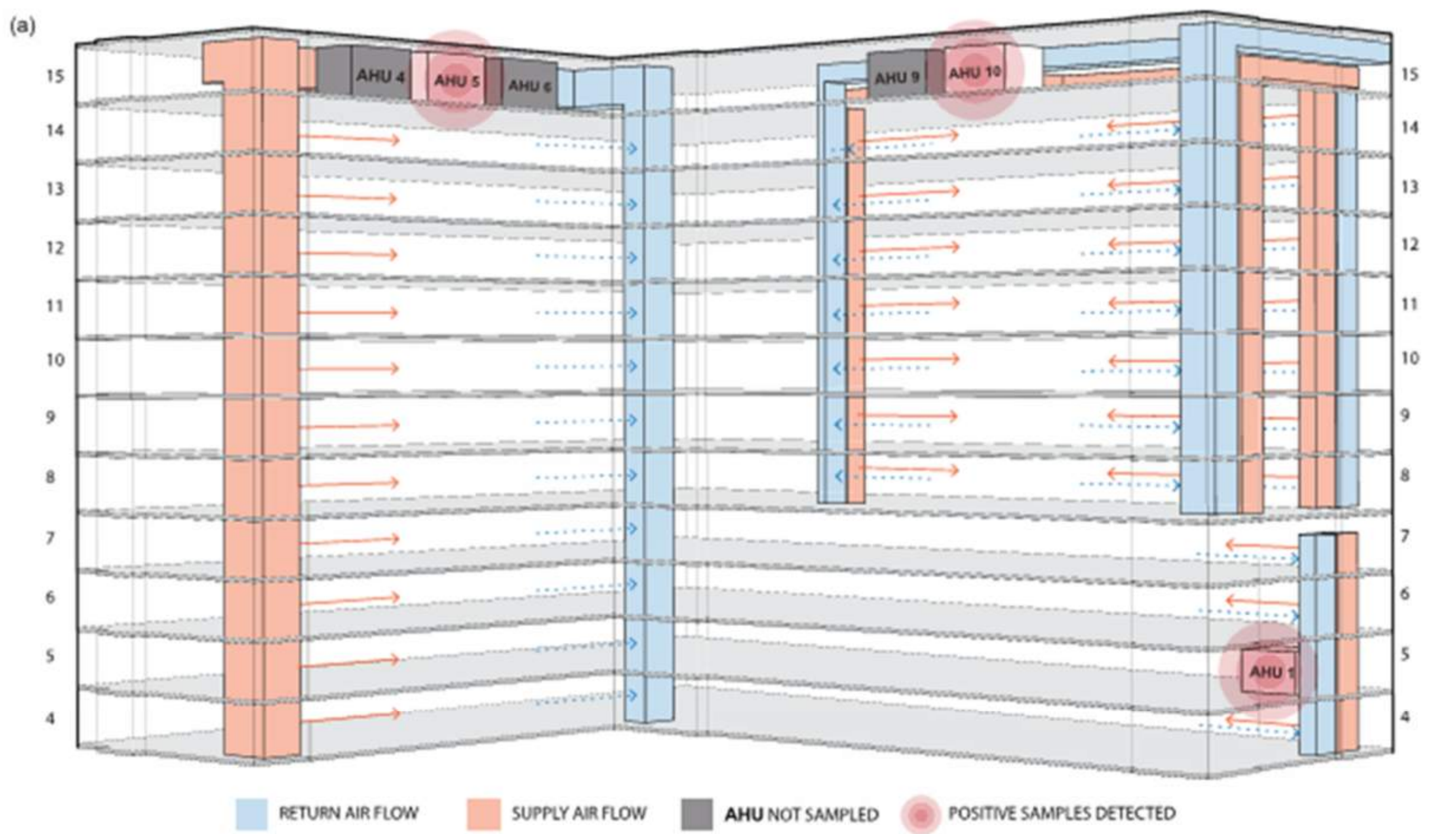
% Virus Decay	Minutes	Hours
50% (half-life):	21.72	0.36
90%:	72.15	1.20
99%:	144.30	2.40

Impact of UV, Temp, RH%



% Virus Decay	Minutes	Hours
50% (half-life):	15.63	0.26
90%:	51.91	0.87
99%:	103.81	1.73

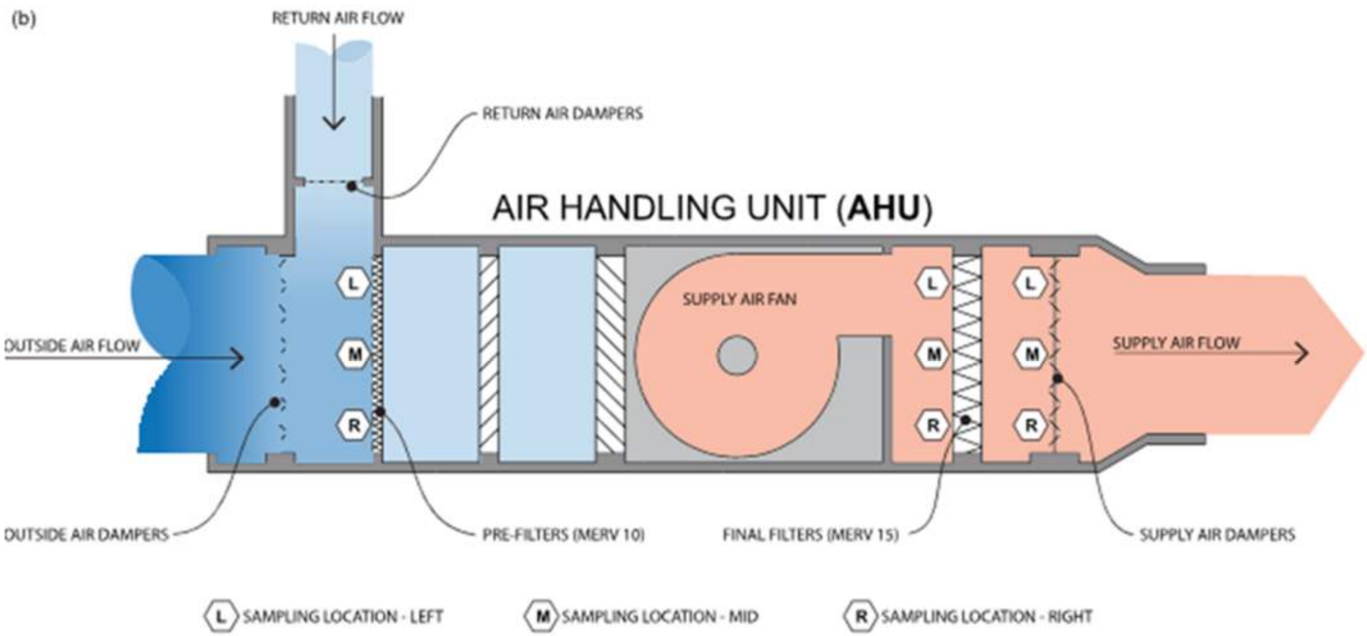
Identification of SARS-CoV-2 RNA in Healthcare HVAC Units



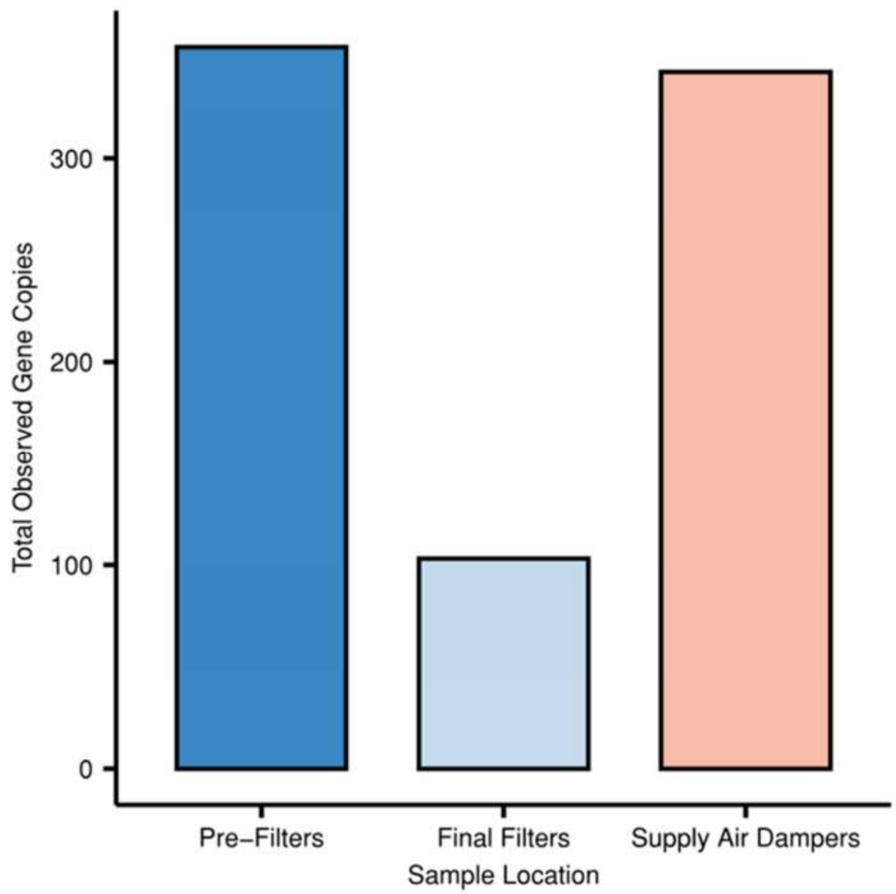
Authors: Patrick F. Horve[1,*], Leslie Dietz[1], Mark Fretz[2], David A. Constant[3], Andrew Wilkes[4], John M. Townes[5], Robert G. Martindale[6], William B. Messer[3], Kevin G. Van Den Wymelenberg[1,2,*]

https://www.medrxiv.org/content/10.1101/2020.06.26.20141085v1

Oregon Health & Science University



Results



300
200
100
0
Total Observed Gene Copies
Pre−Filters
Final Filters
Supply Air Dampers
Sample Location

Further Research

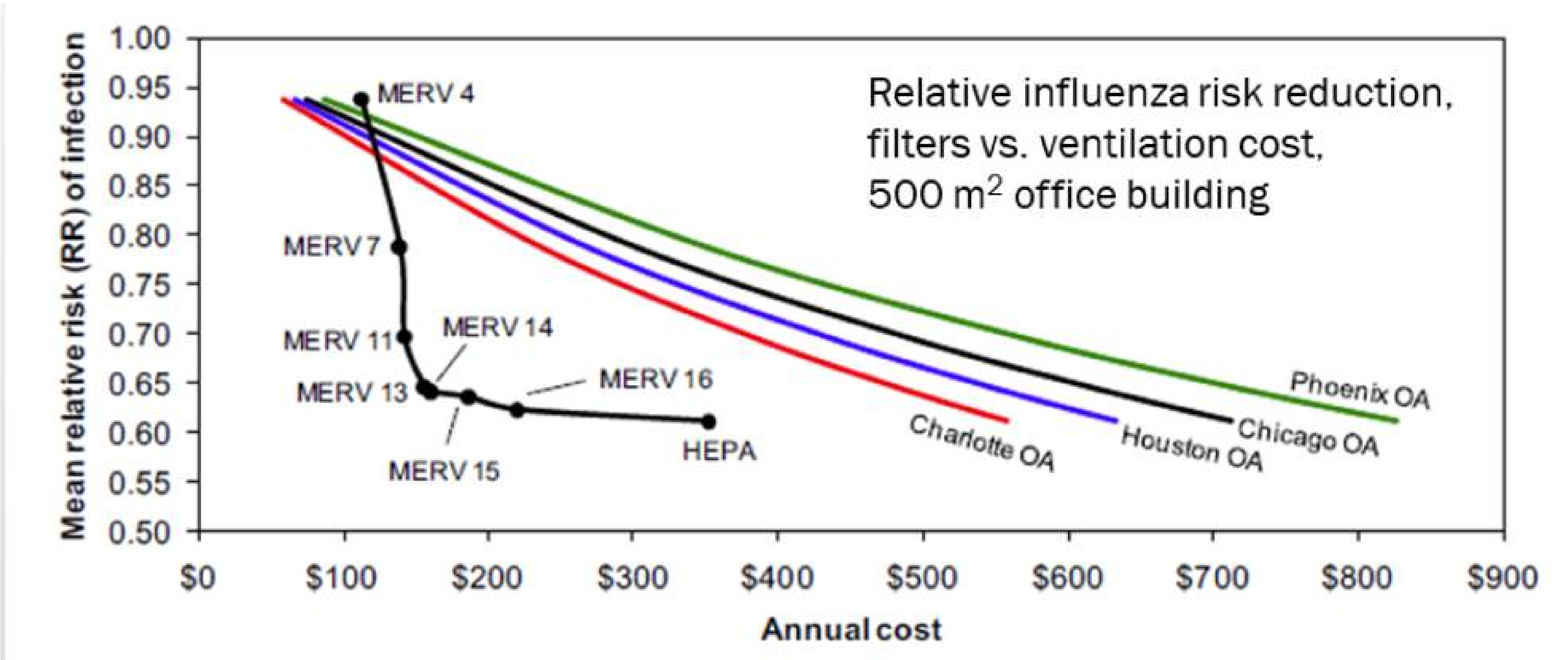
- Extent of Airborne Transmission outside of Aerosol Generating Procedures
- Presence of Viable Virus in HVAC systems
- Infective Dose
- Particle Sizes in different situations – submicron?
- Environmental Conditions


1%
HMM...
BEEEEP
PRIORITIES

How Can We Modify the Built Environment to Mitigate Risk?

- Airflow Patterns – Clean to Less Clean
  - Diffuser adjustment/relocation
  - Negative pressure spaces/source control
  - Furniture layout
  - Recirculating HEPA Filter Unit layout
- Increased Filtration Level (MERV 13 or better, where possible)
- Increase amount of clean outside air being supplied

Filtration vs. Outside Air Dilution

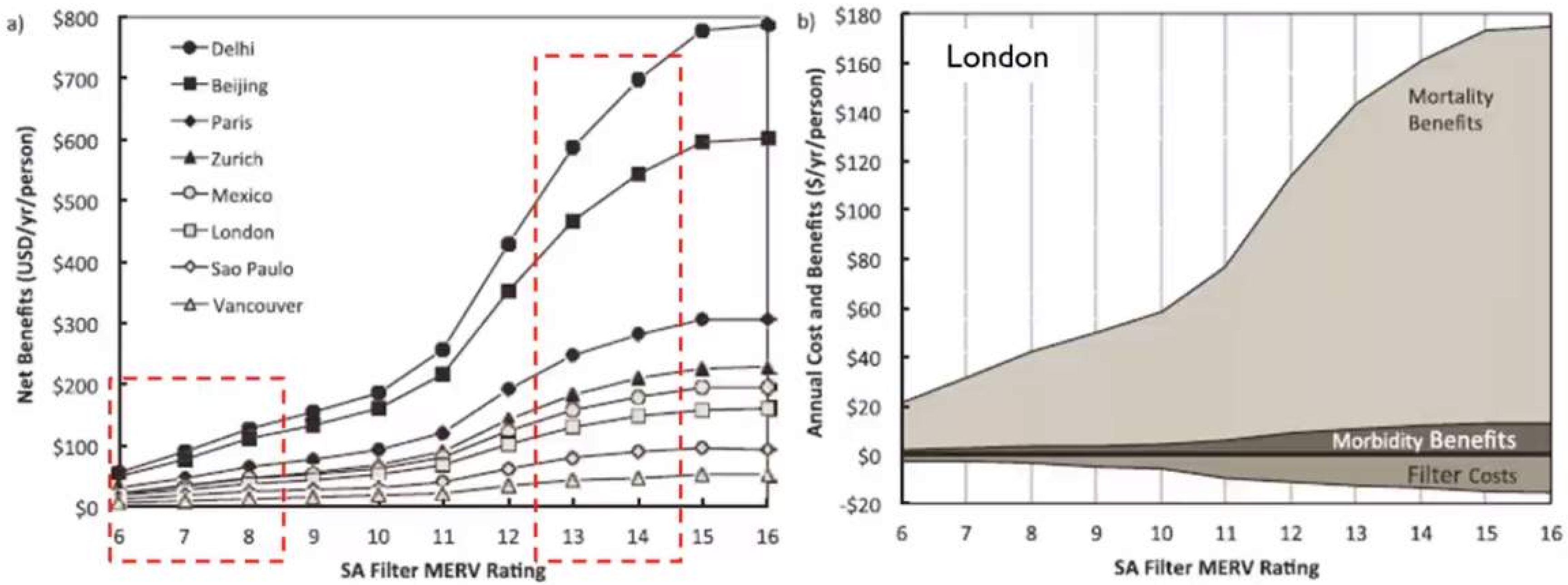


Azimi and Stephens, Building and Environment 70 (2013) 150-160

Health & Mortality impact of increased filtration

Trade-Offs – Benefits

(Montgomery, J., C. Reynolds, S. Rogak, S. Green. 2015. Financial Implications of Modifications to Building Filtration Systems. Building and Environment 85:17-28.)



Benefits of Increased Outside Air

International Journal of
Environmental Research and Public Health

MDPI

Int J Environ Res Public Health. 2015 Nov; 12(11): 14709–14722.
Published online 2015 Nov 18. doi: 10.3390/ijerph121114709

PMCID: PMC4661675
PMID: 26593933

Economic, Environmental and Health Implications of Enhanced Ventilation in Office Buildings

Piers MacNaughton,[1,*] James Pegues,[2] Usha Satish,[3] Suresh Santanam,[4] John Spengler,[1] and Joseph Allen[1]

Gary Adamkiewicz, Academic Editor and M. Patricia Fabian, Academic Editor

5. Conclusions

Go to:

The public health benefits of enhanced ventilation far exceed the per occupant economic costs in U.S. cities. Even with conservative estimates, the increased productivity of an employee is over 150 times greater than the resulting energy costs. Environmental costs are also relatively minor, but should be offset by the incorporation of energy recovery systems, advanced ventilation strategies, and other green building design strategies.

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4661675/

How Can We Modify the Built Environment to Mitigate Risk?

- Airflow Patterns – Clean to Less Clean
  - Diffuser adjustment/relocation
  - Negative pressure spaces/source control
  - Furniture layout
  - Recirculating HEPA Filter Unit layout
- Increased Filtration Level (MERV 13 or better, where possible)
- Increase amount of clean outside air being supplied
- Disinfection
- Advice on evaluating technology
- Toilet Rooms
- Environmental Conditions

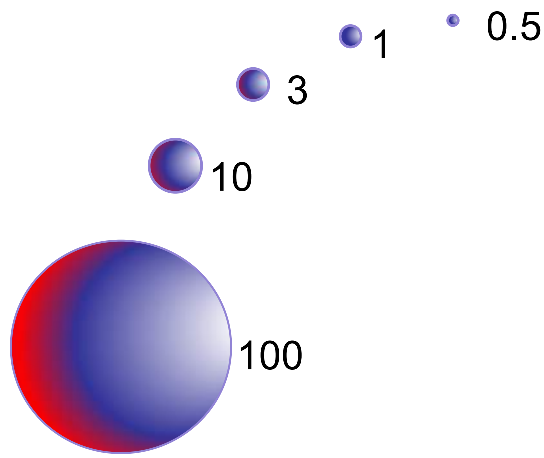
What Factors Determine If This Cough Will Infect Others?

Bourouiba Research Group. See also
https://www.sciencefriday.com/videos/nothing-to-sneeze-at/

Infectious Droplets

Infectious droplets shrink, travel far, and evade surface cleaning when the air is dry.

Droplet diagram in microns (um)



Float time

41 hours – 21 days

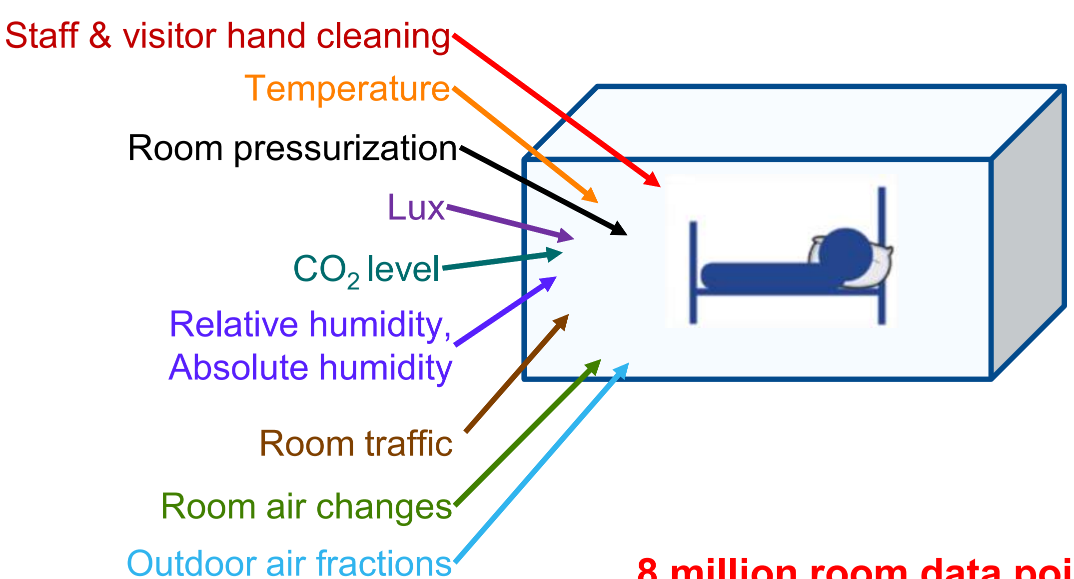
1.5 hours

6 seconds

Distance travelled: 1m 10m+

One year-long study to evaluate the patient room environment and HAIs

Patient room data *vs.* **Patient HAIs**



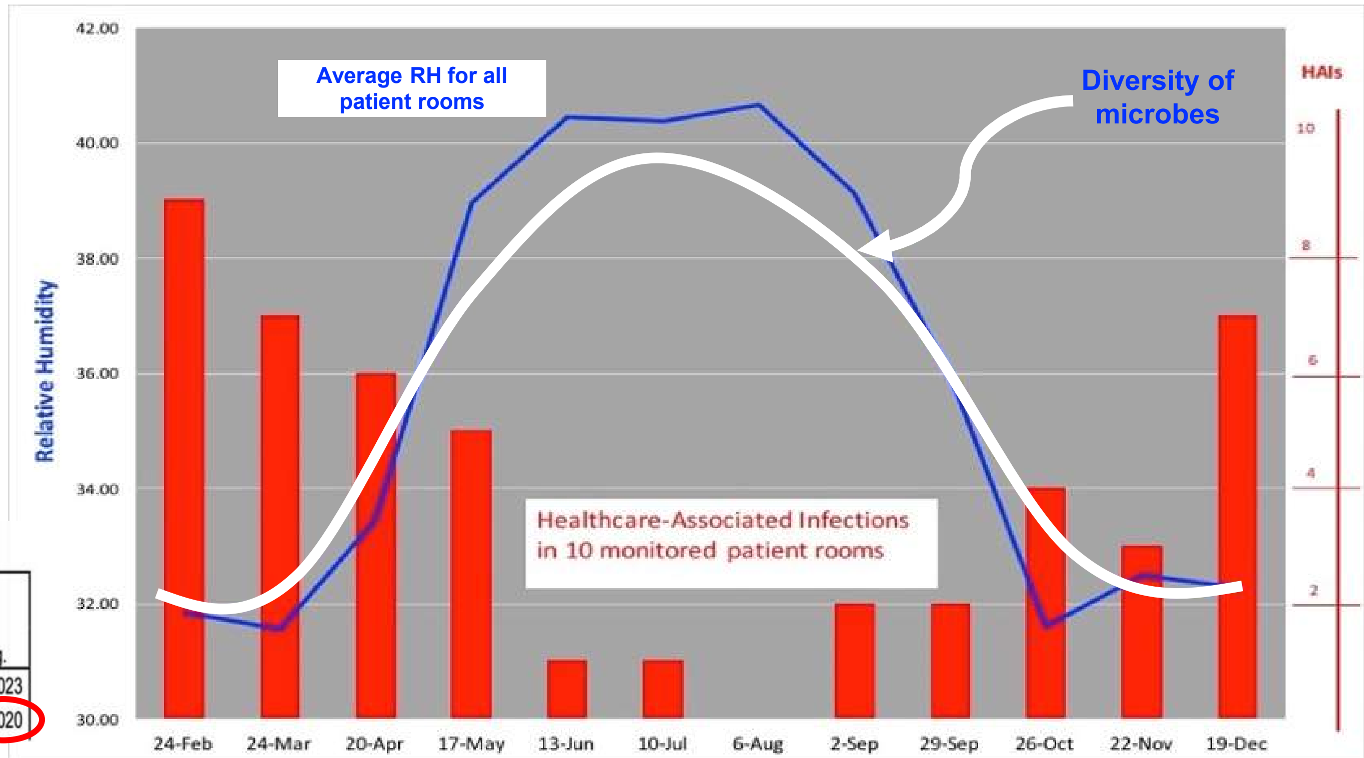
Room	Clinical symptoms	HAI Organisms (if indicated)
xx	pneumonia, viremia	Pseudomonas, Epstein-Barr virus
xx	pneumonia	Staphylococcus aureus
xx	open wound of head, neck, and trunk	
xx	bacteremia, organism unspecified	Citrobacter infection
xx	infection due to vascular device	
xx	cellulitis	Staphylococcus aureus
xx	sepsis, cellulitis, abscess	
xx	bacteremia, organism unspecified	
xx	pneumonia, organism unspecified	
xx	fever; bacteremia, organism unspecified	
xx	viremia	Cytomegalovirus (CMV)
xx	wound infection after surgery	
xx	urosepsis, organism unspecified	
xx	sepsis following cardiac surgery	
xx	pneumonia, organism unspecified	
xx	infection of skin and subcutaneous tissue	
xx	colitis and diarrhea	Clostridium difficile
xx	wound infection after surgery	
xx	urosepsis, organism unspecified	
xx	diarrhea	salmonella enteritis

8 million room data points **~ 300 patient outcomes**

As patient room RH went down, HAIs went up!

Coefficients[a]

Standardized Coefficients Beta	t	Sig.
	-2.348	.023
-9.060	-2.396	.020



2018 Study: Indoor-air RH and health outcomes in residents in a long-term care facility (over 4 years).

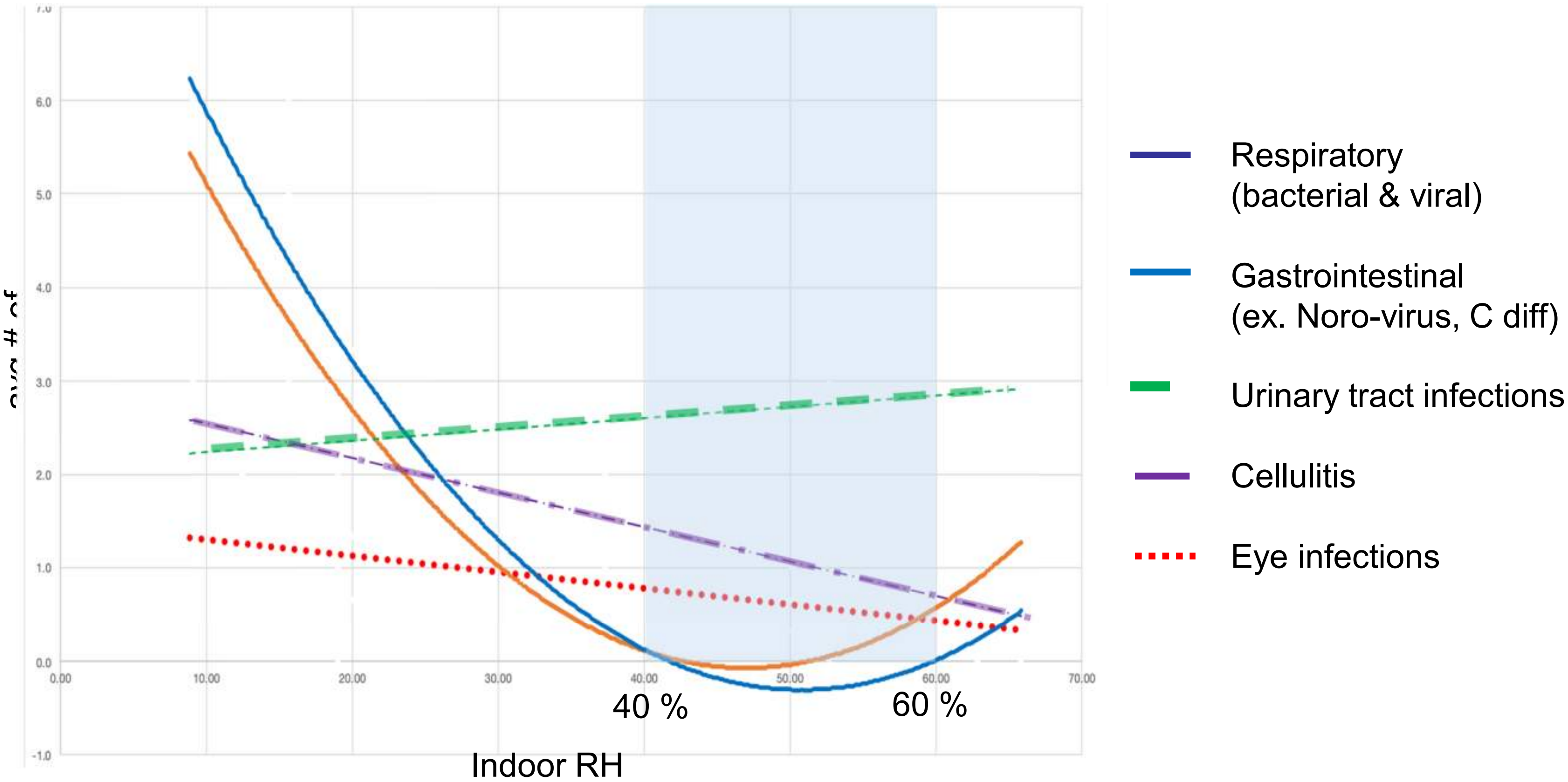
Patient infections **VS** **Environmental data**

Infections
- respiratory (viral & bacterial)
- GI (Noro. & Notovirus, C. diff)
- urinary tract
- conjunctivitis
- cellulitis

Indoor conditions
- temperature
- relative humidity
- visitors
- staff absenteeism

Outdoor climate
- temperature
- relative humidity
- flu outbreaks

Respiratory & GI infection rates were lowest when indoor RH = 40-60%



2018 Study: Humidity decreased Influenza A illness in a pre-school.

January 25 – March 11
(32 days)
Half of the classrooms were humidified, the other half were not

RH of classrooms	% Airborne particles carrying virus (PCR)	Virulence of airborne virus (% cells infected)	# children absent due to influenza illness
20%	49%	75%	22
45%	**19%**	**35%**	**9**

A Key Study Published in PNAS

"Low ambient humidity impairs barrier function & innate resistance against influenza infection"

Proceedings of the National Academy of Sciences, USA. May 19, 2019

Eriko Kudo, Eric Song, Laura Yockey, Tasfia Rakib, Patrick Wong, Robert Homer, Akiko Iwasaki

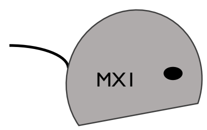
Study Setup

Chamber conditions
Temp = 68° F (20°C)

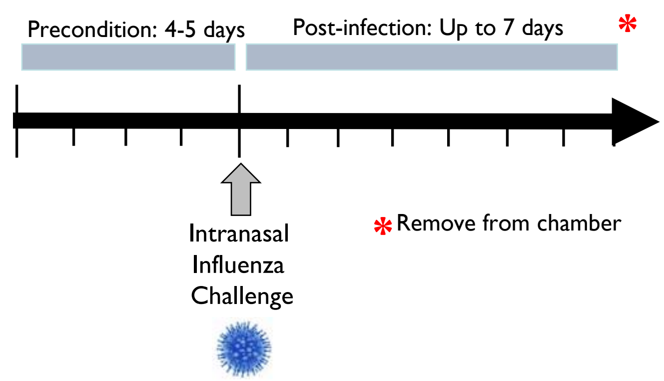
20% RH
$3 g/m^3$ AH

or

50% RH
$9 g/m^3$ AH

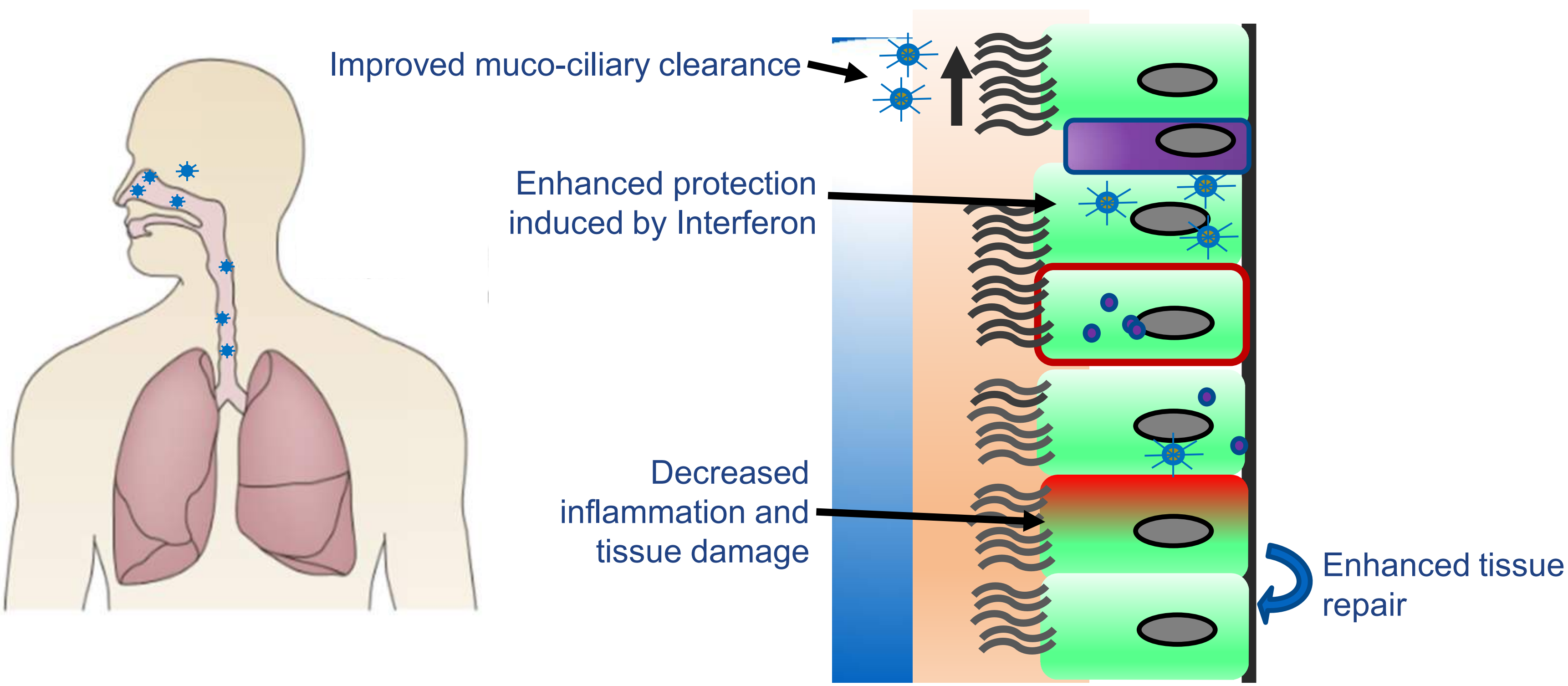


Mx1 mice have functional Type I IFN responses

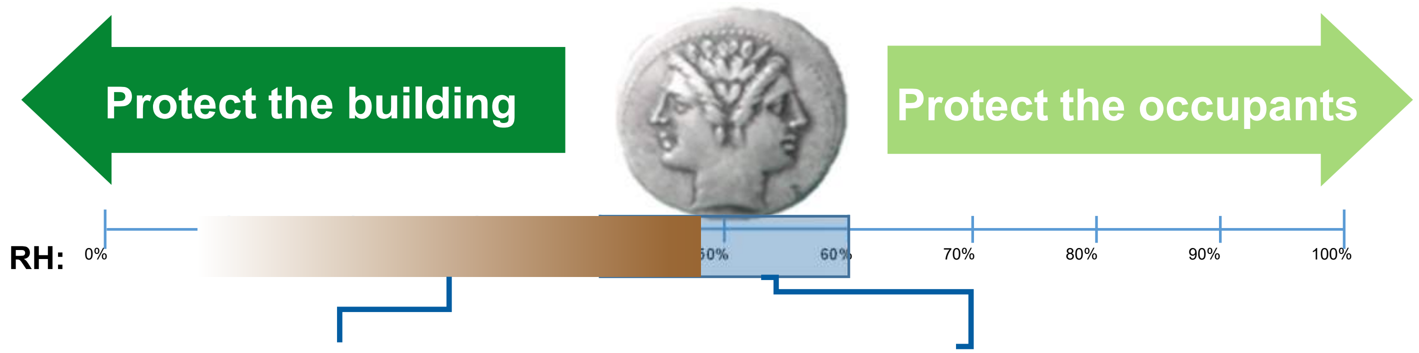


Respiratory Protective Mechanisms

Innate respiratory protective mechanisms are optimal at 50% RH, and impaired at 20% RH



The Great Indoor Air RH Debate!



Buildings don't care about humidity

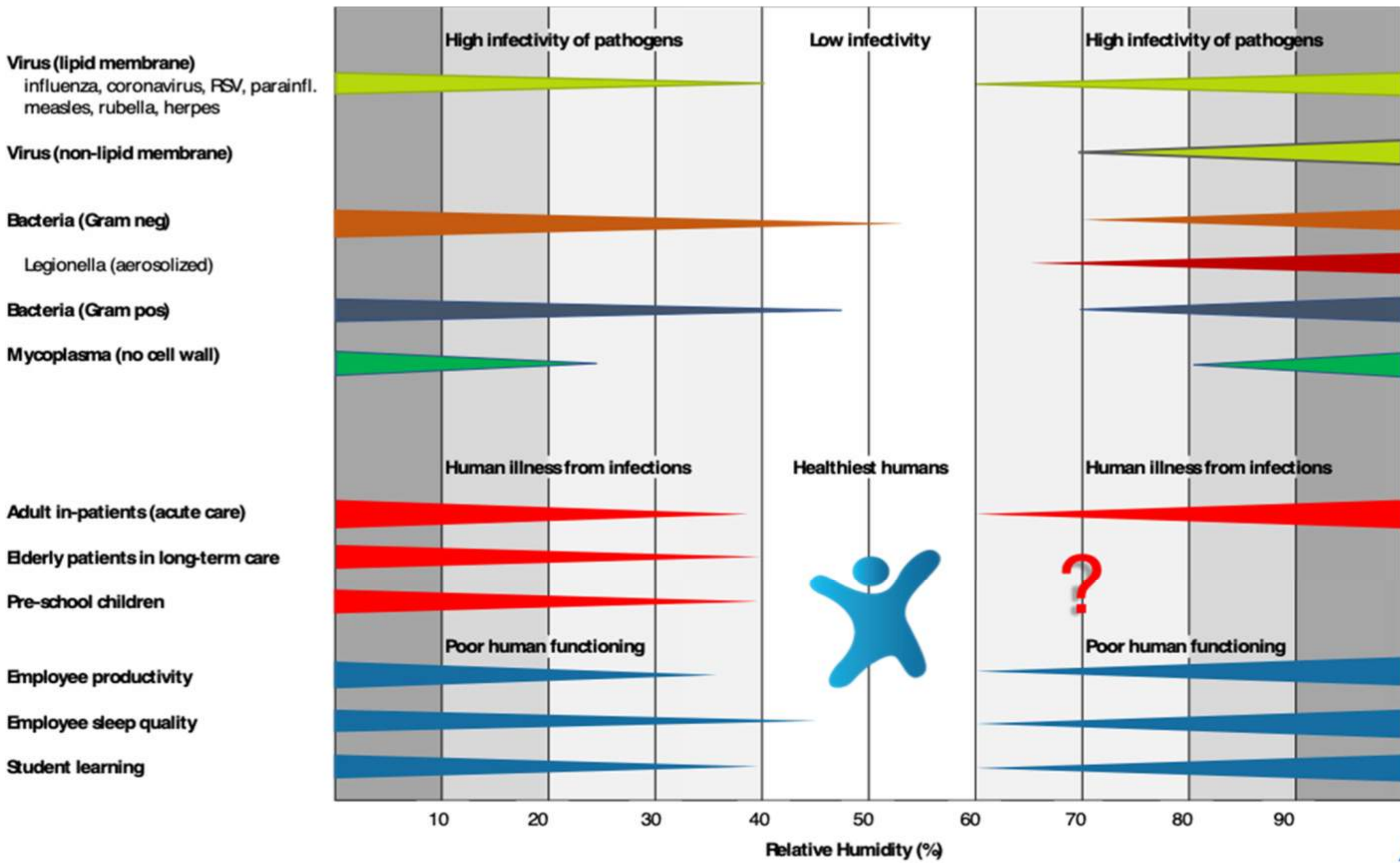
- The drier the air the better
- Easier to dry the air than fix the envelope construction
- Humidification will cost more
- We hate humidifiers!

Occupants need RH between 40% and 60% for health

- Decreased infections
- Fewer allergies
- Improved hydration
- Improved wound healing
- Increased work performance

https://www.ashrae.org/technical-resources/free-resources/publications

40-60% RH – Great for Health!



Technical Checklist for Resiliency (a start)

- ✓ Work to develop less expensive ways to prepare for surge, Ex. Ventilated Headboard
  - ✓ https://www.youtube.com/watch?v=8H2kmZkbuR4&feature=emb_logo
- ✓ Practice/simulate plans and improve on them.
  - ✓ Load shedding scenarios
  - ✓ Wildfires – cardiovascular burden
  - ✓ Power outages
  - ✓ Procedures on infected patients
- ✓ Evaluate utility connections & locations. What could go wrong (at the same time)?
- ✓ Medical Gas: Oxygen vaporizers, extra outlets in surge areas, piping main capacity.
- ✓ Hot water generation and piping capacity.
- ✓ Expanded kidney dialysis infrastructure.

Technical Checklist for Resiliency (a start)

- ✓ Select HVAC systems with <u>inherent flexibility</u> and size equipment to provide options.
  - ✓ Upgraded filtration/frame compatibility
  - ✓ 100% exhaust capability
  - ✓ Capacity for more ventilation
  - ✓ New climate extremes?
  - ✓ Room air distribution modifications
  - ✓ May consider UV light
  - ✓ 40-60% RH capability
- ✓ How would you pressurize a normally neutral area?
- ✓ Create options for staff respite areas, donning & doffing, and patient-proximate labs or diagnostic tests.
- ✓ Exhaust termination locations.
- ✓ Code changes to permit the items above?

Technical Checklist for Resiliency (a start)

- ✓ "Buildings are for people, not for saving energy".
- ✓ Pay extra attention to what we are doing for our most vulnerable – elderly in long term care facilities.
  - ✓ Special ASHRAE Task Group developing Guidance for long-term care and hospice facilities
- ✓ How readily can an area of a building or home be blocked off?
- ✓ Work with clinical staff to consider in what ways a future event could be different for patients and staff.
  - ✓ Natural disasters
  - ✓ Bacterial, viral, fungal, prion, and parasites.

Technical Checklist for Resiliency (a start)

- ✓ Evaluate Building Automation, Ethernet, Cybersecurity, and WiFi
- ✓ You can never have enough system isolation valves and capped branches for future connections
- ✓ Add “Record Drawings” to your list of things to Commission.
- ✓ Plan for manual operation of equipment & print hardcopies of essential information
- ✓ Public Trust Lens vs. Cost
- ✓ Resiliency vs. Program Area

Money Talks

BENEFITS - Year One			Dollars
Increased Revenue	Maximize per day bed value by decreasing LOS	$	1,310,126
	Decrease non-reimbursable HAI costs	$	764,890
Cost Avoidance	3% CMS penalty for re		91,787
	CMS Quality Index penal		TBD
	Joint Commission citation		TBD
	Employee absenteeism		TBD
	HAI litigation by patients		TBD
	Quarterly total		2,166,803
	Cumulative value		2,166,803
INVESTMENTS			
	Gas		
	Installation & Integration of New System	$	(1,198,500)
	Maintenance	$	(23,850)
	Operating Cost	$	(34,573)
	OR & PT Room Down Time	$	(10,000)
	Quarterly total		($1,266,923)
	Cumulative investment		($1,266,923)
NET VALUE			

$899,880

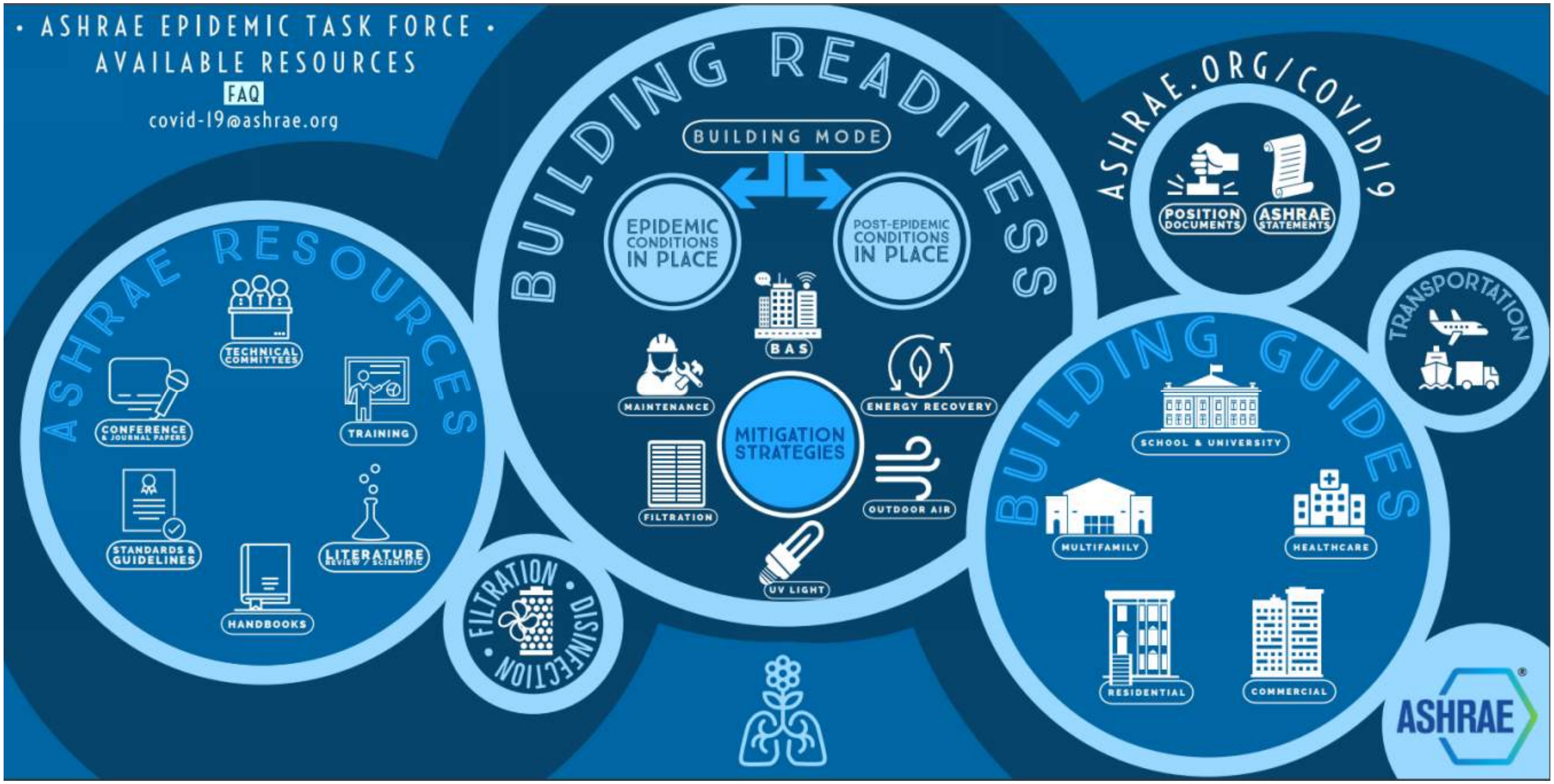
$899,880

$7,225,018

1st Quarter

500.97%

ASHRAE Epidemic Task Force



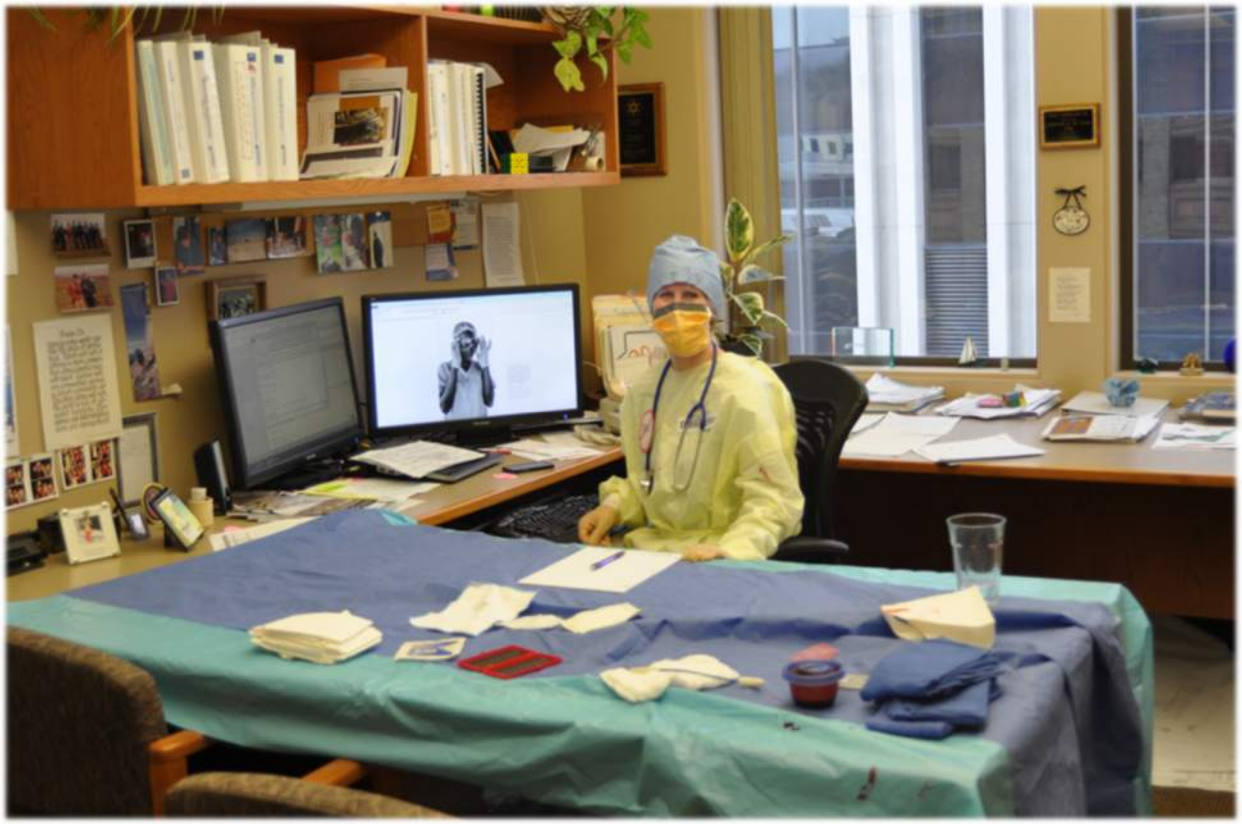
https://www.ashrae.org/technical-resources/resources


ASTEROIDS
...are nature's way of asking:
"How's that space program coming along?"

Acknowledgements

- Stephanie Taylor, M.D., M. Arch, Harvard Medical School Incite Fellow
- Bill Bahnfleth, PhD, PE, FASHRAE, FASME, FISIAQ
- Luke Leung, P.E., P Eng, LEED Fellow
- Paul Bemis, Applied Math Modeling
- Dennis Knight, P.E., FASHRAE

Thank You!



Non-Technical Ideas for Resiliency

EPIDEMIC PREPAREDNESS FOR OUR BUILDINGS

University of Maryland Fire Protection Department in Collaboration with Coffman Engineers

July 28, 2020

University of Maryland, Dr. Jim Milke, Ph.D., PE
milke@umd.edu
Coffman Engineers, Traci Hanegan, PE, FASHRAE
traci.hanegan@coffman.com