

Effective Air Purification for Aircraft Cabins When Face Mask Requirements are Removed

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Key Study Headlines:

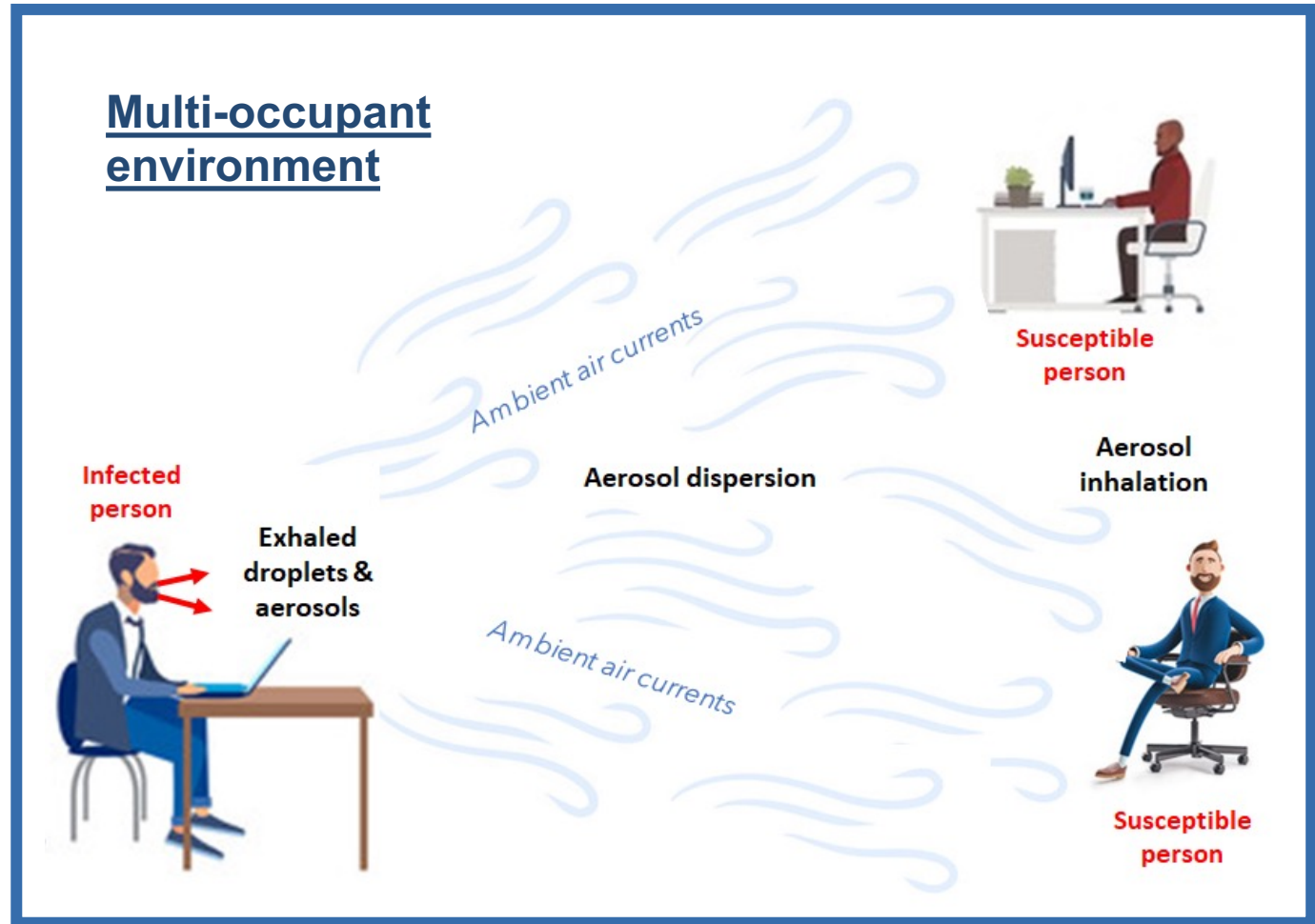
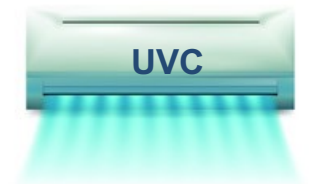
- Aircraft cabin cross-infection can happen in 20-50 sec, while cabin air changes every 2-3 min.
- The novel exhaled-air-handling-system significantly reduces the risk of cross-infection by $> 90\%$.
- The novel exhaled-air-handling-system always yields $R_0 < 1$ regardless of the flight duration.

How It All Started:

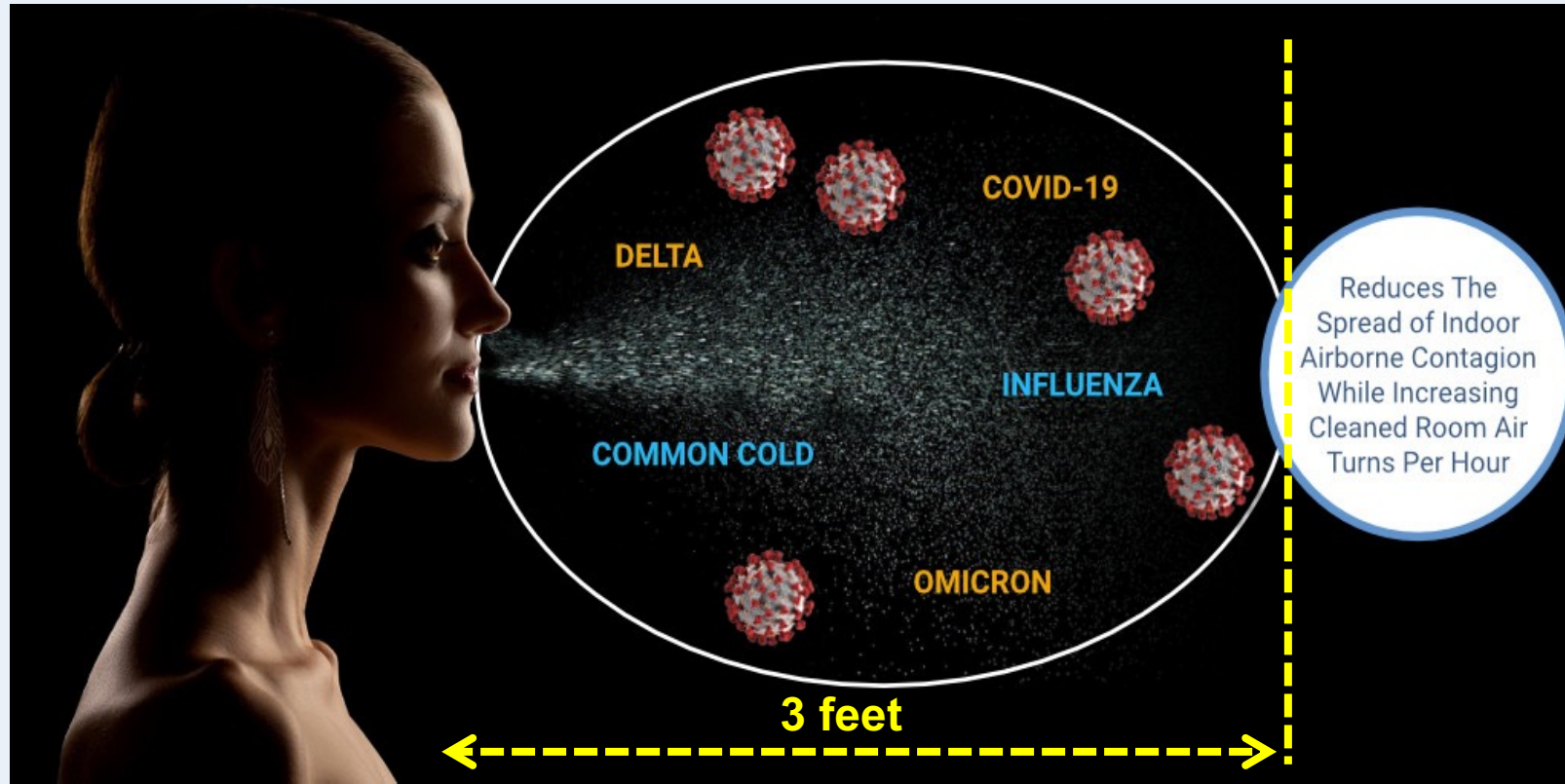
Trying to solve the challenges of multi-occupant indoor venues and answer the related questions:

- Is it possible to capture and clean the exhaled air at the source (i.e. close to the individual's face) before the exhaled air disperses into the venue?
- Is it possible to increase the ACH without opening windows and/or major modification to the HVAC system while also capturing & cleaning exhaled air?

Recommended preventive measures do not solve the problem at the source:



A Patented Technology That Captures and Purifies Exhaled Air Within 3 Feet of One's Face Before It Disperses Throughout The Venue



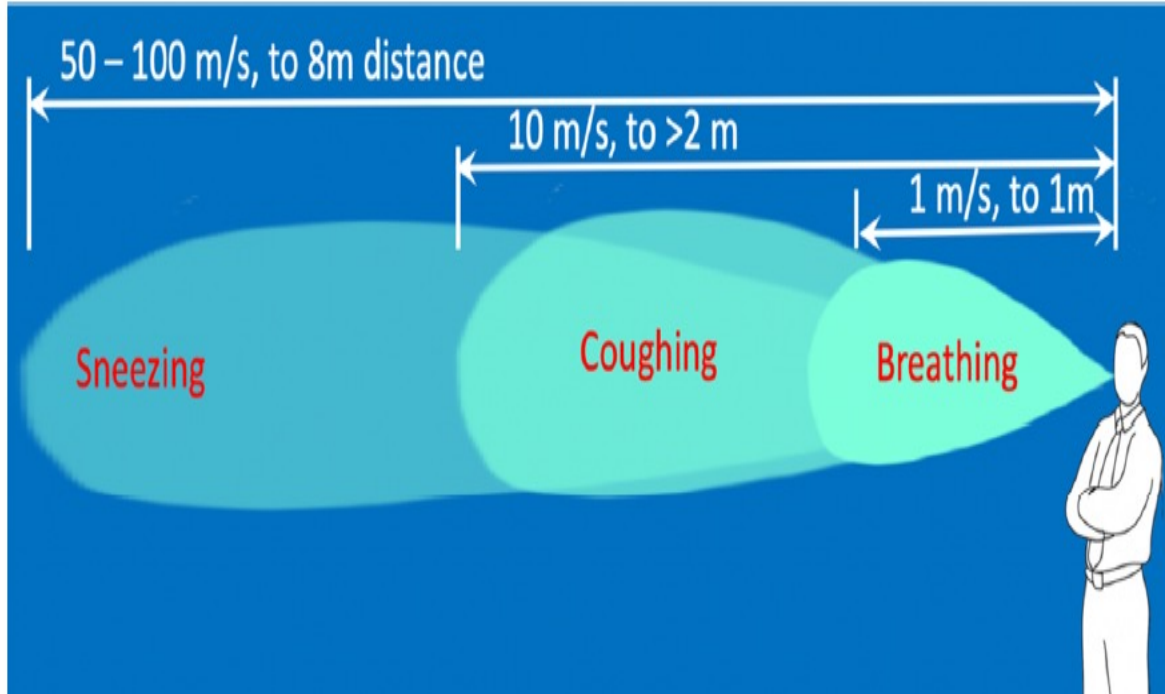
Features:

- Unobtrusive
- Cost-effective
- Quiet (20-40 dB)

Blum, R., Broach, A., French, R., **Exhaled Air Purification Unit and System for Indoor Multi-Person Venues or Environments**, US Patent 11,324,850, issued May 10, 2022

The Challenge: Aircraft Cabin Cross-Infection

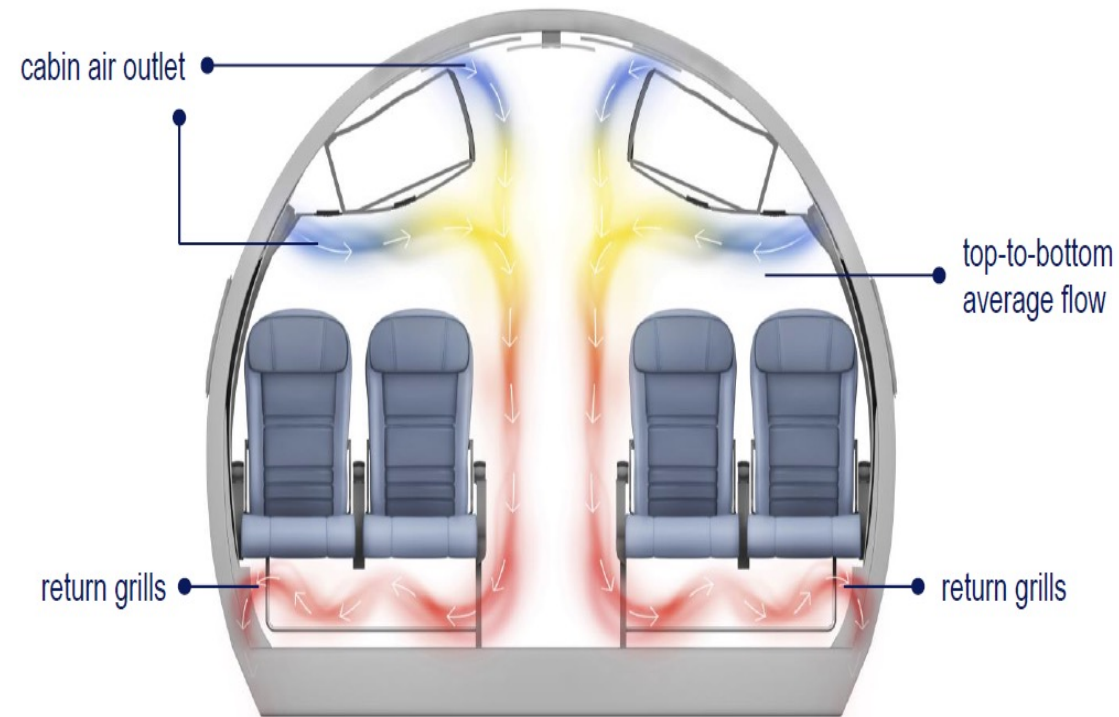
Exhaled air moves FAST



Breathing: 1-2 m/s
Coughing: 10-20 m/s

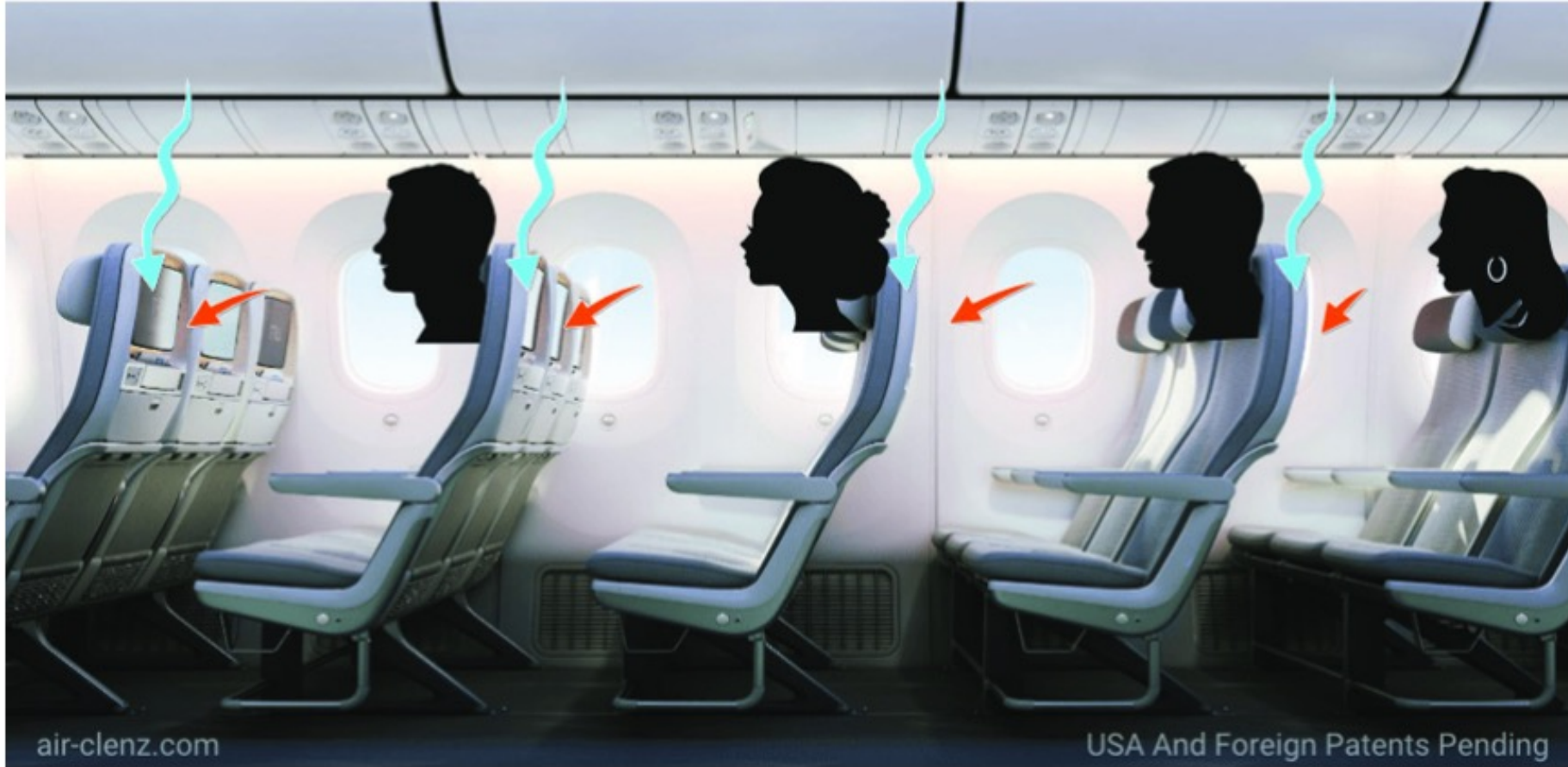
Talking: 4-5 m/s
Sneezing: 50-100 m/s

Cabin air changes SLOWLY



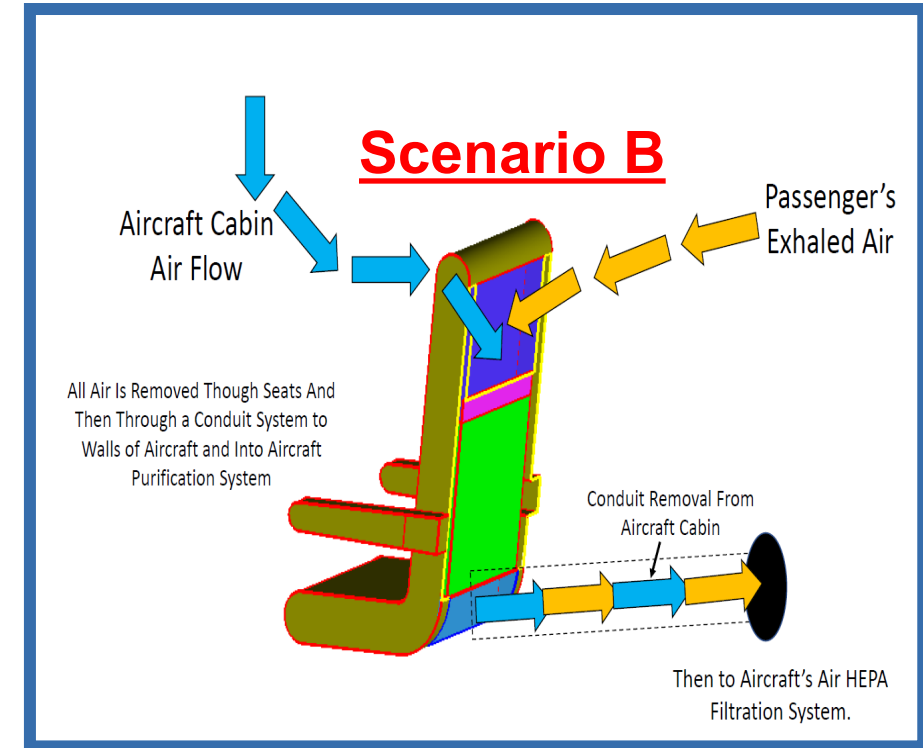
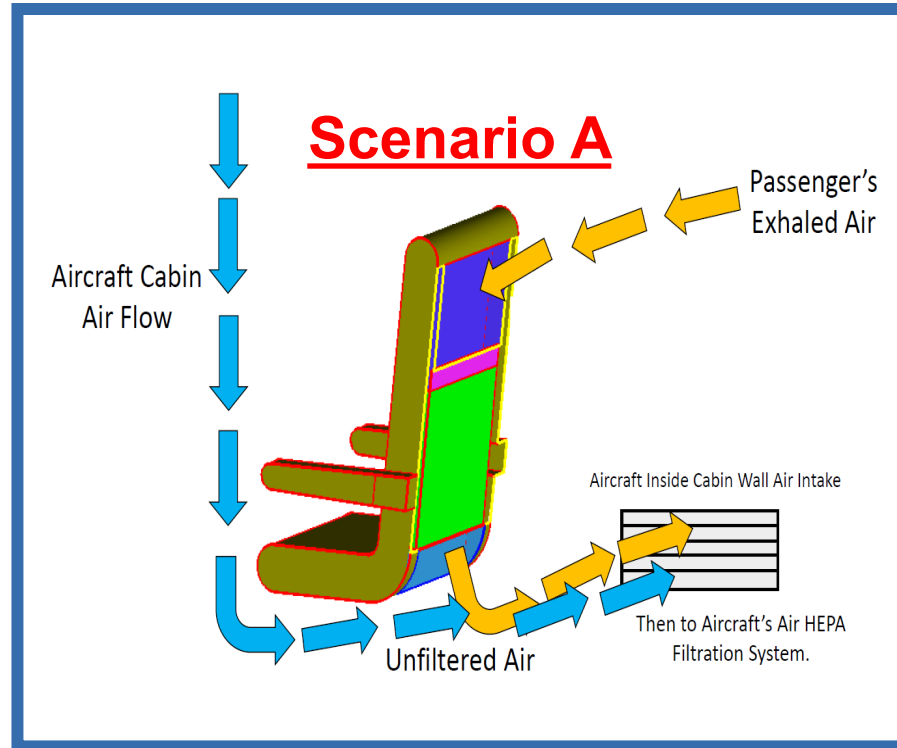
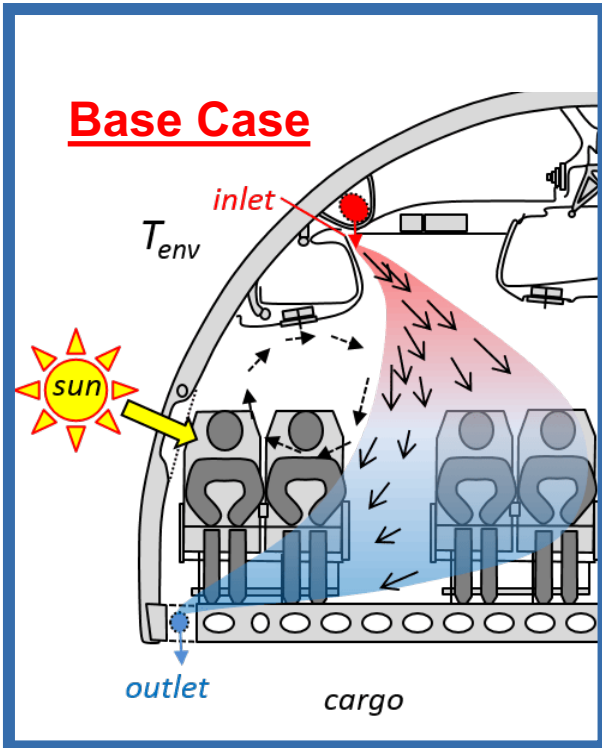
Air changes in the cabin:
every 2-3 minutes

Exhaled Air Capture and Purification Technology Integrated in the Back of Each Cabin Seat



The technology is applicable in any multi-occupant transportation vehicle (plane, bus, train) and indoor venue (office, classroom, call center, etc.)

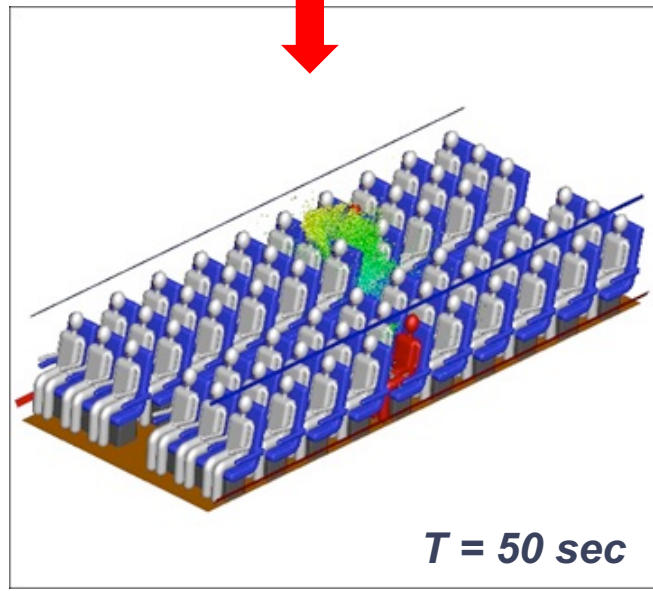
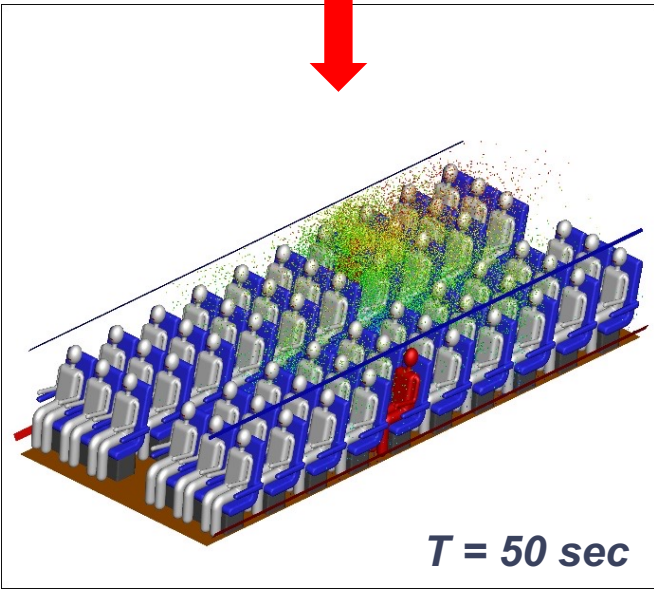
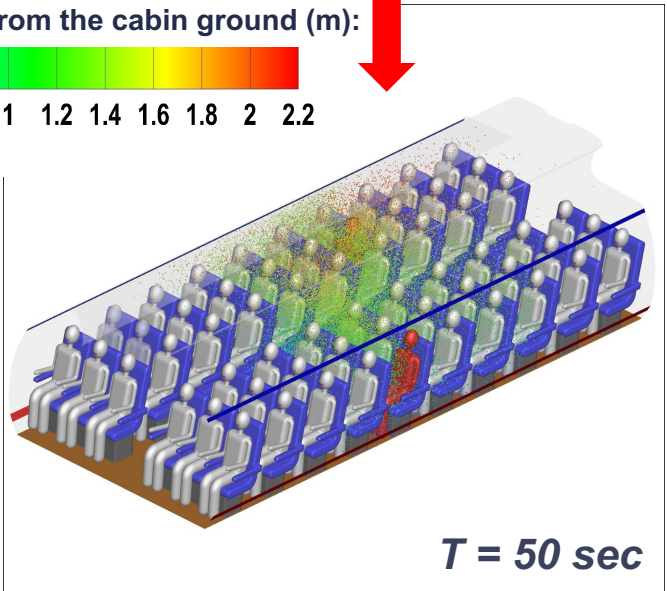
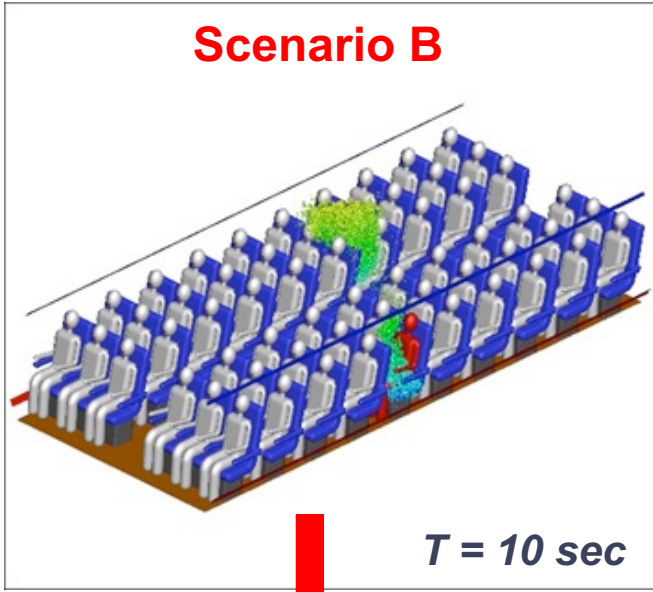
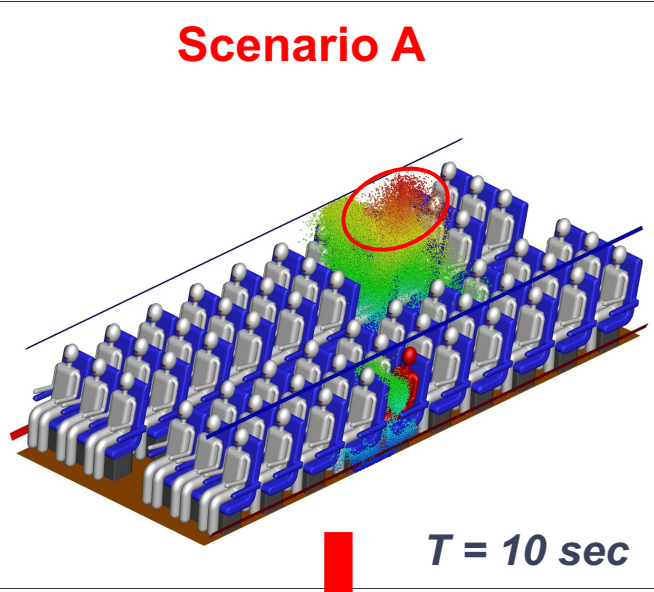
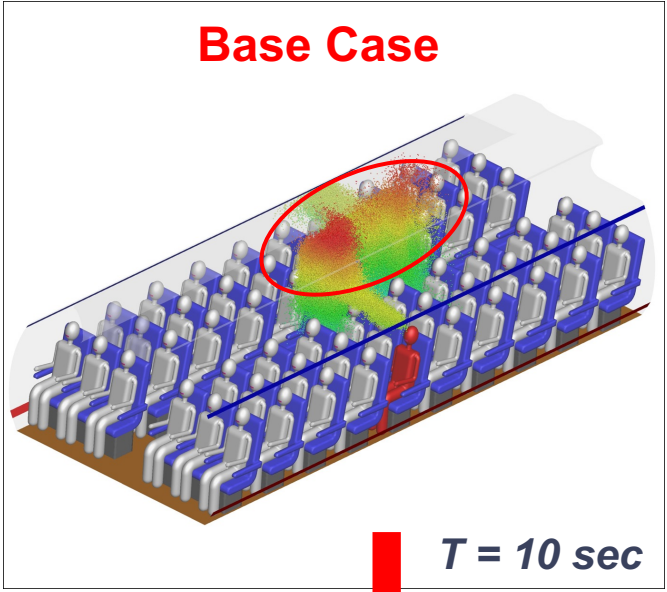
Proof-of-Concept: Simulation Scenarios



- For all three scenarios: two infected passengers are among 60 passengers aboard the coach section of a Boeing 737- 800. **The aircraft HEPA-filtered ventilation system remains intact in all three scenarios.**
- Simulation of 184,000 particles, 1 μm in size, exhaled within a second (e.g. sneeze) from each infected person aboard (total 368,000 simulated particles). The movement of the particles after exiting the mouth was monitored.

*Reference: K. Talaat et al., **Simulation of aerosol transmission on a Boeing 737 airplane with intervention measures for COVID-19 Mitigation**, Phys. Fluids 33, 033312 (2021)*

Simulation Results: Distribution of the Exhaled Particles with Time



Vertical position from the cabin ground (m):

0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2 2.2



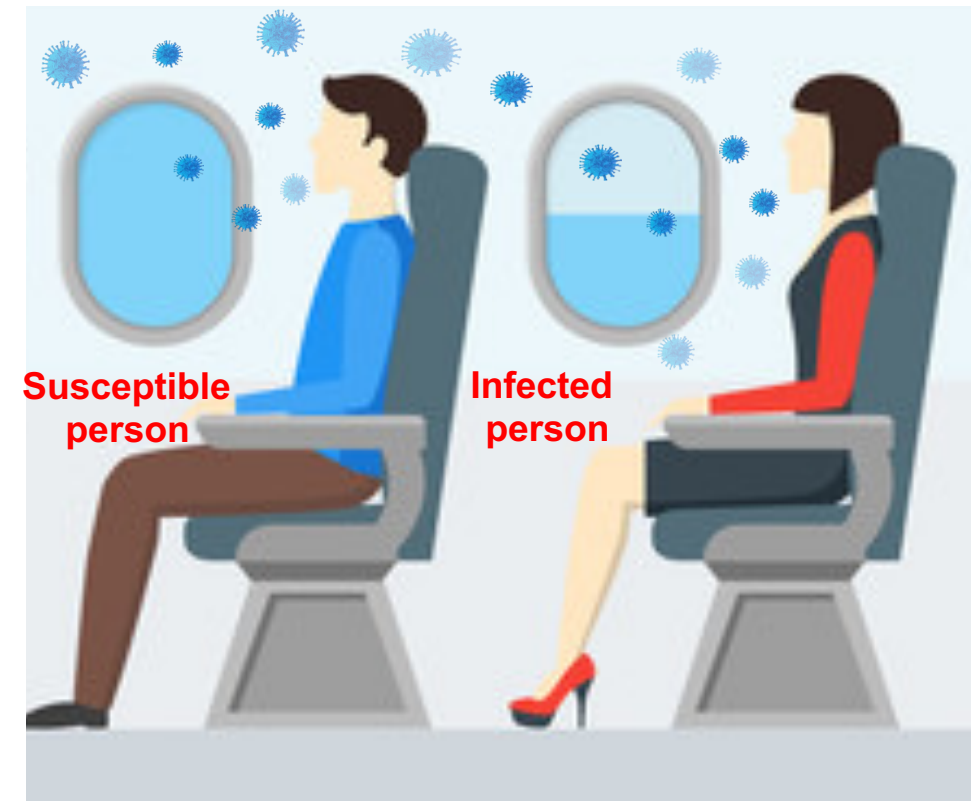
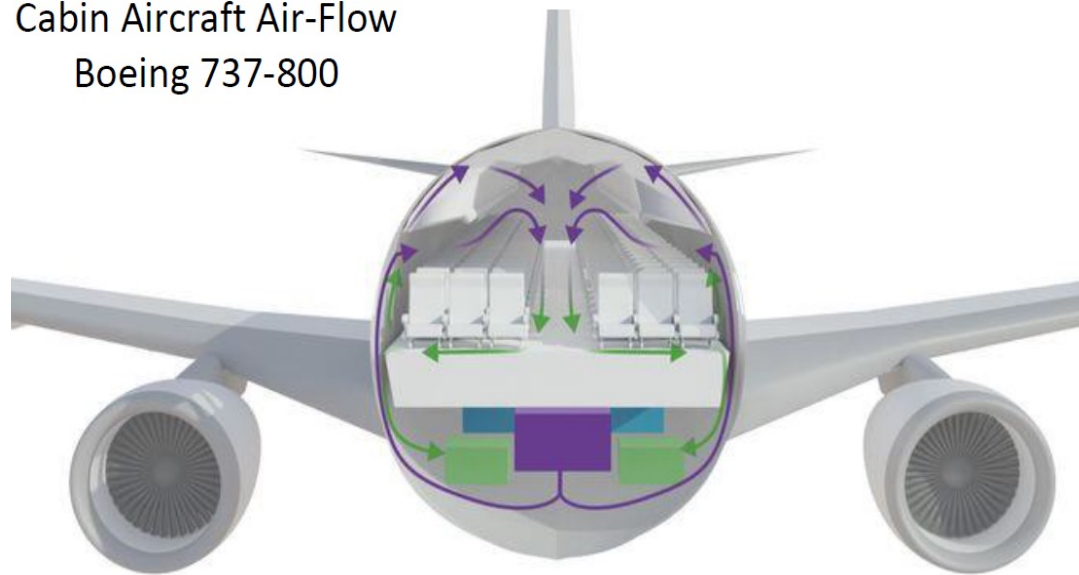
Cross-Infection in the Aircraft Cabin: < 50 Seconds

- Our research shows that cross-infection damage in the cabin can happen within the first 50 seconds of exhaling an infectious breath, cough, or sneeze.



Cabin air changes every 2-3 min
2.5 min = 150 sec

Cabin Aircraft Air-Flow
Boeing 737-800



Simulation Results: Inhalable Fraction

INHALABLE FRACTION AND NUMBER OF INFECTED PASSENGERS*

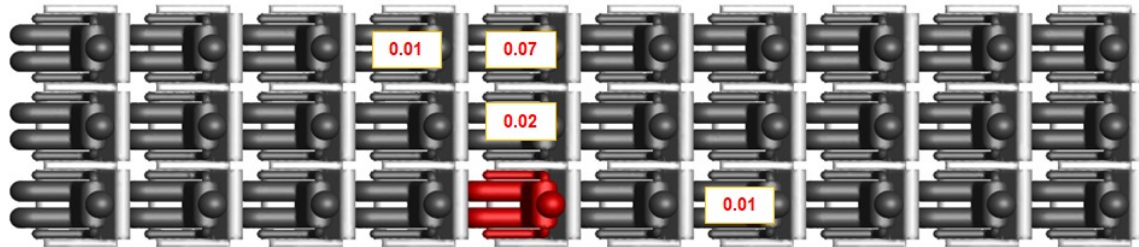
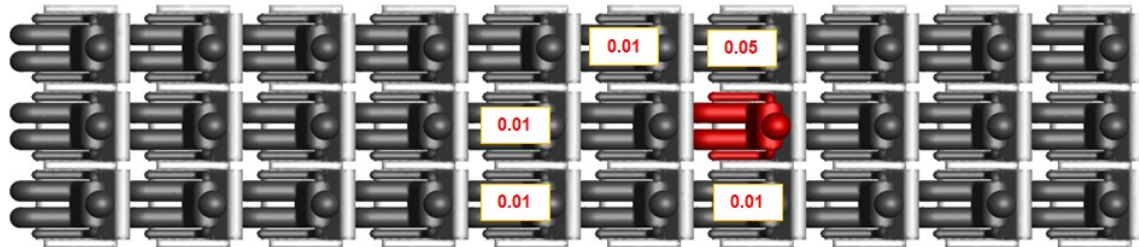
	Base case	Scenario A	Scenario B
Inhalable fraction, %	0.26	0.09	0.01
Maximum number of infected passengers	9	5	0 (or 1)**

* In addition to the two infected passengers.

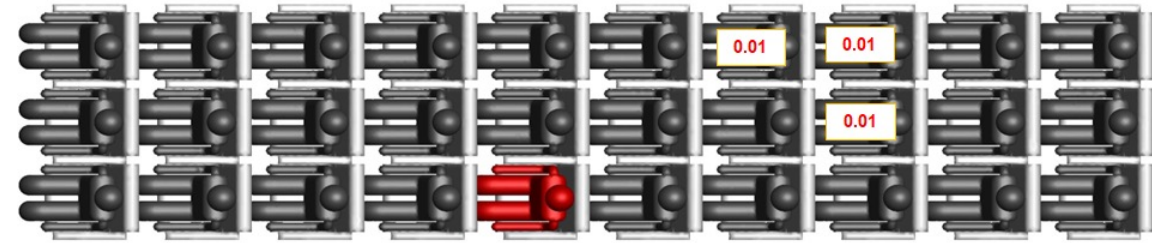
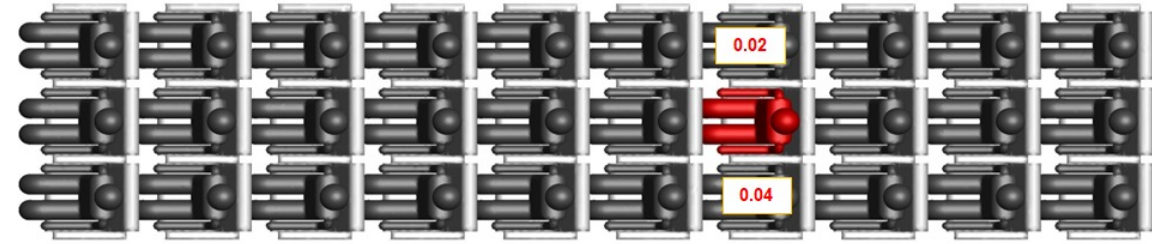
** The inhalable fraction is very low, so the infection will depend on the flight duration and the minimum infective dose (MID) needed to cause infection in the fellow passengers.

Simulation Results: Who Gets Sick?

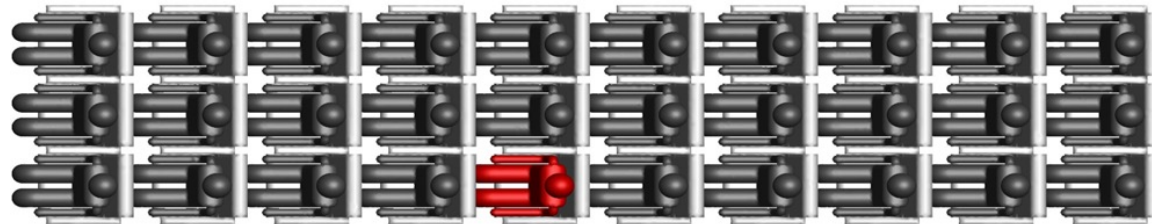
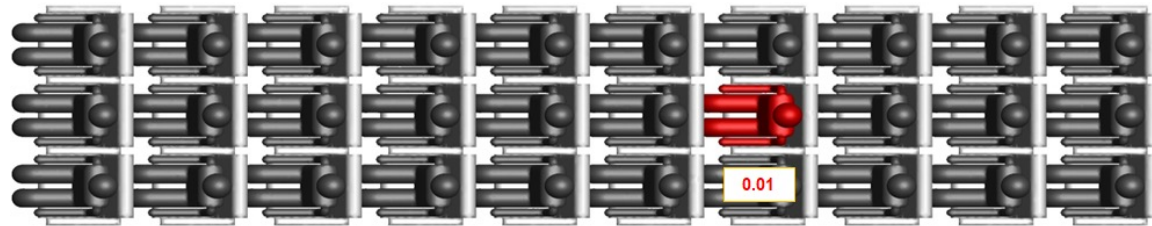
Base Case



Scenario A



Scenario B



Distribution of passengers, who inhale pathogen-containing aerosols exhaled from the infected red-colored passengers. The red numbers represent the inhaled fractions of pathogen-containing aerosols.

Number of Infected Passengers Aboard a Boeing 737

- The number of newly infected passengers was calculated from the simulated inhalable fractions for all 3 scenarios. The calculations assume no movement in the cabin. Also, the following expiratory events were assumed for the two infected passengers per hour:
 - **50 min normal breathing**
 - **10 min talking**
 - **2 coughing events**
- The number of exhaled particles during different expiratory events was taken as follows:
 - **BREATHING:** 1 min breathing = 30 virion-laden aerosols
 - **COUGHING:** 1 cough = 250 virions (aerosols+droplets)
 - **TALKING:** 10 min talking = 3,000 virions (aerosols+droplets)
- The minimum infective dose (MID) for common airborne-transmitted infections was taken from literature.

Number of newly infected passengers during **1-hr-flight**

assuming average shedding rate from two infected passengers in the coach section of Boeing 737

Pathogen	<u>Base Case</u> # of newly infected passengers	<u>Scenario A</u> # of newly infected passengers	<u>Scenario B</u> # of newly infected passengers
SARS-Cov-2 (MID: 100-1,000)	2	1	0
Influenza H1N1 (MID: 600)	1	0	0
Rhinovirus RV15 (MID: 100)	2	1	0
Norovirus (MID: 10-100)	9	5	1
Adenovirus type 4 (MID: 10-500)	9	5	1
M. Tuberculosis (MID: 1-200)	9	5	1
Bordetella Pertussis (MID: 1-150)	9	5	1
Bacillus Anthracis (MID: 1-100)	9	5	1
M. Pneumoniae (MID: 1000)	0	0	0

MID = minimum infective dose (# pathogens needed to cause infection)

Number of newly infected passengers during **6-hr-flight**


assuming average shedding rate from two infected passengers in the coach section of Boeing 737

Pathogen	<u>Base Case</u> # of newly infected passengers	<u>Scenario A</u> # of newly infected passengers	<u>Scenario B</u> # of newly infected passengers
SARS-Cov-2 (MID: 100-1,000)	9	5	1
Influenza H1N1 (MID: 600)	9	5	1
Rhinovirus RV15 (MID: 100)	9	5	1
Norovirus (MID: 10-100)	9	5	1
Adenovirus type 4 (MID: 10-500)	9	5	1
M. Tuberculosis (MID: 1-200)	9	5	1
Bordetella Pertussis (MID: 1-150)	9	5	1
Bacillus Anthracis (MID: 1-100)	9	5	1
M. Pneumoniae (MID: 1000)	3	2	0

MID = minimum infective dose (# pathogens needed to cause infection)

Summary

- This study showed potential cross-infection could occur within 20-50 sec in an aircraft cabin, while the cabin air changes every 2-3 min.
- The new exhaled-air-handling system **reduces the inhalable fraction of potentially pathogen-laden aerosols, and thus, significantly reduces the risk of cross-infection.** In particular,
 - The new exhaled-air-handling system (Scenario A) reduces the number of newly infected passengers by 50%, compared to the Base Case.
 - The new exhaled-air-handling system (Scenario B) reduced the number of newly infected passengers by > 90% compared to the Base Case.
- The new exhaled-air-handling system **reduces the probability of outbreak of airborne-transmitted diseases aboard a Boeing 737-800.**
 - It always yields $R_0 < 1$ regardless of the flight duration.



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