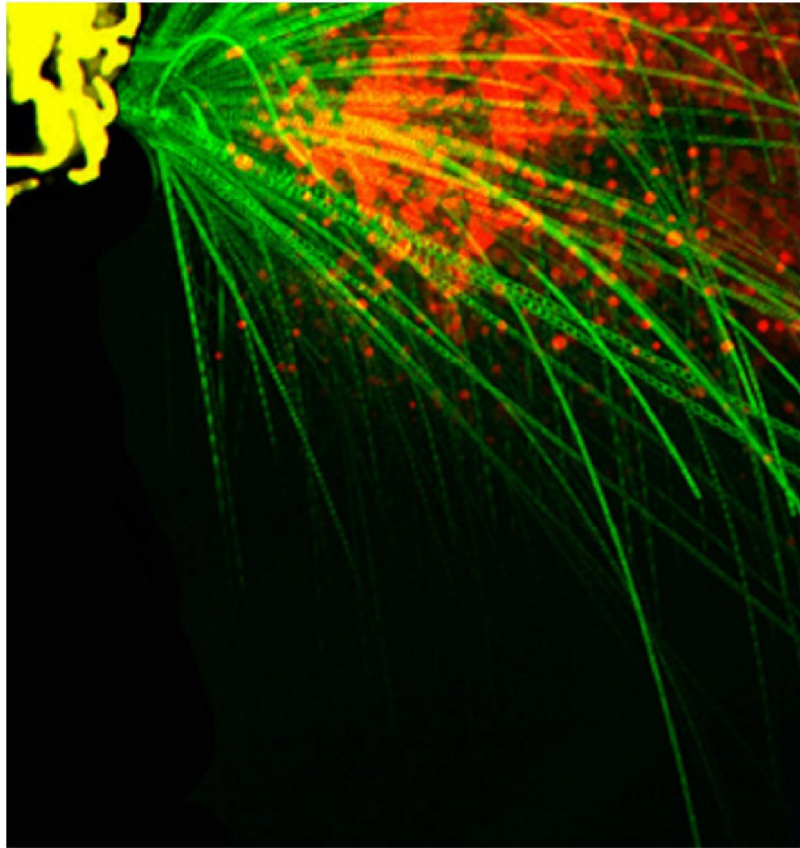




Department of Public Health
and Primary Care
Faculty of Public Health and
Primary Care



Risk assessment of SARS-CoV-2 CORSICA project

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CORSICA project

- RIVM and Netherlands Aerospace Centre (NLR)
- Phase 1: literature review on SARS-CoV-2 transmission in aircraft cabins, published October 2020
<https://www.tweedekamer.nl/kamerstukken/detail?id=2020D41709&did=2020D41709>
- Phase 2:
 - Measurements and simulations particle dispersion in aircraft cabins (NLR)
 - Risk assessment of SARS-CoV-2 transmission by aerosols in aircraft cabins (RIVM)

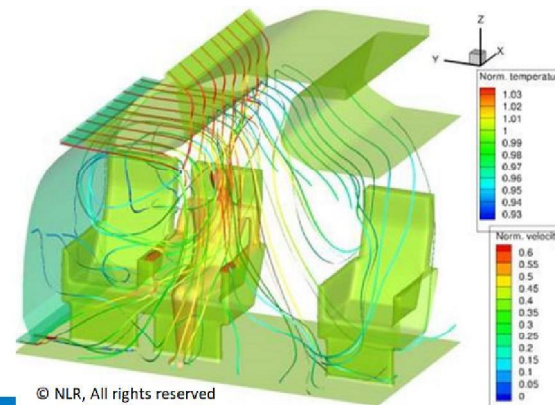
This presentation

- Results and conclusions risk assessment
- Results are confidential!



Measurements + simulations particle dispersion in aircraft cabins

- Three aircraft types (A320, B737, B787)
- Source aerosolizing artificial saliva, similar in size distribution from human breathing or speaking
- 7 rows around source
- 60 mannequins with particle counters





Quantitative Microbial Risk assessment

- Data from measurements + simulations on particle numbers and sizes
- Viral concentration data in mucus of infected individual
- Inhalation volume
- Flight duration
- Mask wearing

→ DOSE FOR A RANGE OF SCENARIOS

- Dose response model

→ PROBABILITY OF ILLNESS FOR A RANGE OF SCENARIOS



First observations of the data

Measurement data:

- A good and useful set of observations
- Aerosolized artificial saliva spreads several meters through aircraft cabin within minutes. Direction depends on aircraft type.
- Aerosolized artificial saliva concentration in air reaches a plateau within minutes
- After source is switched off, aerosol concentration declines to background level within minutes
- Likely due to high ventilation, 30 air changes per hour
- Concentration (aerosol volume / air volume) depends on distance



A320

Fraction exposed

	A	B	C	D	E	F
21	3×10^{-6} 3.6×10^{-6}	3.4×10^{-6} 4.1×10^{-6}	2×10^{-6} 2.4×10^{-6}	3.7×10^{-6} 4.4×10^{-6}	2.7×10^{-6} 3.3×10^{-6}	4.7×10^{-6} 5.7×10^{-6}
22	4.9×10^{-6} 5.9×10^{-6}	3.7×10^{-6} 4.4×10^{-6}	2.5×10^{-6} 3×10^{-6}	0.000011 0.000013	0.000023 0.000026	0.000076 0.000092
23	0.000017 0.00002	5×10^{-6} 5.5×10^{-6}	8.4×10^{-6} 0.000011	0.00015 0.00019	0.0007 0.008	0.0016 0.0019
24	0.00005 0.00006	0.000069 0.000082	0.00013 0.00016	0.00094 0.0011	Source	0.005 0.006
26	0.00013 0.00016	0.00018 0.00022	0.00021 0.00025	Operator	0.002 0.0024	0.0021 0.0025
26	0.00018 0.00019	0.00025 0.0003	0.00015 0.00019	0.00053 0.00064	0.00062 0.00075	0.00099 0.0011
27	0.00018 0.00022	0.00025 0.0003	0.0002 0.00024	0.00036 0.00043	0.00043 0.00051	0.00049 0.00058

B737

Fraction exposed

	A	B	C	D	E	F
21	3.8×10^{-6} 4.5×10^{-6}	3.9×10^{-6} 4.8×10^{-6}	4.8×10^{-6} 5.7×10^{-6}	3.4×10^{-6} 4.1×10^{-6}	4.4×10^{-6} 5.3×10^{-6}	3.5×10^{-6} 4.2×10^{-6}
22	4.4×10^{-6} 5.3×10^{-6}	4.2×10^{-6} 5×10^{-6}	4.1×10^{-6} 5×10^{-6}	5.5×10^{-6} 6.6×10^{-6}	3.8×10^{-6} 4.5×10^{-6}	7.7×10^{-6} 9.3×10^{-6}
23	8.3×10^{-6} 9.9×10^{-6}	6×10^{-6} 7.2×10^{-6}	8.8×10^{-6} 8.1×10^{-6}	0.000027 0.000033	0.000075 0.00009	0.000053 0.000064
24	0.000028 0.000034	0.000052 0.000053	0.00022 0.00027	0.00049 0.00059	Source	0.0025 0.003
25	0.00012 0.00015	0.0002 0.00024	0.00019 0.00023	Operator	0.00072 0.00087	0.002 0.0024
26	0.00023 0.00027	0.00028 0.00034	0.00019 0.00023	0.00045 0.00054	0.00044 0.00053	0.00048 0.00055
27	0.00024 0.00029	0.00025 0.0003	0.00021 0.00026	0.00025 0.0003	0.00027 0.00033	0.00029 0.00035

B787

Fraction exposed

	A	B	C	D	E	F	G	J	K
32	0.00022 0.00026		0.00033 0.0004	0.00022 0.00027		0.00012 0.00015	0.00034 0.0004		0. 0.
33	0.00035 0.00042	0.00047 0.00057	0.00048 0.00055	0.00019 0.00023	0.00019 0.00023	0.00012 0.00015	0.00018 0.00021	0.00023 0.00027	0.00031 0.00038
34	0.00051 0.00062	0.00063 0.00076	0.00088 0.001	0.00027 0.00033	0.00026 0.00031	0.00023 0.00027	0. 0.	0.00029 0.00035	0.00039 0.00046
35	0.00043 0.00052	0.00078 0.00093	0.00067 0.00081	0.0011 0.0013	Source	0.0024 0.0028	0.00041 0.00049	0.00035 0.00042	0.00035 0.00042
36	0.00029 0.00034	0.0003 0.00036	0.00038 0.00043	Operator	0.0012 0.0015	0.0008 0.00096	0.00055 0.00065	0. 0.	0.00049 0.00059
37	0.00028 0.00034	0.00027 0.00033	0.00037 0.00044	0.00053 0.00063	0.00081 0.00097	0.00072 0.00087	0.0005 0.0006	0.00065 0.00078	0.00044 0.00053
38	0.00029 0.00035	0.00028 0.00034	0.00028 0.00033	0.00036 0.00044	0.00058 0.0007	0.00036 0.00044	0.00038 0.00046	0.00035 0.00042	0.0003 0.00036



Risk calculations - assumptions

- One index case present in aircraft
- Breathing 80% of the time, breathing + speaking 20% of the time
- Supershedder: 10^{10} copies / mL (2.7% of cases, RIVM data)
- The results pertain to the passengers seated on the 7 rows surrounding the index patient. The number of passengers per aircraft in case of full capacity is for the A320: 180; B737: 215; B787: 330.
- Average and high flight duration. A320 and B373 typically short flights (1 – 1.5 hour), B787 typically long flights (9 hours)
- Masks worn 90% of the time, with combined removal efficiency of 72% (literature)



Results – typical cruise flight

- *What was the predicted risk of SARS-CoV-2 transmission via aerosols during typical cruise flight conditions?*
- The predicted probability was that 1 in 212-1188 passengers get ill.

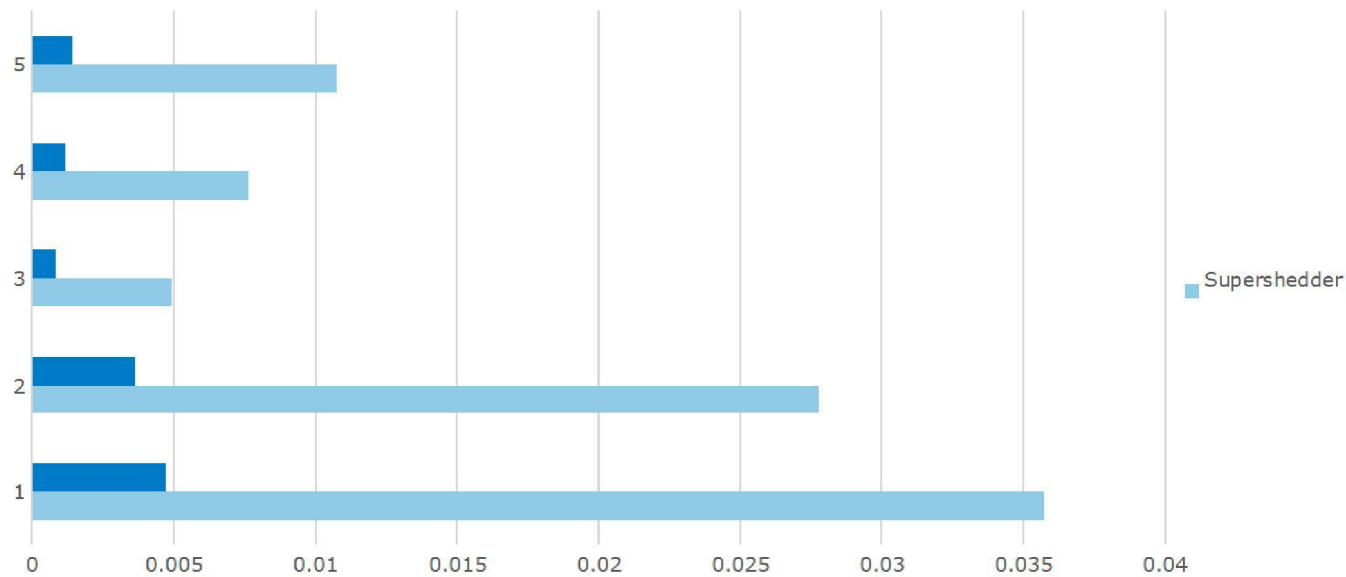
Results - supershedder

- *What if a supershedder was on board?*
- In the case that a supershedder was on board, risk of SARS-CoV-2 transmission may be considerably (5-10x) higher than in the case of an 'average shedder'. The predicted probability was that 1 in 28-203 passengers get ill.



Results – typical viral shedder vs. supershedder

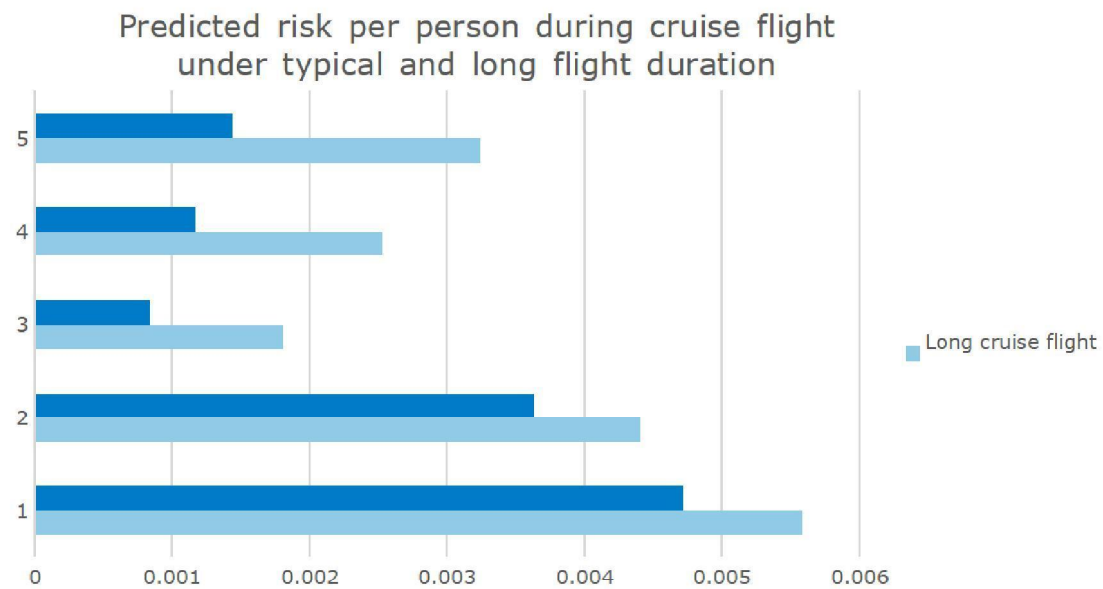
Predicted risk per person during cruise flight
for a **typical viral shedder** and a **supershedder** as index
patient





Results – typical vs. long flight

Risk increases with increasing flight time

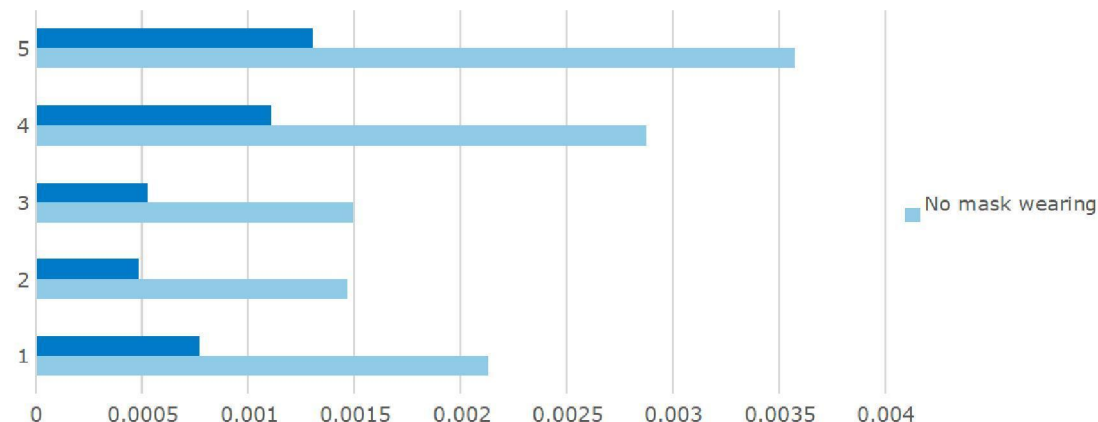




Results – 1 hour flight with and without mask

- *How do the three aircraft types compare per hour of cruise flight?*
- Predicted risk per hour is highest for the A320 aircraft
- *What is the effect of mask usage on board?*
- Risk during continuous mask wearing is predicted to be approximately a factor three lower than risk without any mask wearing (literature).

Predicted risk per person during 1 hour flight
with and without mask wearing

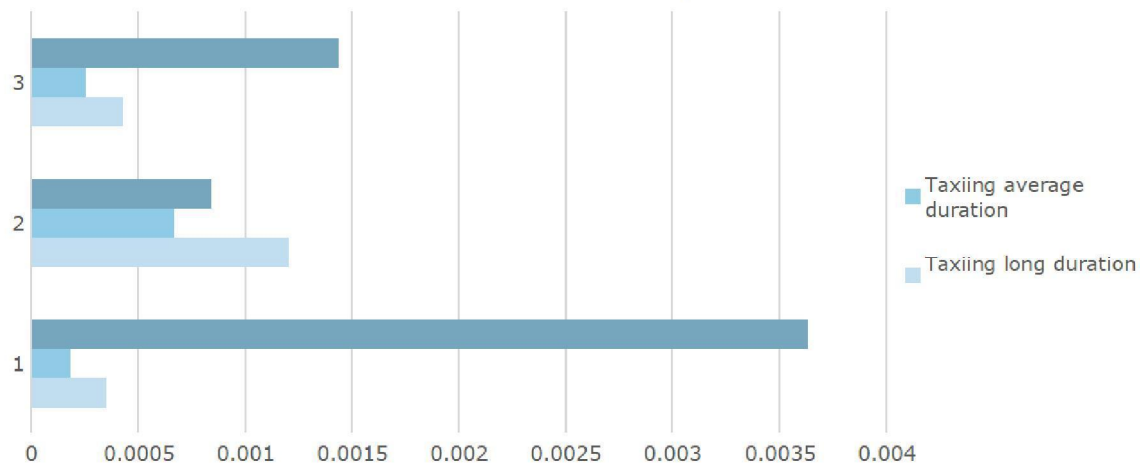




Results - taxiing

- *What is the risk during taxiing?*
- Risk during taxiing appears to differ per aircraft type, with highest risk predicted for the B737

Predicted risk per person during typical cruise flight
vs. taxiing (average and long duration)





Discussion points

- There is variability and uncertainty in the data (averages shown)
- Not included:
 - Probability an infectious person gets on board (triage, testing, epidemiological situation over time):
 - > 89th OMT advice: chance of false negative test probability considerable in high prevalence situations
 - > 100th OMT advice: validity of (rapid) test 24 hrs before end of event
 - > NL: validity of (rapid) test from high risk area 24 hrs before boarding
 - > Field labs assume testing takes out 95% of infectious people
 - The effect of coughing and sneezing
 - Other routes than aerosol route (e.g. ballistic droplets, fomites)
 - Moving index (e.g. infectious crew member) or multiple indices
 - Newer SARS-CoV-2 variants (e.g. British, Brazilian, South African), and the risk of introduction of new variants in the Netherlands (independent of risk of infection on board)
 - Other aircraft than the three tested
 - Risk for passengers outside the 7 rows
- Dose-response model is for other human coronavirus, current best estimate



Comparison (1)

- Risk and exposure from other studies modelling / measuring in aircraft are comparable in order of magnitude
 - Wang et al. schatte op basis van modellering het gemiddelde risico in tussen 1/625 en 1/63 voor typische scenario's, oplopend tot 1/15 voor een 'super spreader'
 - Marcus et al. schatte op basis van simulaties, het gemiddelde risico op infectie per vlucht-uur in tussen 1/238 voor een matig besmettelijke, tot 1/34 voor een zeer besmettelijke index passagier
 - Experimenteel bepaalde transfers in Kinahan et al. (TRANSCOM) lagen binnen een factor 3 van die bepaald in CORSICA
- Modelling for other (less ventilated) indoor spaces of similar size (Schijven et al. AirCoV2 tool)



Comparison (2)

- Epidemiological data for aircraft outbreaks (as investigated in the CORSICA literature report, October 2020)

Table 1: Literature describing case studies of potential in-flight transmission of SARS-CoV-2, sorted by date of flight

Paper	Date of flight	Origin	Destination	Passengers COVID-19	Passengers likely infected during flight
Schwartz et al, 2020	22/01/2020	Guangzhou	Toronto	2	0
Yang et al, 2020	23/01/2020	Singapore Changi	Hangzhou Xiaoshan	12	10
Chen et al, 2020	24/01/2020	Singapore Changi	Hangzhou Xiaoshan	16	1
Eldin, 2020	25/02/2020	Bengui	Yaoundé	3+	One or more
Pavli, 2020	27/02/2020	Tel Aviv	Athens	6	5
Khanh et al, 2020	02/03/2020	London	Hanoi	16	15
Hoehl, 2020	09/03/2020	Tel Aviv	Frankfurt	9	2
Choi, 2020	10/03/2020	Boston	Hong Kong	4	2
Speake et al, 2020	19/03/2020	Sydney	Perth	29	11
Lytras, 2020	20/03/2020	London x 3	Athens	13	Not examined
Lytras, 2020	25/03/2020	Istanbul	Athens	2	Not examined
Qian et al, 2020	Unknown	Unknown	Zhejiang	11	10
Lytras, 2020	23/03/2020	Spain	Athens	25	Not examined



Comparison (3)

- Epidemiological data for aerosol transmission in other settings
 - High attack rates (>10%) are observed in some indoor settings (e.g. choirs, Hamner et al. Skagit choir, RIVM study, submitted)
 - Other transport: Hu et al.: the attack rate in train passengers on seats within a distance of 3 rows and 5 columns of the index patient varied from 0 to 10.3% with a mean of 0.32 (=1/312)
<https://pubmed.ncbi.nlm.nih.gov/32726405/>
 - Influence of ventilation rate, (directional) air currents and possibly low humidity
 - › Pokora et al. found low ventilation rate to be associated with higher aerosol transmission rates in meat processing plants
<https://arxiv.org/abs/2011.11153>
 - › Lu et al. restaurant outbreak associated with directional air flow from air-conditioning
<https://pubmed.ncbi.nlm.nih.gov/32240078/>

Comparison (4)

- Current RIVM advice on aircraft and aerosols

June 2020:

- <https://www.rtlnieuws.nl/nieuws/nieuws-1/vliegen-coronavirus-verspreiding-veilig>
- Het RIVM is niet bang dat vliegtuigpassagiers elkaar infecteren als we straks weer mogen vliegen. Dat zegt hoofd infectieziektenbestrijding 5.1.2e tegen de NOS.
- Het RIVM onthoudt zich van advies over of je wel of niet in een vliegtuig moet stappen. Eerder zei het instituut wel dat 100 procent zekerheid niet gegarandeerd is, maar dat reizigers zich geen zorgen hoeven te maken.
- Risicovermindering: "Het is belangrijk dat de branche zelf criteria opstelt voor veilig vliegen. Dat zal nooit 100 procent zijn, maar het gaat erom dat de risicovermindering zo groot mogelijk is."





Conclusions (1)

- Good and useful set of observational data
- Aerosolized droplets from a source breathing / speaking in an aircraft travels several meters through cabin and the concentration reaches a plateau phase within minutes
- Concentration depends on distance and direction
- People seated in aircraft are exposed to a fraction of this aerosol cloud and can be exposed to SARS-CoV-2 virus via this route



Conclusions (2)

- The control measures (triage, testing) are targeted at preventing infectious people from boarding aircraft, it is likely/possible that these are not 100% effective
- In case an infectious person does get on board there is a chance of virus transmission. This probability is especially high when the infectious person carries a high viral load (supershedder)
- There is variability and uncertainty in the estimates
- Risk is dependent on (among others)
 - Viral load of the source (supershedder)
 - Flight duration
 - Aircraft type
 - Mask wearing