Memo / Preprint

AERO_M_Airbus-CabinAir_Explanation_20-06-19.pdf

Datum: **2020-06-19**

Author:
Prof. Dr. **Dieter Scholz**, MSME
Aircraft Design and Systems Group (AERO)
Department Automotive and Aeronautical Engineering
Hamburg University of Applied Sciences Hamburg
Berliner Tor 9, 20099 Hamburg, Germany

E-Mail: info@ProfScholz.de
WWW: http://AERO.ProfScholz.de
PURL: https://purl.org/corona/M2020-06-19 (persistent link to this document)
DOI: https://doi.org/10.31224/osf.io/b9dkp (persistent link to preprint)

Airbus' Cabin Air Explanations during the Corona Pandemic – Presented, Analyzed, and Criticized

Abstract

The technical expertise of the aircraft manufacturer on cabin air in passenger aircraft during the Corona pandemic is paramount. Not much of it is out in the public domain. The little information found, is presented here, analyzed, and criticized. Airbus is using the same arguments in support of flying during times of COVID-19 as other stakeholders in the aviation industry. The three facts: high air change rate, use of HEPA filters, and a ventilation concept for each cross section along the length of the fuselage justifies for Airbus to wave otherwise accepted commandments about social distancing. Every possible argument is used to play down the health risk from SARS-CoV-2 for the sake of inviting passengers back into the aircraft. The wealth of arguments can be found in an interview with Airbus chief engineer Jean-Brice Dumont. This memo presents some of the arguments from the video in written form.

1 Introduction

Aviation organizations like the International Air Transport Association (IATA) are lobbying successfully already since the beginning of May for flying in densely filled aircraft (Pearce 2020). Certainly, Airbus would have informed its customers – the airlines – about cabin air related details in view of COVID-19. At least, this would explain the uniform wording used by stakeholders in Germany. But openly, Airbus entered the scene only relatively late at the end of May. This is much in contrast to Boeing. Boeing appointed Mike Delaney to lead the company's "Confident Travel Initiative" already on May 14th. Delaney said: "we want passengers and crews to board Boeing airplanes without hesitation" (Boeing 2020). In comparison, Airbus came as late as May 29th with a text about air conditioning on its planes (Airbus 2020a), including an animation about cabin air flow (Airbus 2020b) enhanced by a Facebook life event now available as an online streaming video (Airbus 2020c). Similar to Boeing, also Airbus intends to educate or convince passengers. Aim is to provide technical arguments to make passengers feel save and to downplay the real risk and danger of a possible infection in an airplane. The motivation for the education of the public about air conditioning systems on aircraft is clearly expressed in the video: "We hope you'll be flying soon ... thank you so much ... and enjoy your next flight" (Airbus 2020c). This memo comments on Airbus' web page about cabin air and Airbus' video found on Facebook. As the discussion about health risks from flying during the Corona pandemic intensifies (for Germany see e.g. Hegmann 2020, Benndorf 2020, Berndt 2020) it is important also to present Airbus' view and comment on it. These are the sources:

1.) **Airbus: Cabin and Comfort – Passenger Aircraft – Cabin Air**
https://www.airbus.com/aircraft/passenger-aircraft/cabin-comfort.html#airquality
Archived on 2020-06-18: https://perma.cc/U6FN-QA28
Find the separate **video** "**Cabin Air Flow**" here: https://youtu.be/rcfq9a1_27I

2.) **Airbus: Facebook Live – Jean-Brice Dumont, Airbus EVP Engineering, 2020-05-29, 15:30 CET**
#KeepTrustInAirTravel #COVID19 (see Figure 1).
Find the **video** here: https://www.facebook.com/watch/?v=582384906021127

In addition one news article (DPA 2020) was found with an interview of Jean-Brice Dumont. However, it is not clear in this article where the statements made are coming from. For this reason this news article has not been considered further. French media have not been reviewed.

The technical background to this analysis can be found in the 24-page press release (Scholz 2020a). A short version is Benndorf 2020 – both in German.

This is the second version of this document. Most of the "**Aircraft Cabin Ventilation Theory**" was moved to a separate document: Scholz 2020b (https://purl.org/AERO/M2020-06-27).

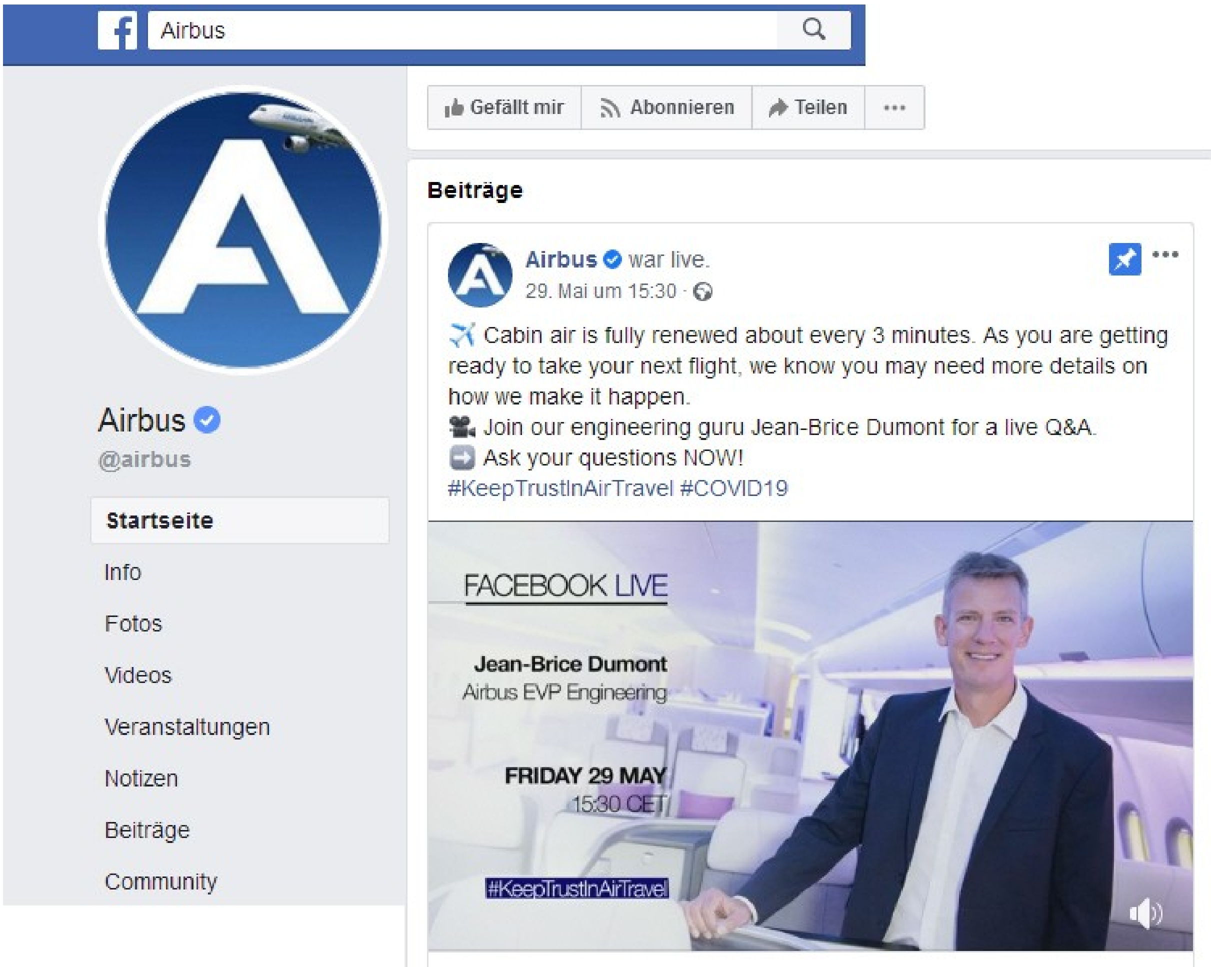

Figure 1: The Airbus engineering chief is introduced on Airbus' Facebook page (archived on 2020-06-23 as https://perma.cc/YA6L-JEJ6) as "engineer guru". "in Sanskrit guru means the one who dispels the darkness and takes towards light". "In the Western world, the term is sometimes used in a derogatory way to refer to individuals who have allegedly exploited their followers' naiveté" (Wikipedia 2020a)

2 Analysis of the WWW-Page "Airbus: Cabin and Comfort – Passenger Aircraft – Cabin Air"

Statement 1:
"It [the air] flows from top to bottom at one meter per second, and is subsequently removed through the floor. This airflow is optimised to prevent longitudinal movement, so there is no spread between adjacent seat rows."

Criticism:
- The fact that air is mixing in the cabin cross section is left unmentioned.
- "there is no spread between adjacent seat rows" is wrong. A horizontal flow in longitudinal direction (though substantially smaller than in lateral direction) is present in the cabin. Mixing of cabin air in longitudinal direction takes place also due to turbulence and dilution.

Statement 2:
"such that it [the air] is fully renewed / exchanged with fresh air about every two to three minutes. For comparison, air in hospital rooms and classrooms is exchanged about every 10 minutes and about 20 minutes in offices."

Wrong parameter selected: The aircraft cabin must be ventilated. For this purpose, the certification regulations (CS 25.831) require at least a mass rate of 0.25 kg (0.55 lb) of fresh (outside or filtered) air per minute per passenger. Under standard cabin conditions, this is equivalent to a volume flow of about 5 l/s per passenger. With 200 passengers that would be a volume flow of 1 m³/s of fresh air. 3600 m³ of fresh air would then be required per hour. An airplane for 200 passengers has a volume of approximately 400 m³. This means that the air in the cabin is changed 9 times an hour. The value 9 1/h is called the air change rate per hour (ACH) and results in a theoretical air change every 6 to 7 minutes (60 min / 9 = 6.7 min). For reasons of comfort, a higher volume flow (about 8 l/s) is selected for new aircraft models, which leads to an air change every 4 minutes. The air is of course not completely renewed. Mixing occurs; the 4 minutes are therefore only a theoretical value. Office buildings are also ventilated with 5 l/s or even 10 l/s (Wikipedia 2020b). According to IDC 2012 offices and restaurants need 9.4 l/s, patient rooms in a hospital 10.4 l/s, and a public rest room 23.6 l/s. The air change rate is high on the plane, but not because the ventilation per person is exceptional, but because the cabin volume per passenger is with 2 m³ so small compared to residential buildings or even churches. The important variable is and remains the volume flow per passenger.

Not "fully renewed": The air in the cabin cannot be compared to the air in an air pump. There, the air is carried out by a piston and new air is sucked in (ventilation by displacement of air). In contrast, the cabin mixes new and old air (ventilation by mixing of air). Due to the mixing of air the ventilation efficiency is only about 0.5 (Wikipedia 2020c). The three minutes are the inverse to the so-called air change rate (per hour, ACH). If the air is exchanged theoretically 20 times per hour (ACH = 20 1/h) the time for one change is the theoretically 1 hour or 60 minute divided by 20 or 3 minutes. This is a purely theoretical value. The air is therefore not "fully" exchanged, and certainly not in the specified time. A detailed explanation based on the fundamental ventilation equation is given in a separate document called "**Aircraft Cabin Ventilation Theory**" (Scholz 2020b). A few aspects are repeated in this text.

The fundamental **ventilation equation** is summing all the mass of a particular substance in a volume per time – the mass generated inside the volume, the inflow of that substance minus the outflow of that substance results in the change of that substance in the volume

$$S + Q_e C_o - Q_e C = V \frac{dC}{dt} \quad .$$

S: source strength in kg/s
Q_e: effective air flow rate for ventilation in m³/s
C: concentration of CO2 or any other substance in kg/m³ in the room
C_o: concentration of CO2 or any other substance in kg/m³ outside of the room
V: volume of the room

The air change rate *n* (in 1/h) – the number of theoretical air changes per hours – is

$$n = \frac{Q}{V}$$

Q: air flow rate for ventilation in m³/s

The time for one theoretical air exchange, t_{n1} is

$$t_{n1} = 1/n \quad .$$

In case of a **steady state** situation (no change in concentration *C*), where *C* is now understood as the difference of the concentration to the outside (ambient) concentration, the equation simplifies to

$$C = \frac{S}{Q_e}$$

We learn: The concentration is independent of the volume *V* and depends only on the source strength *S* and the effective air flow rate Q_e.

The **effective air flow rate** can be determined from the **measured** CO2 concentration on the aircraft during a steady state situation. The source strength, *S* can be estimated from the number of persons on board.

$$Q_e = \frac{S}{C} = \eta\, Q \quad .$$

A sample calculation in Scholz 2020b is showing the ventilation efficiency η in an aircraft having typical values a low as 25% ... 50%.

The difference between the *effective* air flow rate for ventilation, Q_e and the air flow rate for ventilation, Q (the inflow) becomes apparent from Figure 2. Some air entering a room may leave the room without mixing with the air in the room and as such without rinsing the room.

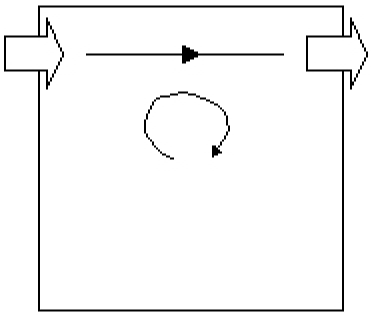

Figure 2: A short circuit in room ventilation. Not all of the air entering the room is used for ventilation. Some air leaves the room without reducing the concentration of the substance in question in the room (Wikipedia 2020).

The simplified **equation for the unsteady case** can be written as

$$\frac{C(t)}{C_0} = e^{-\eta\, n \cdot t} = e^{-\eta \frac{t}{t_{n1}}} \quad .$$

$C_0 = S/V$ is the initial (steady state) concentration in the room at t = 0. $C(t)/C_0$ is the remaining relative concentration after time t.

We learn: The speed with which the system reacts to change is characterized by the effective air change rate $\eta\, n$.

With this we can fill Table 1 and draw Figure 3.

Table 1: Relative remaining concentration for a ventilation efficiency of η = 1 versus relative time

$t = x \cdot t_{n1}$	x =0.1	x =1/3	x =1/2	x =1	x =2	x =3	x =4	x =5
$C(t)/C_0$	90.5%	71.7%	60.7%	36.8%	13.5%	5.0%	1.8%	0.67%

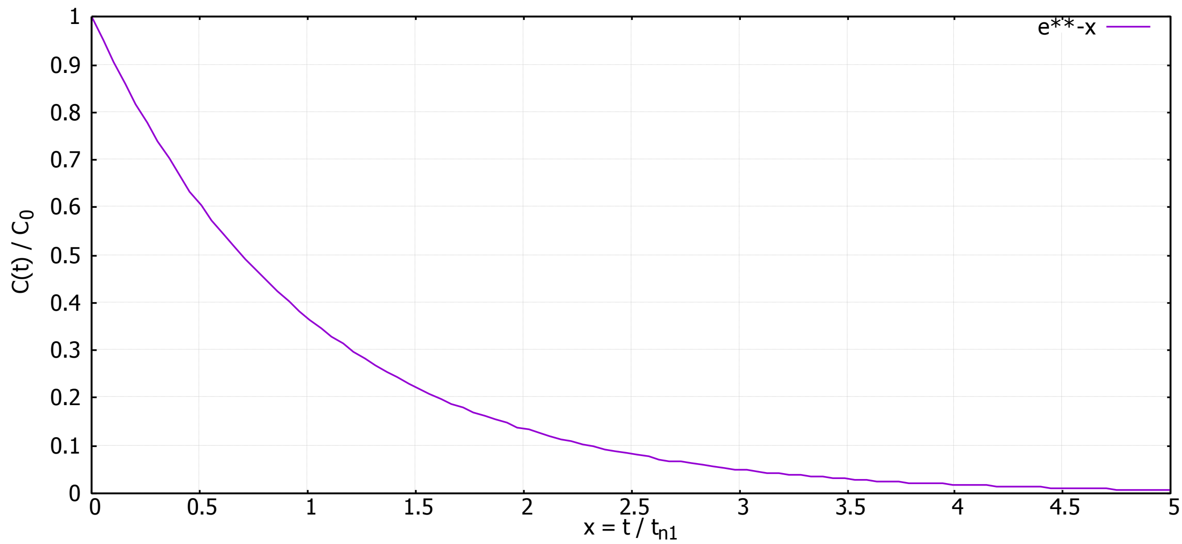

Figure 3: Relative remaining concentration for a ventilation efficiency of $\eta = 1$ versus relative time

Rinsing is an asymptotic process. A concentration (e.g. of viruses) will only reach the value 0% of the initial amount (i.e. "full" rinsing) after an infinitely long time. That is significantly more than "two to three minutes".

Criticism:

- Airbus is using numbers in its comparison between aircraft and offices that are not relevant in indoor ventilation (Wikipedia 2020b), especially when comparing indoor spaces of different volume per person (aircraft, office, church).
- Airbus states "fully renewed" together with the air change rate. This is not true, as the air change rate is only a theoretical value. The real air change rate depends on the ventilation efficiency, which is always smaller than one. In a mixing (dilution or rinsing) process a concentration of zero is reached only asymptotically. A relative concentration of less than 1% is only achieved after 5 air changes (if full mixing is assumed). During practical ventilation ($\eta \approx 0.5$) a relative concentration of less than 1% may only be achieved after 10 air changes (Scholz 2020b).

Statement 3:
"The cabin air is exchanged about every 2-3 minutes which enables a high virus dilution rate."

Remark:

- It is not clear what a dilution rate is. Probably the reduction of the concentration per time. It is true; the high air change rate is responsible for <u>fast dilution</u>. However – probably more important – is the steady state concentration of viruses. It depends on the effective air flow rate, which in an aircraft is comparable to office spaces. As such, the aircraft cannot claim any advantage.

3 Analysis of the Video "Airbus: Cabin Air Flow"

The video shows an animation of the environmental control system (ECS) of an Airbus single aisle aircraft. The video has no sound. The key message of the video can be presented here with a few screen shots (Figure 4, Figure 5 and Figure 7).

Criticism:

Figure 4: The impression is given; the outside air would be drawn from the top of the wing. Fact is the air is tapped off from the compressor of the engine with known problems of possible cabin air contamination due to engine oil (http://CabinAir.ProfScholz.de).

Figure 5: The impression is given; the flow would go around the passengers. Staying clear of the passengers, the air would not be able to transport droplets from one person to the other. In contrast, reality is indicated in Figure 6 with more details to the flow in an A320 cabin cross section. Mixing of air between passengers in one row is possible. Such a circulating flow pattern is known from other aircraft and sources (Chen 2011: B767 and NRC 2002). Also Mr. Dumont, Airbus EVP Engineering explains in the Facebook-Video (see Section 4): "the circulation of air around that person is limited to that person's row". The flow from the gasper system is not indicated in Figure 5.

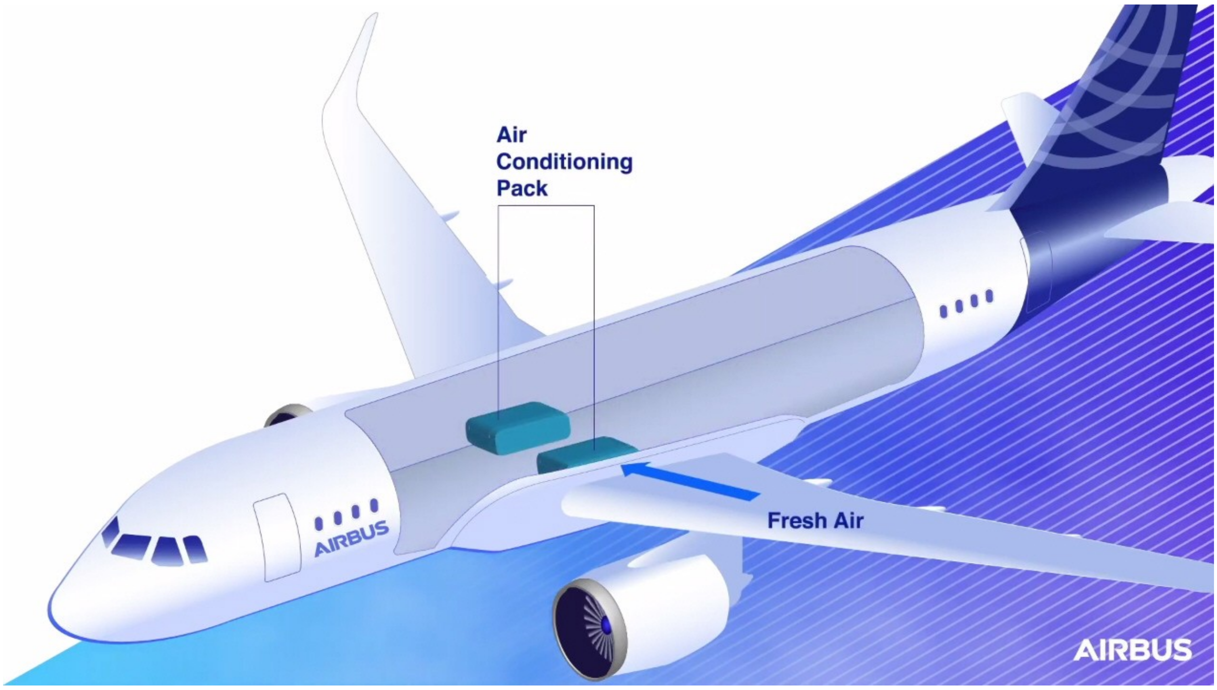

Figure 4: Airbus-Video "Cabin Air Flow". Fresh air input is in reality not taken from the upper surface of the wing, but from the engine compressor (https://youtu.be/rcfq9a1_27I).

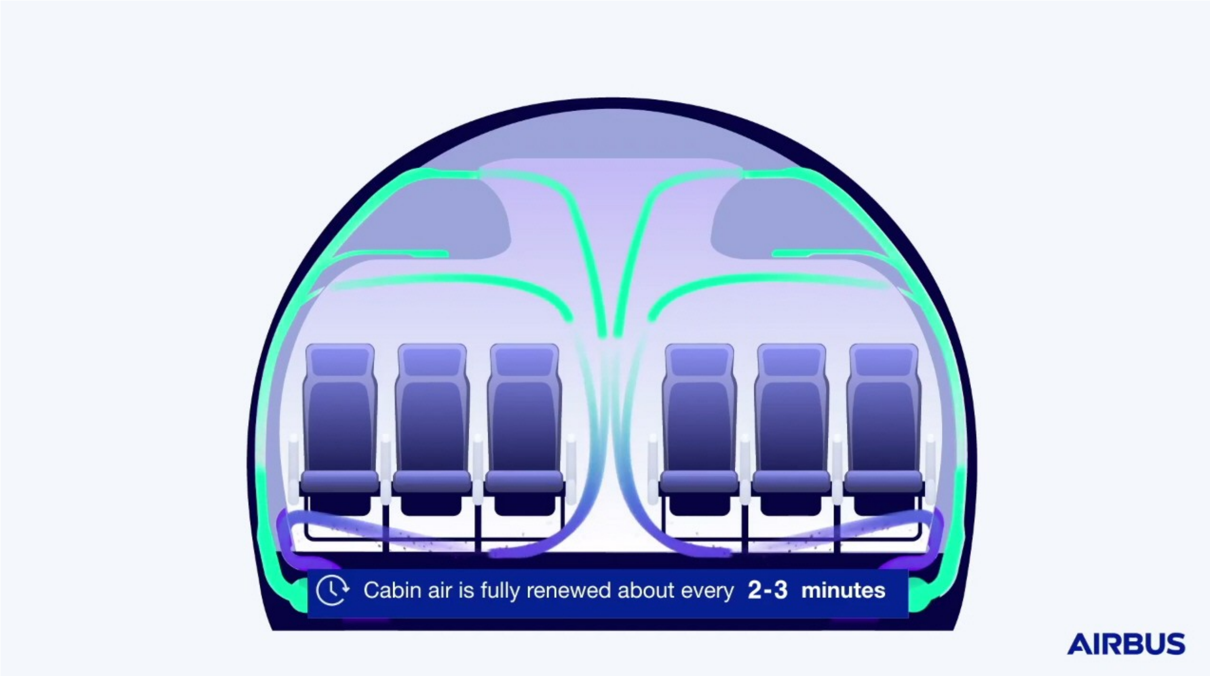

Figure 5: Airbus-Video "Cabin Air Flow". According to this figure, the air flow in the cabin cross section has its origins above and below the overhead compartments. The air descents in the aisle and leaves horizontally over the floor where it finds its way into the cargo compartment (https://youtu.be/rcfq9a1_27I).

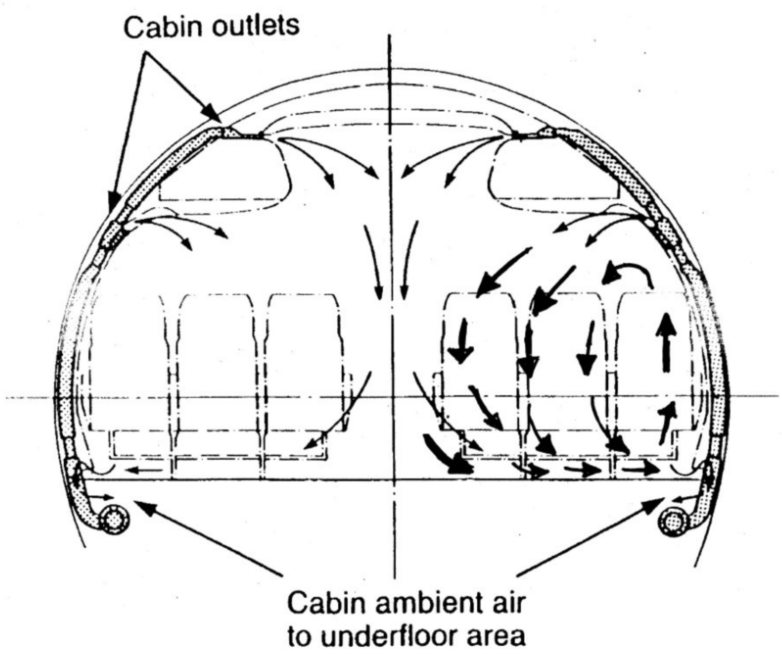

Figure 6: Air flow in an A321 cabin cross section. On the left, the drawing is left in its original form (Scholz 2014, from Airbus Training Course). On the right the velocity vectors are hypothetically extended to show a likely flow pattern. The direction of the arrow is important. Here, arrow length does *not* indicate velocity (in m/s). As can be seen, mixing of air between different seats is possible.

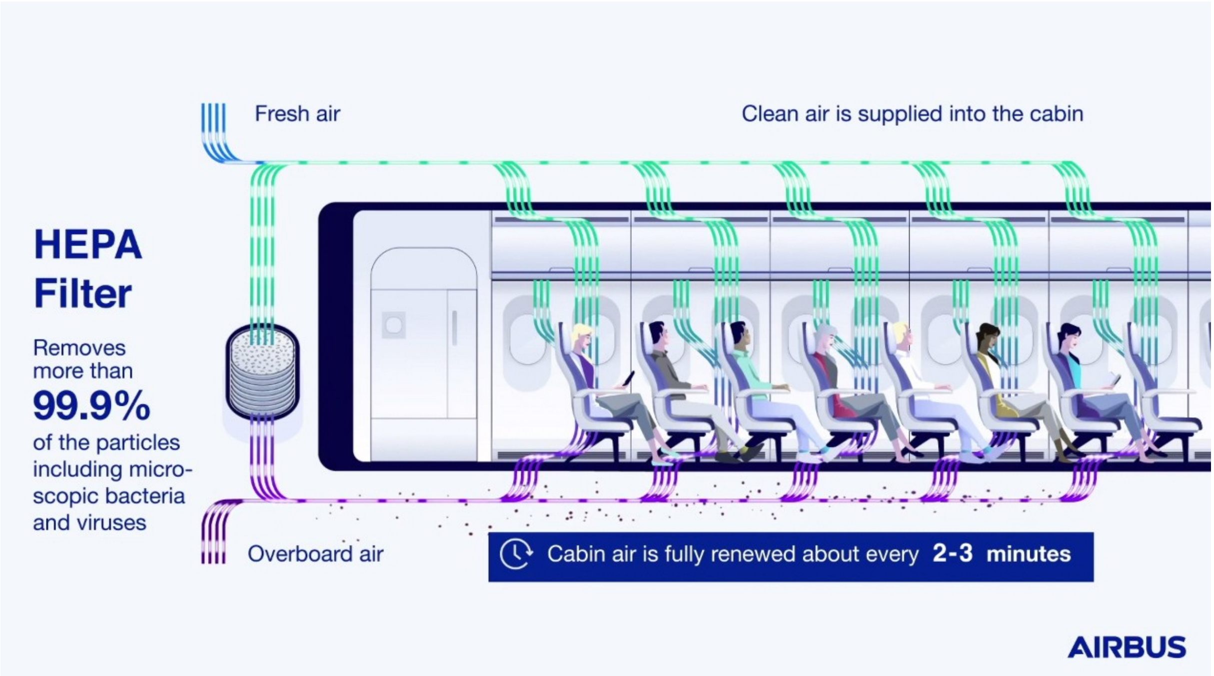

Figure 7: Airbus-Video "Cabin Air Flow". Shown is a longitudinal cut through the cabin along the aisle. Air is coming from above and below the overhead compartments. The air flows around the passengers (in contrast to Figure 5, where the air stays clear of the passengers) and leaves the cabin towards the cargo compartment (https://youtu.be/rcfq9a1_27I).

Figure 7: Also according to this figure, the air flow has its origins above and below the overhead compartments. But in contrast to Figure 5, the air seems to descent over the seats (it is shown to be deflected by the passengers) and not in the aisle. It is worth to note that the air has also a horizontal direction in longitudinal direction.

4 Analysis of the Video "Facebook Live – Jean-Brice Dumont, Airbus EVP Engineering, 2020-05-29, 15:30 CET"

This video shows Jean-Brice Dumont, Airbus EVP Engineering in a live conversation with Justin Devon on Facebook to explain cabin air and cabin air flow in an economy class section of the Airbus A350 in the cabin mock-up in Toulouse (Figure 8). The video was produced during the live event on Friday, 29 May 2020, 15:30 CET. The video remains subsequently available on Facebook. A copy is available also on YouTube (Airbus 2020c). Purpose of the video was/is to convince the travelling public that flying is safe. "We hope you'll be flying soon. To our viewers: Thank you so much for joining us and enjoy your next flight". Some questions and answers where prepared beforehand for the video other questions where taken live from the Internet audience. This caused substantial redundancy in the answers.

Figure 8: Title page of the Facebook video with Jean-Brice Dumont, Airbus, explaining why it is safe to fly also during the Corona pandemic (https://www.facebook.com/watch/?v=582384906021127).

The interview starts with an explanation of the need for air conditioning in a passenger aircraft and cabin air flow (1:00, time code of YouTube copy). Arguments are given why the air on board is clean: HEPA-Filter, air blown down, no horizontal flow, and the air is renewed every 2 to 3 minutes (2:00). The air flow is explained (4:45): vents, direction, and evacuation at floor level.

Debating 100% of fresh air (5:50): "100% fresh air would mean changing the mix. The recirculated air is much purer than anything else."

Discussing a sick person on board (6:50): "If you consider that somebody is sick ... that the ability of that person to potentially contaminate the neighbor is very limited. So that's on the one hand the air does not move forward and backwards, so that the circulation of air around that person is limited to that person's row, and on the other hand that the air is renewed powerfully every 2 to 3 minutes, so that even though that person may have contamination around him or her that air is evacuated an renewed."

Remark: Since air conditioning takes place for each row – as Airbus says – an ill person can have an effect on the entire row.

Debating air conditioning with the aircraft on the ground (9:00): "When the aircraft is waiting on the ground ... the crew has the choice. The ventilation could be off."

Remark: Accordingly, COVID-19 has not changed the use of the air conditioning system. It is still the choice of the crew.

Discussing the high density of people on board (12:10): "Minimizing the risk of people entering the aircraft being contaminated. This risk will never be zero – does not exist in life, but taking temperature checks at the airport having people filling declarations, tracing apps ... a set of measures. That ensures that the persons entering the aircraft have a low risk to be contaminated is the first thing. Then it's about the behavior on board ... cleaning hands when you enter, wearing a mask during the whole flight ... the fact that you are seated around somebody for a couple of hours does not mean a higher risk than being in another area where you are close to people in a given period of time like shops."

Remark: Temperature checks are not widely applied because they are ineffective. COVID-19 patients can be without symptoms. Tracing apps are just being introduced with unknown effect. Cleaning hands when entering the aircraft is not applied at German airports. Masks are not worn during the whole flight. They are taken off for drinking and eating. In a shop I do not sit elbow to elbow with another person and certainly not for hours. Hence the comparison is unjustified.

Discussing viruses around you (17:05): "within a minute everything [all viruses] has vanished". "The likelihood to contaminate your neighbor is very low. You are facing forward and even when you are looking at each other, when I am talking to you like this [see Figure 9] that [the viruses] is going in that direction [forward]. The risk of contamination cross seat is very limited much more limited than in other environments."

Remark: According to the calculation above (Table 1, x = 1/3) after a minute 72% of the concentration is still left (much more than "vanished"). According to simulations (Chen 2011) droplets do not even vanish within 4 minutes. After 4 minutes dilution is to 12% of the original concentration.

Figure 9: Jean-Brice Dumont, Airbus, explaining that all viruses will move forward, even when looking to your neighbor – as in this picture (https://www.facebook.com/watch/?v=582384906021127).

Remark: It is not a very convincing model that droplets from sneezing will only spread in a cone with limited cone angle. With the cone angle even so narrow that the seat neighbor will not come into the blast of droplets if the sneezer is turning towards his/her neighbor.

Remark: Related to "The risk of contamination cross seat is very limited much more limited than in other environments." What other environments? If the other environments are not specified, how can I judge that the risk in the aircraft is much more limited? The argument why social distancing does not apply to passenger aircraft is not convincing. The real reason, the financial implications, is not mentioned.

Discussing the free middle seat (21:00): "We do consider to let the middle seat free makes no real sense and has no added value in terms of protecting you ... When you are sneezing, when you are talking, most of the droplets – imagine you wear no mask, what is not the case – would go forward or diagonal. So it's more the back of the seat in front of you, which is hit by the droplets, therefore a cleaning question, rather than your neighbor. **The question about the middle seat is not the right question!**"

Remark: If you run out of arguments, the question must be wrong.

References

AIRBUS, 2020a. *Cabin and Comfort – Passenger Aircraft – Cabin Air*. Available from: https://www.airbus.com/aircraft/passenger-aircraft/cabin-comfort.html#airquality, archived at: https://perma.cc/U6FN-QA28 (2020-06-18), with video Airbus, 2020b

AIRBUS, 2020b. *Cabin Air Flow* [video]. Available from: https://youtu.be/rcfq9a1_27I

AIRBUS, 2020c. *Facebook Live – Jean-Brice Dumont, Airbus EVP Engineering, 2020-05-29, 15:30 CET* [video]. Available from: https://www.facebook.com/watch/?v=582384906021127, backup copy: https://youtu.be/LV00dLUdK0k

BENNDORF, Anja, 2020. Experte für Flugzeugsysteme: "Man kann sich im Flugzeug infizieren". In: *Die Rheinpfalz*, 2020-06-16. Archived at: https://perma.cc/46DL-MGM6

BERNDT, Christina, 2020. Das Virus fliegt mit – In Flugzeugen ist es kaum möglich Abstand zu halten. Experten halten das für problematisch. In: *Süddeutsche Zeitung*, 2020-06-19. Archived at: https://perma.cc/49V3-D3LP

BOEING, 2020. *Boeing Names Delaney to Lead Confident Travel Initiative*. News Release, 2020-05-14. Available from: https://boeing.mediaroom.com/2020-05-14-Boeing-Names-Delaney-to-Lead-Confident-Travel-Initiative, archived at: https://perma.cc/3PL3-FK7R

CHEN Qingyan, GUPTA, Jitendra K., LIN, Chao-Hsin, 2011. Transport of Expiratory Droplets in an Aircraft Cabin. In: *Indoor Air*, vol. 21, no. 1, pp. 3-11. Available from: https://doi.org/10.1111/j.1600-0668.2010.00676.x, Open Access at: https://engineering.purdue.edu/~yanchen/paper/2011-2.pdf

DPA, 2020. Klimaanlagen in Flugzeugen sind keine Virenschleudern. In: *Zeit Online*, 2020-05-20. Available from: https://www.zeit.de/news/2020-05/20/klimaanlagen-in-flugzeugen-sind-keine-virenschleudern, archived at: https://perma.cc/8HW8-86CY

IDC TECHNOLOGIES, 2012. *Fundamentals of Heating, Ventilation & Air-Conditioning (HVAC)*. Perth: IDC Technologies. ISBN: 978-1-921007-85-9. Purchase: https://www.books.idc-online.com. Available from: https://www.eit.edu.au/cms/resources/books/practical-fundamentals-of-heating-ventilation-and-air-conditioning-hvac-for-engineers-and-technicians, archived at: https://perma.cc/D2AC-XMEK

HEGMANN, Gerhard, VETTER, Philipp, 2020. Das neue Reise-Risiko. In: *Welt am Sonntag*, 2020-06-08. Archived at: https://perma.cc/S92Q-DYYH

LINDNER, Ludwig, 2005. *CO2-Abgabe an die Atmosphäre durch menschliche Atmung*. Available from: http://www.buerger-fuer-technik.de/body_co2-abgabe_an_die_atmosphare.html, archived at: https://perma.cc/46HT-SMDR

NATIONAL RESEARCH COUNCIL (NRC), 2002. *The Airliner Cabin Environment and the Health of Passengers and Crew*, Committee on Air Quality in Passenger Cabins of Commercial Aircraft, Board on Environmental Studies and Toxicology. ISBN: 0-309-56770-X. Download possible: National Academies Press, http://www.nap.edu/catalog/10238.html

PEARCE, Brian, 2020. *COVID-19 - Cost of Air Travel once Restrictions Start to Lift*. International Air Transport Association (IATA), 2020-05-05. Available from: https://www.iata.org/en/iata-repository/publications/economic-reports/covid-19-cost-of-air-travel-once-restrictions-start-to-lift, archived at: https://perma.cc/4A7U-V97W

SCHOLZ, Dieter, 2014. Flugzeugsysteme. In: HORST, Peter; ROSSOW, Cord; WOLF, Klaus (Ed.): Handbuch der Luftfahrzeugtechnik. München: Carl Hanser. Open Access at: http://handbuch.ProfScholz.de

SCHOLZ, Dieter, 2020a. *Sommer 2020, COVID-19, Fliegen: ja oder nein? Vorsicht: Gesundheitsrisiko und unklare Rechtslage!*. Pressemitteilung, 2020-06-05. Available from: https://purl.org/corona/PR2020-06-05 (PDF), https://www.pressebox.de/bx/1009320 (HTML)

SCHOLZ, Dieter, 2020b. *Aircraft Cabin Ventilation Theory*. Memo, 2020-06-27. Available from: http://purl.org/AERO/M2020-06-27 (PDF)

WIKIPEDIA, 2020a. *Guru*. Available from: https://en.wikipedia.org/wiki/Guru

WIKIPEDIA, 2020b. *Ventilation (architecture)*. Available from: https://en.wikipedia.org/wiki/Ventilation_(architecture)

WIKIPEDIA, 2020c. *Luftführung*. Available from: https://de.wikipedia.org/wiki/Luftführung

WIKIPEDIA, 2020d. *Lüftungseffizienz*. Available from: https://de.wikipedia.org/wiki/Lüftungseffizienz