 

TRANSCOM/AMC Commercial Aircraft Cabin Aerosol Dispersion Tests

Submitted To:
United States Transportation Command (USTRANSCOM) &
Air Mobility Command (AMC)

Submitted By:
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Acknowledgements

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Abstract

The COVID-19 pandemic, has led to questions regarding the potential risk of SARS-CoV-2 exposure, which may lead to transmission, amongst passengers on an aircraft, and the safety of travelers. It is difficult to determine the potential exposure risk using available computational fluid dynamics models or contact tracing methods, due to the lack of experimental validation of aerosol transport in the aircraft environment and the lack of detailed tracking of human interactions in aircraft. Using fluorescent aerosol tracers between 1-3 µm and real time optical sensors, coupled with DNA-tagged tracers to measure aerosol deposition, we completed the largest aircraft aerosol experimental validation testing to date, with 8 days of testing involving both inflight and ground tests on Boeing 777-200 and 767-300 airframes.

Tracer aerosols were released from a simulated infected passenger, in multiple rows and seats, to determine their risk of exposure and penetration into breathing zones of nearby seats. In particular, penetration into the breathing zones of passengers seated in the same row and in numerous rows in front and back of the source were measured. Over 300 aerosol release tests were performed repeatedly releasing 180,000,000 fluorescent tracer particles from the aerosol source (simulated virus aerosol), with 40+ Instantaneous Biological Analyzer and Collector (IBAC) sensors placed in passenger breathing zones for real-time measurement of simulated virus particle penetration. In total, more than 11,500 breathing zone seat measurements were taken with releases in 46 seats of the airframes.

Results from the Boeing 777-200 and 767-300 airframes showed a minimum reduction of 99.7% of 1 µm simulated virus aerosol from the index source to passengers seated directly next to the source. An average 99.99% reduction was measured for the 40+ breathing zones tested in each section of both airframes. Rapid dilution, mixing and purging of aerosol from the index source was observed due to both airframes' high air exchange rates, downward ventilation design, and HEPA-filtered recirculation. Contamination of surfaces from aerosol sources was minimal, and DNA-tagged 3 µm tracers agreed well with real-time fluorescent results. Transmission model calculations using the measured aerosol breathing zone penetration data indicates an extremely unlikely aerosol exposure risk for a 12 hour flight when using a 4,000 virion/hour shedding rate and 1,000 virion infectious dose.

Introduction & Background

United States Transportation Command (USTRANSCOM), The Defense Advanced Research Project Agency (DARPA) and Air Mobility Command have sponsored testing efforts to better understand aerosol particle distribution from potentially infected passengers within the passenger compartment on commercial aircraft. Information gained from such testing will be used to inform USTRANSCOM in its COVID-19 risk reduction planning for Patriot Express flights.

In August 2020, the team brought together instrumentation to implement testing of a large series of aerosol tracer releases simulating a passenger who may be COVID-positive on 767-300 and 777-200 airframes. The tests were designed to measure the relative aerosol penetration within passenger breathing zones in neighboring seats and rows from the simulated infected passenger. The tests were also designed to measure passenger breathing zone aerosol concentration distributions at different sections of the airframes and with the simulated infected passenger seated at various locations.

The process provided a real-time method for mapping tracer particle concentration for passenger breathing zones in four sections of the 777-200 and three sections for the smaller 767-300. Over 300 aerosol releases were performed in eight days. Testing for each airframe included terminal loading and unloading simulations, simulated inflight conditions in a hangar (with more seats and replicates then are possible during inflight testing), and then two days of inflight testing at altitude (~35000 ft). DNA-tagged aerosol tests were also performed along with surface sample collections to evaluate aerosol deposition and potential fomite risk.

The main objectives of these tests were to collect aerosol data sets for COVID-19 risk analysis for USTRANSCOM planning especially with respect to determining the optimal capacity of flights, determining relative risk under different seating configurations, optimizing strategies for boarding and deboarding, and to determine what contact tracing requirements might be necessary in the event that a passenger tests positive soon after landing. Additionally, there was an added benefit to assembling a data package that was shareable with the scientific community at large, to encourage analysis by other parties including validation of computational fluid dynamics and other transmission models.

This report will give a background on the tests performed, results, some transmission model calculations using the aerosol dispersion data, and troop transport recommendations. This report is pending submission to a scientific journal for peer review and publication. USTRANSCOM is releasing this report before peer review, recognizing the need for timeliness of this information to the public. Reliance on the data and the scientific methods used to derive the data are at the risk of the user.

Methodology

The test process involves the use of tracer aerosols and two types were used in the commercial airframe tests: 1 µm fluorescent microspheres and 3 µm DNA-tagged microspheres. Discrete fluorescent particle counters were used for real-time aerosol sampling and selective detection of the fluorescent tracer particles. For the effort, 42 IBAC sensors were loaned from the DHS Science & Technology Directorate and the National Guard Bureau Weapons of Mass Destruction Civil Support Teams, in coordination with MIT-Lincoln Laboratory and L2 Defense respectively.

Viral Shedding and Infectious Dose

SARS-CoV-2 viral shedding numbers in literature vary, with no definitive answer on the number or size of particles an infected patient releases. Liu et. al (2020) determined that for SARS-CoV-2 aerosol collections in a clinical setting, viral RNA concentrations are maximum in a distinct bimodal distribution with one peak between 0.5 and 1 µm, and the other above 2.5 µm, leading to the tracer sizes utilized here (1 and 3 µm).

Santarpia, et al. (2020), using Sartorius gel filtration collectors found maximum evidence of viral shedding for a normal (non-nasal cannula ventilated) patient was 8.339 genomic copies of virus per liter of air. Lednicky, et. al. (2020 preprint) collected an estimated maximum 74 viable virus per liter of air in a patient's hospital room using an aerosol collector and a median tissue-culture infectious dose ($TCID_{50}$) assay, with an average of 31.25 viable virus count per liter of air. However, the assumptions necessary to derive aerosol production from these measurements become difficult to justify. Given these limitations, it is more reasonable to look at aerosol production by people infected with other human coronaviruses. Leung et al. (2020) collected aerosol, droplet and diagnostic samples from individuals infected with 3 human coronaviruses, as well as other respiratory diseases both while wearing and not wearing surgical masks. Their findings indicate that aerosol production by infected individuals range from 0 to 10^5 genome copies in a 30 minute time period. Most means were near zero, but one coronavirus (NL63) had a mean between 10^3 and 10^4. This is consistent with what might derived from Santarpia et al., 2020 and Lednicky, et al., 2020 if the concentrations measured in the rooms were consistent with concentrations in the exhaled breath of the individuals in that room at average human tidal volumes and breathing rates.

The number of droplets generated via various human movements (coughing, talking, breathing, etc) varies based on methodology and sample. Morawska et. al. (2009) examined aerosol formation between 0.3 and 20 µm, and found concentrations of 100 to 1100 for particles per liter, when ranging from typical breathing to continued vocalization. Gupta, et. al. (2011), reviewing multiple articles to determine source terms for inputs into airplane modeling, found estimates of approximately 10^3 particles per liter of air, utilizing 525 per breath. Coughing was shown to generate an average droplet mass of 2.2 mg, with 99% of the droplets <10 µm, and the majority smaller than 0.5 µm. The total number concentration was approximately 10^7 droplets, and increased above age 50 (Zayas, et. al. 2012). Since this analysis is focused on those travelers who do not have significant symptoms, breathing is focused on more strongly than coughing.

Similarly, infectious dose studies are currently lacking, given the recentness of the outbreak, a lack of human volunteers (with safe, approved studies), and only recent improvements in animal and exposure models. The range in literature estimates varies from 300 to several thousand infectious virus to cause an infection (Basu, 2020; Schröder, 2020).

Fluorescent Tracer Aerosol Detection

The team utilized a suite of Instantaneous Biological Analyzer and Collector (IBAC, FLIR Systems) discrete particle detectors that simultaneously measures an airborne particle's elastic scatter and intrinsic auto-fluorescence at an excitation wavelength of 405nm. The sensor has been deployed since 2006 for 24/7 facility protection applications as an early warning component to biodefense monitoring architectures. The IBAC is capable of utilizing two fluorescence channels, one for biological aerosols and the other for fluorescent tracer aerosol detection.

For the airframe tests, Fluoresbrite Plain yellow-green (YG) polystyrene latex (PSL) microspheres (Polysciences) sized at 1 µm were used with intrinsic fluorescence orders of magnitude more intense than naturally-occurring particles. The resulting backgrounds in a test environment (including airframes) is negligible (<5 particles per liter of air (pla), or 100 particles over a 6 minute integrated test).

The instrument samples at 3.5 liters per minute (lpm), and reports tracer concentrations per second (convertible to per liter), by counting individual particles and filtering the exhaust, so that they are removed from the test after sampling. Prior to the airframe tests, the 42 IBACs were calibrated against a referee IBAC and the fluorescent particle tracer counts were matched to within an average variance of ±10%, with over 34 of the sensors within 5%. IBAC sensors, as setup to sample within the breathing zone (Figure 1) were primarily in individual seats surrounding a test release.

The IBAC sensors have been used to characterize exposure risk and real-time spatiotemporal aerosol dispersion mapping of indoor environments such as subway systems, airports, skyscrapers, large building complexes, critical infrastructure facilities, commercial aircraft and numerous other types of buildings. IBAC sensors have been used for fluorescent tracer particle dispersion tests in numerous government, research, and clinical settings (DeFreez, 2009 & de Sousa et al., 2020).

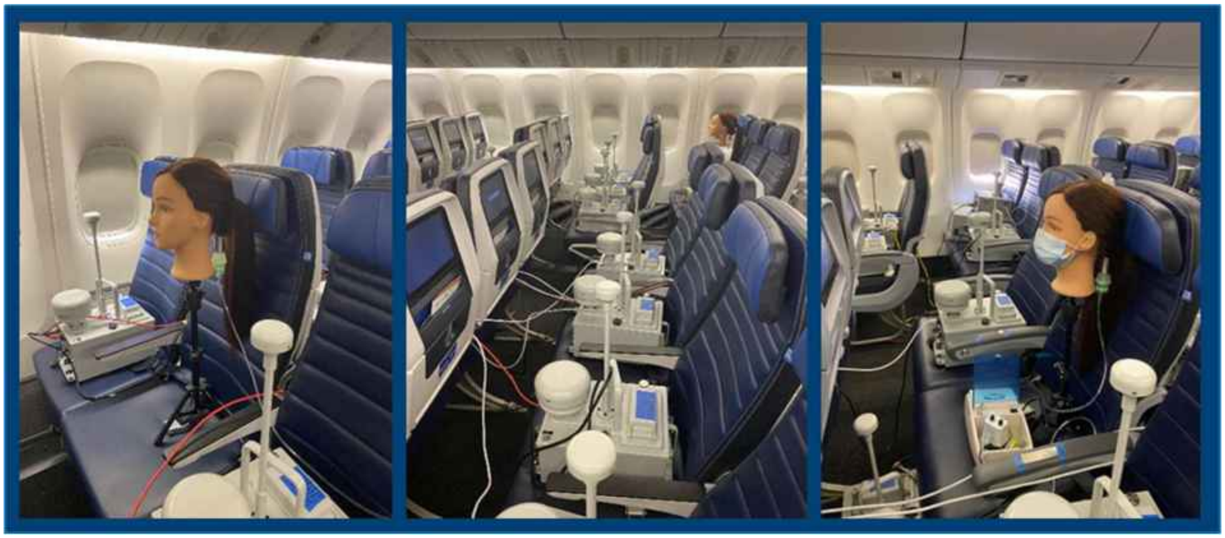


Figure 1: IBAC sensors with extended inlets and tripod mounted mannequin with integrated aerosol generation

DNA-Tagged Microspheres

Streptavidin-coated PSL microspheres sized at 3 µm (Bangs Laboratories) were tagged with four unique 5'-biotynlated DNA fragments. We designed each fragment, 170 base pairs in length, to be non-coding and completed a BLAST search to ensure that they did not match existing natural sequences. Complimentary quantitative real-time polymerase chain reaction (qRT-PCR) assays were designed for detection (IDT Inc.) targeting a 60°C extension and anneal step.

Binding of biotinylated DNA occurred per the manufacturer's protocol, scaled to a 3 mL production volume, with the test particles washed five times via centrifugation at 10,000 rpm to ensure removal of any unbound DNA.

Standard curves were developed for each oligo and tracer dilutions to inform resulting collections and quantify the number of beads, using a 40 cycle 95°C melt, and 60°C anneal and extension protocol on a QuantStudio 3 (ThermoFisher Inc). All samples were run in triplicate, with dilutions of positive and negative controls in parallel, and each oligo using a uniform threshold for detection. No cycle threshold's (Ct) above background negative controls were accepted, and at least two of three replicates were required to be positive for analysis.

Aerosol and Surface Collection

DNA-tagged tracers were collected at 50 liters per minute onto gelatin filters using an Airport MD8 aerosol sampler (Sartorius), which operated for fifteen minutes, and collects 99.9995% of particles

(Parks, 1996). Gel filters are extracted into 15 mL of deionized water, vortexed for 30 seconds, and diluted 1:10 in nanopure water for PCR analysis. A total of five high volume air collectors were utilized, distributed near release rows and in the galley.

Surface coupons were made of 8.89 cm long, 2.54 cm wide (0.6 mm thick) stainless steel taped using new 1.27 cm painters tape, leaving a total area of 16.13 cm^2 exposed during a test release. These coupons were aseptically collected into 50 mL conical tubes, suspended using deionized water (10 mL), vortexed for 30 seconds, with this extraction solution utilized for PCR. In between tests, areas were wiped using DNAaway and deionized water to remove any carryover between tests. Coupon locations targeted common touch surfaces including arm rests, tables, and seatbacks (Figure 2).

Figure 2. Example coupon locations highlighted in red. Left: Economy seat. Right: First class seat.

DNA-tagged beads were released in flight from three (767) locations (forward, mid-forward, and aft) or four (777) locations (forward, mid-forward, mid-aft, and aft), with surface coupons dispersed near the release seats, to look at fomite risk from a sick passenger due to aerosol particulate. Testing was completed in triplicate and averaged. In each case, PCR data was converted into a number of beads per mL of solution based on the qPCR standard curves. We then convert this concentration to a total number of beads based on the volume of the sample and the dilution. Comparing the number of beads collected at a given aerosol collector to the total number released based on the chamber characterization, gives a percentage of the total number of beads captured at each location.

In the case of surface samples, where the number of beads is per unit area, the percentage of beads captured at each location is based on a larger 1 square foot standard surface area.

Nebulization

The team generated tracer particles using either a Devilbiss Traveler (DNA-tagged tracer) or Devlibiss PulmoMate (fluorescent tracer). DNA-tagged beads were generated for five minutes to examine deposition on nearby surfaces, whereas the fluorescent tagged microspheres were generated for one minute in a breathing pattern using a timing circuit for 2 seconds on and 2 seconds off. The output of the nebulizer cup (Hudson Micro Mist) is plumbed through a tripod mounted mannequin head (Figure 1), and reaches a velocity of 1.43 m/s at the mannequin’s lips. The mannequin was used specifically to allow for control of velocity of output air, the location of a release in the breathing zone, and to incorporate testing of a facemask using anatomically correct facial features and fit.

For the 767-300 inflight tests, additional measurements of simulated coughs were performed. To achieve this the mannequin was equipped with a mouth insert that increased the exit velocity of the aerosol to 12.84 m/s. Although it was not a simulation of a complete distribution of cough aerosol spanning from submicron aerosol to hundreds of micron diameter droplets it did provide a representation of 5 micron diameter or less droplets.

Mask Choice

Given the range of mask choice available, the team chose to focus on surgical masks, which are the most likely to be handed out when other masks are not available, or not brought by a traveler. A recent survey suggests that in the US, cloth masks were most commonly worn at least weekly by participants at 75%, but surgical masks were next most common at 57% of participants engaging in weekly use (McKinsey & Company, 2020). Mask variability is higher for non-surgical masks, since gaiters, cotton, and other materials vary in their weave and filtration efficiency. The masks used during testing were standard pleated 3-ply surgical masks supplied by United Airlines.

Chamber Characterization and Source Terms

In an effort to better understand the tracer releases, we worked to characterize the tracer releases with and without masks in an aerosol chamber. The chamber is a High Efficiency Particulate Air (HEPA)-filtered, rapidly-purged test chamber, where naturally-occurring background aerosols are minimized. During a test, the chamber is purged of particulate for two minutes, and then enters a static, dead-air mode. We nebulized the tracer solution, briefly mixed (20-25 seconds), and then characterized the resulting aerosols using three high-resolution TSI Inc. 3321 Aerodynamic Particle Sizers (APS) instruments and four IBACs. Of the four IBACs two are indoor IBACs with a traditional 10 µm inlet, and two are tactical IBACs with longer stackable inlets, also capped with a 10 µm inlet.

Test Condition (n=3)	Total Particles	Std. Dev	Std. Error	% Std Error
1 minute breathing	1.8E+08	1.3E+07	7.8E+06	4.3%
1 minute breathing (with mask)	1.7E+08	5.7E+06	3.4E+06	2.0%
5 minute DNA-Tagged Tracer	2.4E+07	4.3E+06	2.5E+06	10.34%

At 11902 liters, the average concentration across the aerosol detectors is multiplied by the total volume to give the amount of tracer particulate released, and verify the size distribution.

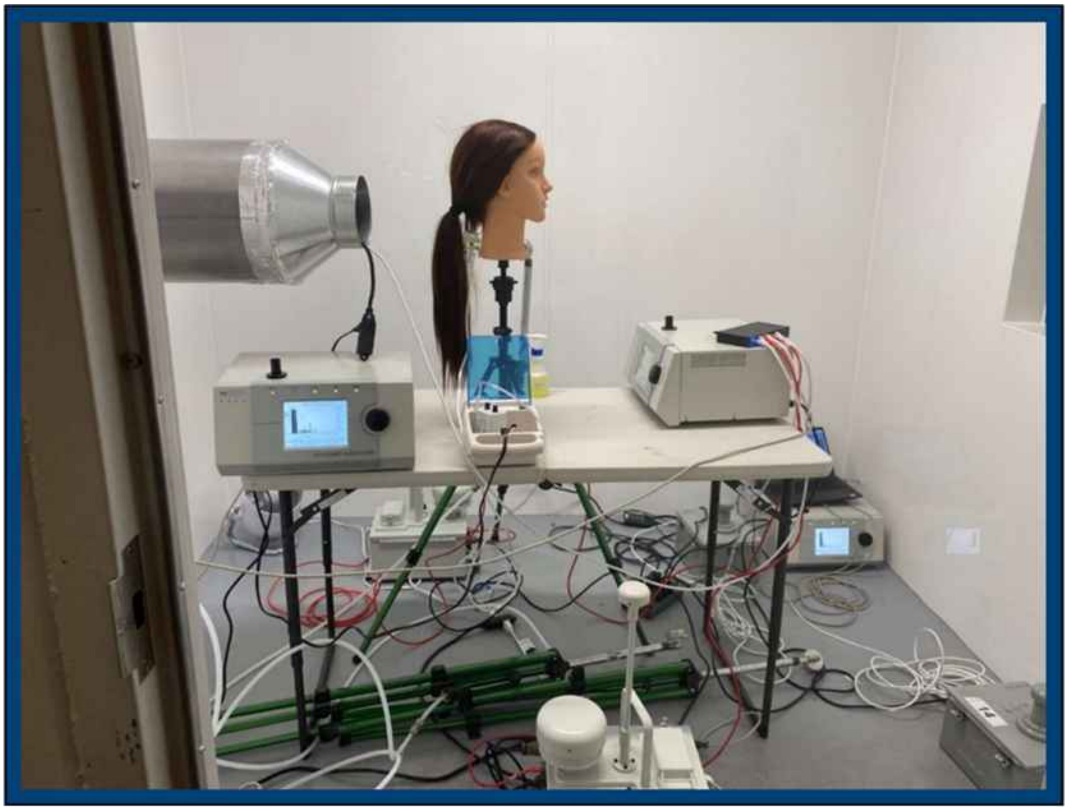


Figure 3. Chamber testing using a mannequin, three APS particle sizers, and four IBACs.

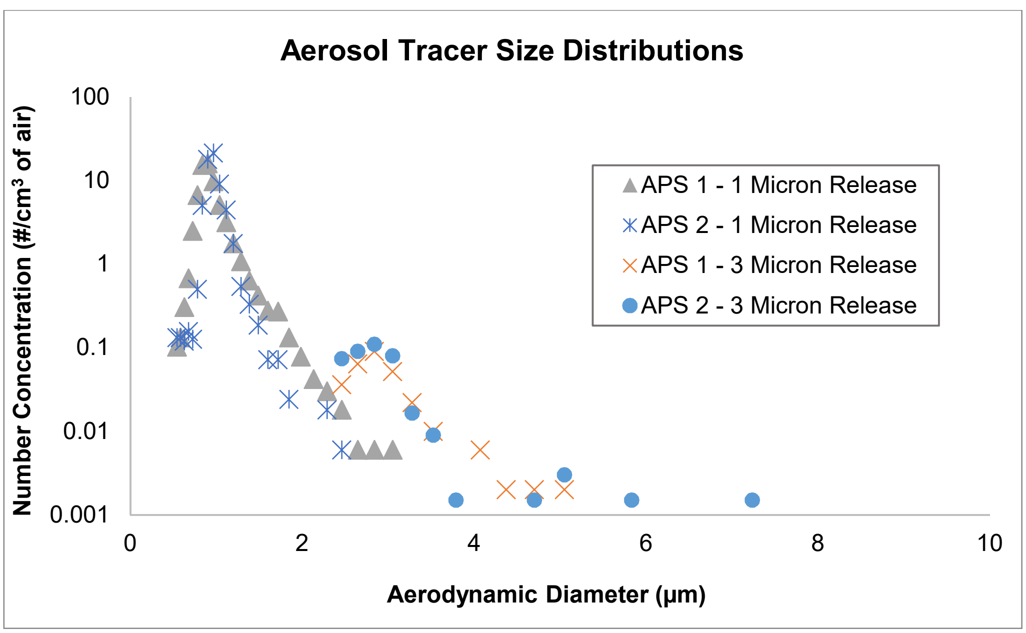


Figure 4. Characterization of Aerosol Tracer Particles at 1 and 3 μm.

Exposure Model

A multiplication factor of 2.14 was applied to the breathing zone penetration to account for the difference between the sampling rate of the IBAC, and an average adult 7.5 lpm passenger inhalation rate, using a tidal volume of 0.5 L per breath and respiration rate of 15 breaths per minute. Breathing zone penetrations listed in the results include maximum aerosol penetration percentages measured for the breathing zone with the highest penetration (MAX), and average breathing zone penetrations (AVG) across all seats with sensors in a given release. The tables also show breathing zone penetrations for each mannequin test condition; breathing with no mask (BNM), breathing with mask (BM), coughing with no mask (CNM) and coughing with mask (CM). All exposure model calculations were done using BNM data only. The exposure model parameters assumed the following:

- Inhalation Rate: 7.5 lpm
- Viral Shedding Rate: 4,000 virions per hour
- Infectious Dose: 1,000 virions

This model also assumes that each particle contains a single infectious particle, whereas in reality a fraction of the total aerosols generated are likely to contain infectious material, and the number of infectious virions per particle vary.

Airframe Testing

Testing of each airframe totaled four days, with two days reserved for ground testing, and two days reserved for in-flight testing at altitude. Of the two ground days, one day was reserved for simulation of in-flight testing, with the aircraft door closed, and the Environmental Control System (ECS) system powered by the Auxiliary Power Unit (APU), with recirculation activated as it would be in flight. We utilize this longer day to achieve more replicates in additional seats, and prepare for inflight testing, where pressure and temperature gradients may cause different airflow patterns.

The second test day was at a Dulles Airport terminal, with the jetway attached and the aircraft door open, to examine airflow during loading and unloading conditions. This test day also examined the ground air supply and thermal loading on the ECS system's behavior. Testing occurred at Dulles International Airport (IAD) between August 24th and August 31st, 2020, with the first four days reserved for the Boeing 777, and the second four reserved for the Boeing 767.

Testing conditions also included the gaspers as a variable in some cases. These gaspers are the personal air supplies, located above passengers and pointed at each seat for personal comfort adjustment, were tested both on and off, with the majority of testing occurring in the off position.

Ground testing supply temperatures varied from 56 to 59.8°F, when measured intermittently at the vents on the 777 and powered by the APU, indicating a cooling mode was active during ground testing at IAD. For the 767, temperatures varied from 51.5 to 67°F, and it was raining intermittently outside, indicating that it was typically in an active cooling mode. For both planes, limited tests were done with 40 watt heaters (Sunbeam) to increase thermal loading and investigate any differences in feedback and airflow. Specifically, heating vs cooling modes had the potential to drive airflow direction differently. These blankets were distributed in the rows of the release, behind the release, in front of the release, and under the nearest overhead temperature feedback sensor.

Air exchange rates for the tested 767 and 777 airframes were 32 and 35 air changes per hour (ACH), respectively, with total cabin volumes of 9320 and 15075 cubic feet (E-mail exchange with Boeing engineers). Both ECS systems achieve approximately 50% of the air exchange through HEPA-filtered recirculation, and 50% through fresh bleed air. The cockpits and cabins are designed to have separate supply systems with no mixing between them.

Figure 5 provides IBAC sensor layouts and release locations for each airframe and section tested. The sections were intended to distribute releases evenly throughout the airframe, with multiple sections in economy seating. Although a single release seat is marked, in all cases (ground, terminal, and inflight) multiple releases were completed at multiple seats in a row throughout each section.

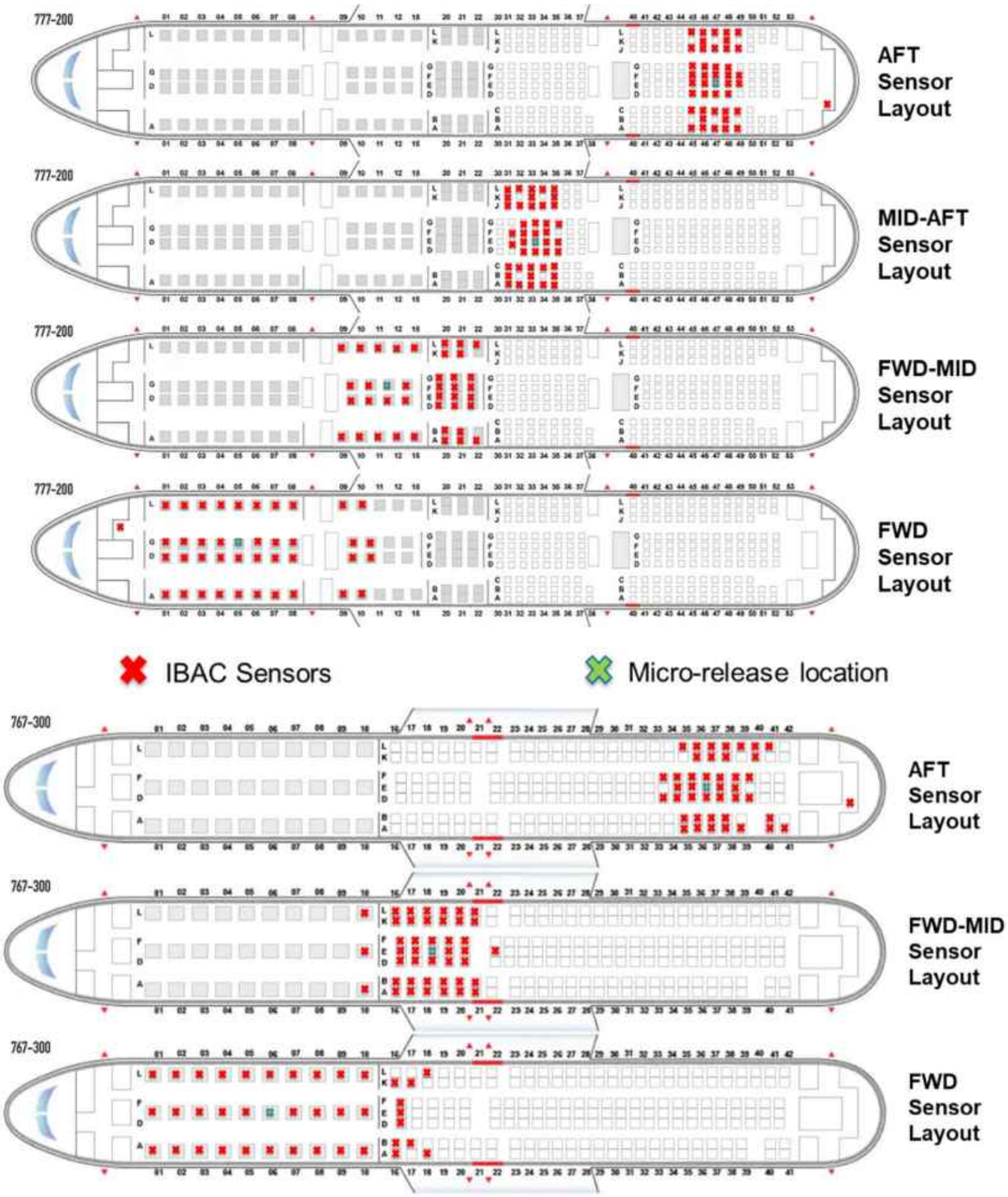


Figure 5. IBAC sensor layouts for each airframe and section tested. A single release seat is shown, but releases were done in multiple seats within a given row.

777-200 Hangar Testing

Fluorescent tracer particles were released in the AFT, FWD, FWD-MID and MID-AFT sections of the airframe for a total of 38 releases (see Appendix A for complete list of test tables). All simulated inflight Hangar tests were performed with gaspers off and no mask was applied to the mannequin. For each airframe section releases occurred at each seat location within the specified row. Duplicate measurements were taken for each seat and 1 min disseminations were performed for AFT tests, while single measurements were taken in the remaining zones. For the AFT tests, the mannequin was first placed in seat 47A and then seats 47B, 47C, 47D, 47E, 47F, 47G, 47J, 47K and 47L. The sensors were then repositioned to the FWD section and mannequin releases were performed in seats 5A, 5D, 5G and 5L. The sensors were then repositioned to the FWD-MID section and mannequin releases were done in seats 11A, 11D, 11G, and 11L. The MID-AFT section was tested next and after sensor repositioning to this section releases were done in seats 33A, 33B, 33C, 33D, 33E, 33F, 33G, 33J, 33K and 33L.

777-200 Terminal Jetway Testing

Fluorescent tracer particles were released in the MID-AFT, FWD-MID and AFT sections of the airframe for a total of 25 releases (See Appendix A – Test Tables). For the first 3 tests 40W heating blankets were installed onto seats in the MID-AFT section, to increase thermal loading and provide feedback to temperature sensors in the ECS system. IBAC sensors were located in the jetway (Figure 6), as the airflow had an increased likelihood of exhausting through the jetway rather than the outflow valve. The mannequin was placed in seat 33E for the releases. The first group of tests collected dispersion data for ground air vs. APU supplied conditioned air to the cabin. For Test 1, ground supply air was used to supply conditioned air to the cabin and the airframe's recirculation fans were not active. For Test 2, ground air supply equipment failed in the middle of the test but was repaired later on. For Test 3, the airframe's APU was used to supply air with recirculation fans on along with the heating blankets. For Test 4, the airframe's APU was used to supply air and the heating blankets were turned off. The remaining 21 tests were performed in the typical APU cooling configuration. Figure 7 provides the air supply Configurations for the first 6 tests.

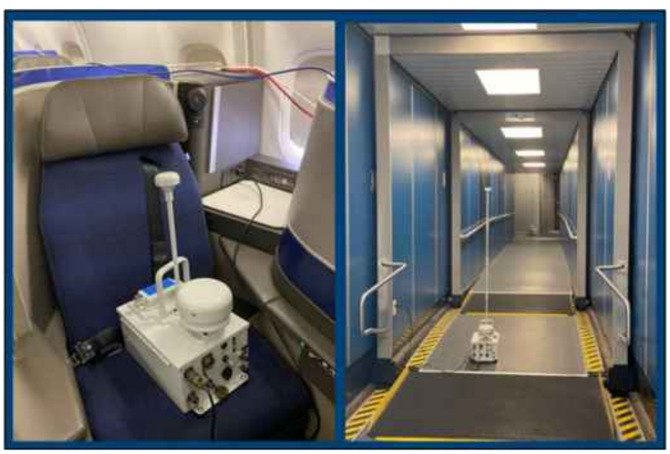


Figure 6. 777-200 Terminal/Jetway MID-AFT tests

Ground Tests at Terminal	Cooling Configuration	Airframe Section	Thermal Blanket	Gaspers	Mannequin Mask
Test 1	Ground Air - Recirc OFF	MID-AFT	YES	ON	OFF
Test 2	Ground Air OFF - RECIRC OFF	MID-AFT	YES	OFF	OFF
Test 3	APU: PACs ON RECIRC ON	MID-AFT	YES	ON	OFF
Test 4	APU: PACs ON RECIRC ON	MID-AFT	NO	ON	OFF
Test 5	APU: PACs ON RECIRC ON	MID-AFT	NO	OFF	OFF
Test 6	APU: PACs ON RECIRC ON	MID-AFT	NO	ON	ON

Figure 7. 777-200 Terminal/Jetway Cooling Configuration Tests

777-200 Inflight Testing

Fluorescent tracer particles were released in the AFT, MID-AFT, FWD, and FWD-MID sections of the airframe for a total of 64 releases (See Appendix A for Test Tables) inflight. The releases included 40 tests with the mannequin not wearing a mask and 24 tests with a mask. Limited by the amount of test time available, multiple seats were prioritized over testing the mask at every seat. Two days of inflight testing occurred. The first day the AFT and MID-AFT sections were tested. For the AFT section, mannequin releases were performed in seats 47B, 47E and 47K. For the MID-AFT section releases occurred in seats 33B, 33E and 33K. Some gasper conditions were also tested inflight in the AFT section during the 47K releases including: gaspers on, off and positioned downward. For all other tests, the gaspers were closed. For the next flight day the FWD-MID and FWD sections were tested. The FWD-MID releases occurred in seats 11A, 11G and 11L (Figure 8). The FWD releases occurred in seats 5A, 7A, 5G and 5L. Triplicate releases were performed for each mask on/off condition. The gaspers were closed for all FWD-MID and FWD section tests.

Figure 8. 777-200 Inflight Tests

767-300 Hangar Testing

Fluorescent tracer particles were released in the AFT, FWD, and FWD-MID sections of the airframe for a total of 53 releases (See Appendix A - Test Tables). All simulated inflight hangar tests were performed with gaspers off and no mask was applied to the mannequin. For each airframe section releases occurred at each seat location within the specified row. Gaspers were closed for all tests. Triplicate measurements were taken for each seat. For the AFT tests, the mannequin was first placed in seat 37A and then seats 37B, 37D, 37E, 37F, 37K, and 37L. The sensors were then repositioned to the FWD section and mannequin releases were performed in seats 5A, 7A, 6D and 5L. After FWD section testing, the sensors were then repositioned to the FWD-MID section and mannequin releases were done in seats 18A, 18B, 18D, 18E, 18F, 18K and 18L.

767-200 Terminal Jetway Testing

Fluorescent tracer particles were released in the FWD-MID, FWD, and AFT sections of the airframe for a total of 33 releases (See Appendix A – Test Tables). In the FWD-MID section releases were performed in seat 18E. Heating blankets were applied to seats, in the same three row configuration centered around the release row in the FWD-MID section, for the first 9 tests (Figure 9). Fluorescent tracer particle dispersions in ground air supply and APU powered cooling configurations were both measured. For both air supply conditions the airframe's recirculation fans were active, to further increase HEPA-filtration and particle removal, and triplicate releases were performed for all tests. The sensors were then repositioned to the FWD section and releases were performed in seat 6D with triplicate measurements for mask on and off conditions for the mannequin releases. The AFT section was then tested with releases in 37E with triplicate measurements for mask on and off conditions. Following completion of the tests, the sensors were kept in the AFT section for next day of inflight tests.

Figure 9. 767-300 Terminal/Jetway Tests, including three rows of 40W heaters.

767-200 Inflight Testing

Fluorescent tracer particles were released in the AFT, FWD-MID and FWD sections of the airframe for a total of 85 releases (See Appendix A - Test Tables). The inflight tests occurred over two days. Mannequin releases were performed in the AFT section at seats 37B, 37E and 37K followed by the FWD-MID section in seats 18A, 18E, and 18L and then in the FWD section in seats 6A, 6D, and 6L (Figure 10). Triplicate measurements were made for the mannequin releases with and without masks. In addition, simulated mannequin cough releases were performed and represented 30 of the 85 releases.

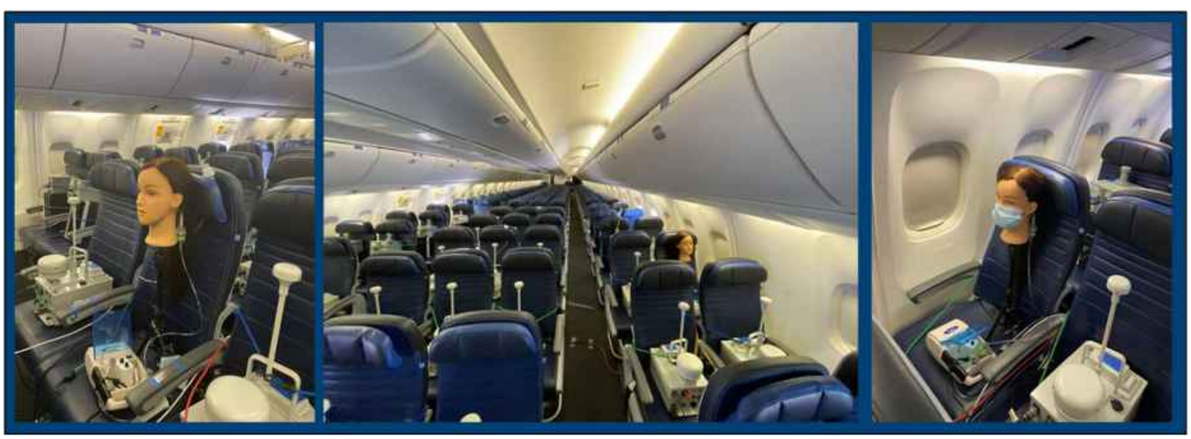


Figure 10. 767-300 Inflight Tests

Throughout the 8 days of testing, the only technical issues encountered were an occasional loss of power to some IBAC sensors due to either a loose connection to an airframe power outlet or some sort of power cycling occurring with the airframe's electrical power.

Results and Discussion

Fluorescent Tracer Particle Results

Due to both airframe's high air exchange rates the 1.8 x 10^8 disseminated particles were rapidly diluted, mixed and purged from the cabin by filtration and exhaust through the outflow valve. Fluorescent tracer particle residence times in the cabin averaged less than 6 minutes. Figure 11 provides a comparison to a house, where air exchange change rates are lower. For the data shown, a release was performed in a home using the same mannequin and release conditions as performed on the airframes. There is a large difference in the aerosol decay curve for this suburban house (A) vs. the 767-300 (B), corresponding to 1.5 hours vs. 5min, respectively, with the two shown overlayed in (C). Additionally, since dosage is a function of concentration and exposure time, the cumulative particle exposure was 10 times less on the 767-300 due to the airframe's rapid air exchange.

Figure 12 provides a 767-300 inflight AFT zone test example of a single IBAC sensor response located in seat breathing zone 37D and demonstrates repeatability. The figure shows the single IBAC sensor response to 31 releases with triplicates typically performed for each test condition (release location, breathing or coughing, mask on/off). Coefficients of variance within releases of the same condition for the sensor in Figure 12 were a maximum of 14.2% and averaged 9.2%. Average standard error of less than 15% was observed for all other releases performed in both airframes in the aft and mid-aft sections. The dissemination process was demonstrated to be repeatable in an aerosol chamber (standard error 4.2%, n=3) but was shown to be similarly repeatable in the aircraft cabin.

Figures 13 & 17 are described in terms of their 95% confidence interval, in relation to their standard error, to capture the uncertainty and possible range of values, with replicates occurring in triplicate at each seat. Additional penetration maps can be found in Appendix B.

For each test, a data set comprised of 40+ IBAC sensors providing date and time stamped fluorescent particle counts on a per second basis has been compiled and organized. In addition, cumulative tracer counts for each sensor for every test has also been compiled. Last, excel formatted dispersion maps for most tests have been created and include cumulative trace counts for each sensor breathing zone organized as seat maps for each airframe and section tested. The dispersion maps also include seat map tables showing the aerosol penetration for each sensor breathing zone relative to the characterized release.

The aerosol penetration into each breathing zone was determined by dividing the cumulative tracer counts for any specific breathing zone by the total amount released in the simulated infected passenger zone. In all but one test (777-200 Hangar MID-AFT section seat 33J – 3 min release) the cumulative amount released of 1.8 x 10^8 fluorescent tracer particles was applied to the analysis based on the chamber characterization. Figures 13-17 show dispersion maps expressed as aerosol penetration for each sensor breathing zone. As can be seen from figures 13-17, there is a significant reduction of aerosol penetration for breathing zones in proximity to the simulated infection zone. As shown in Figure 17, the application of a mask provided significant protection against micron diameter droplets released during the cough simulations and reductions greater than 90% were measured.

It is important to emphasize that the 3-color gradient of green, yellow, and red are not intended to correlate to transmission likelihood, and are instead utilized to visualize order of magnitude changes. Further, although the tracer detection process was able to measure and quantify aerosol concentration gradients for each release condition from seat to seat or row to row, especially under different release conditions (release seat, airflow, mask, etc), in every breathing zone location there was a significantly low overall risk of aerosol penetration compared to the release location. This consideration impacts how all the test results are interpreted, particularly different countermeasure modes, such as the application of a certain gasper direction, ground air supply vs. APU cooling for boarding and deboarding, etc. The dispersion data (Figures 14-17) demonstrates the dominant protective factors, as tested, are the airframe's high air exchange rates, downward ventilation design and HEPA-filtered recirculation and that other test conditions have measurable but minimal effects for aerosol risk. The dispersion data also shows that inflight, ground, and boarding conditions provide similar protection provided the air exchange rates are similar and maintained.

Scaling the instrument sampling rate from 3.5 lpm to an average human inhalation rate of 7.5 lpm and combining all of the releases performed in each airframe and section an average and maximum aerosol reduction (worst seat) of 99.99% and 99.8% was measured, respectively (Figures 18 & 19).

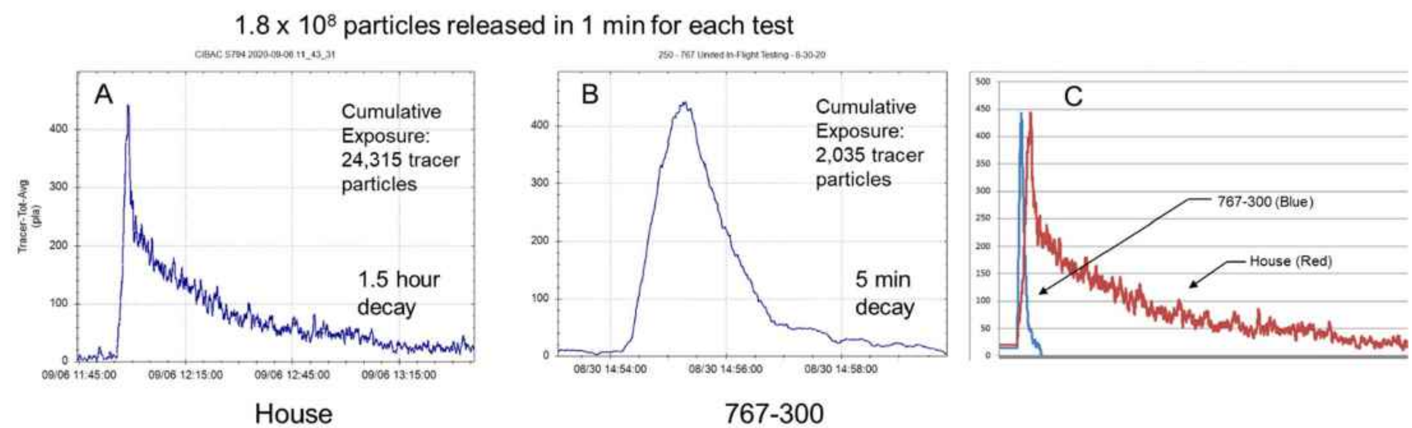
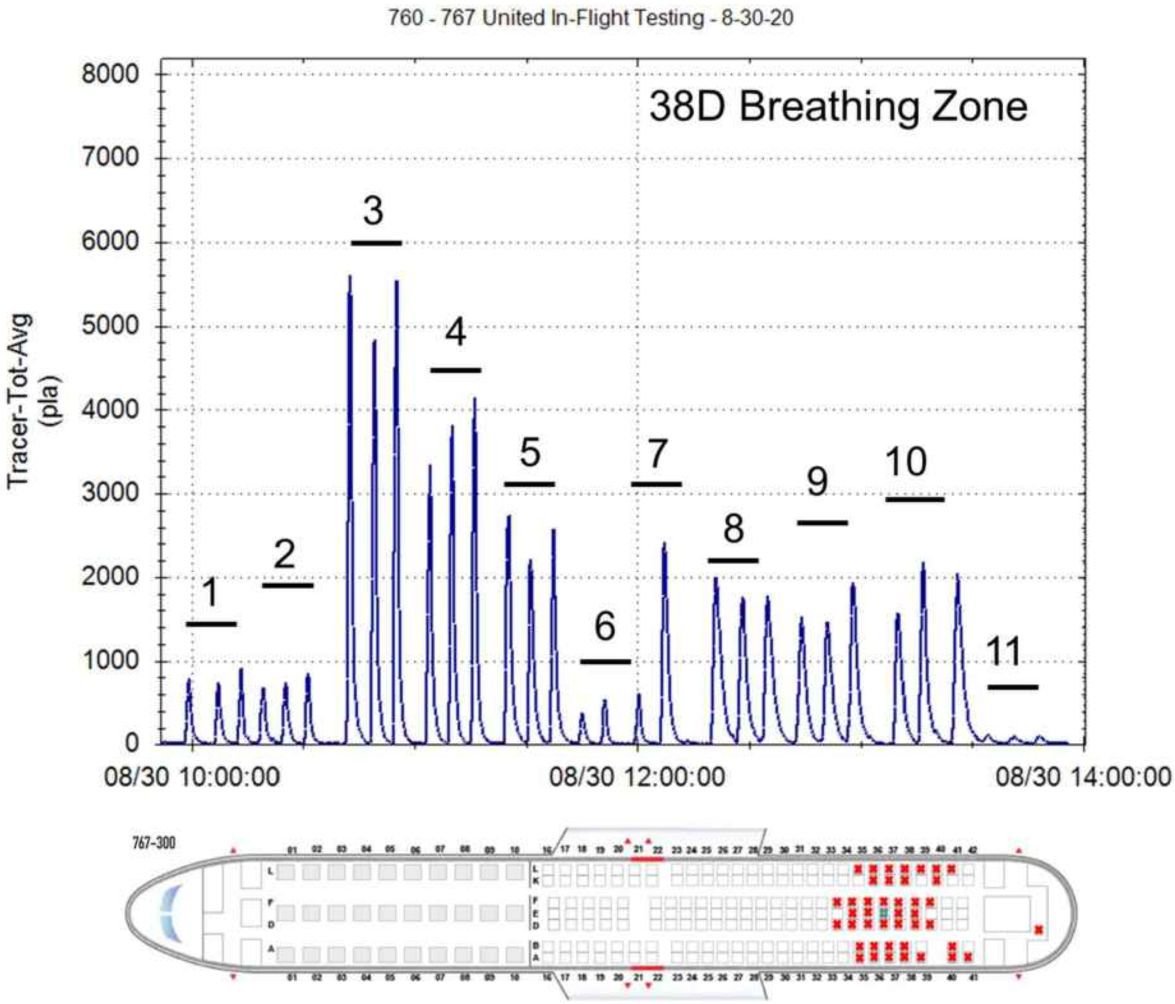


Figure 11. House vs. 767-300 Aerosol Decay Comparison



1. 37B Release - Mask off – Breathing - 3x
2. 37B Release - Mask on – Breathing – 3x
3. 37E Release - Mask off – Breathing – 3x
4. 37E Release - Mask on – Breathing - 3x
5. 37E Release - Mask off – Cough – 3x
6. 37E Release - Mask on – Cough – 3x
7. 37E Release - Mask off – Cough - 1x
8. 37K Release - Mask off – Breathing – 3x
9. 37K Release - Mask on – Breathing – 3x
10. 37K Release - Mask off – Cough – 3x
11. 37K Release - Mask on - Cough – 3x

Figure 12. 767 Inflight 38D Breathing Zone Data

777 - Inflight - AFT - 47B - BNM - Tests 1-3										
	A	B	C	D	E	F	G	J	K	L
45	0.0003%		0.0001%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%		0.0003%
	0.0014%		0.0005%	0.0002%	0.0003%	0.0000%	0.0000%	0.0008%		0.0011%
46	0.0011%	0.0006%	0.0000%	0.0001%	0.0001%	0.0001%	0.0001%	0.0005%	0.0017%	0.0015%
	0.0025%	0.0032%	0.0019%	0.0003%	0.0004%	0.0003%	0.0001%	0.0009%	0.0029%	0.0029%
47	0.0000%	100.0000%	0.0018%	0.0015%	0.0006%	0.0001%	0.0001%	0.0011%		0.0029%
	0.0545%		0.0523%	0.0047%	0.0055%	0.0042%	0.0013%	0.0037%		0.0069%
48	0.0092%	0.0104%	0.0067%	0.0062%	0.0077%	0.0073%	0.0030%	0.0039%	0.0051%	0.0063%
	0.0171%	0.0133%	0.0213%	0.0165%	0.0316%	0.0138%	0.0141%	0.0092%	0.0080%	0.0100%
49	0.0086%		0.0117%		0.0150%	0.0056%		0.0058%		0.0068%
	0.0142%		0.0179%		0.0169%	0.0136%		0.0138%		0.0106%

777 - Inflight - AFT - 47B - BM - Tests 4-6										
	A	B	C	D	E	F	G	J	K	L
45	0.0003%		0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%		0.0000%
	0.0005%		0.0004%	0.0000%	0.0000%	0.0000%	0.0000%	0.0006%		0.0014%
46	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
	0.0016%	0.0021%	0.0015%	0.0003%	0.0007%	0.0005%	0.0003%	0.0009%	0.0030%	0.0026%
47	0.0017%	100.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%		0.0008%
	0.0079%		0.0393%	0.0000%	0.0056%	0.0041%	0.0028%	0.0047%		0.0040%
48	0.0020%	0.0024%	0.0026%	0.0038%	0.0074%	0.0098%	0.0063%	0.0031%	0.0045%	0.0010%
	0.0129%	0.0113%	0.0126%	0.0095%	0.0154%	0.0140%	0.0130%	0.0070%	0.0054%	0.0131%
49	0.0061%		0.0085%		0.0105%	0.0052%		0.0098%		0.0058%
	0.0089%		0.0108%		0.0128%	0.0110%		0.0109%		0.0091%

777 - Inflight - AFT - 47E - BNM - Tests 7-9										
	A	B	C	D	E	F	G	J	K	L
45	0.0005%		0.0003%	0.0000%	0.0001%	0.0000%	0.0000%	0.0001%		0.0001%
	0.0005%		0.0019%	0.0000%	0.0003%	0.0000%	0.0000%	0.0004%		0.0006%
46	0.0011%	0.0025%	0.0066%	0.0008%	0.0000%	0.0000%	0.0003%	0.0000%	0.0000%	0.0007%
	0.0067%	0.0073%	0.0121%	0.0016%	0.0039%	0.0023%	0.0007%	0.0010%	0.0000%	0.0017%
47	0.0030%		0.0082%	0.0379%	100.0000%	0.0017%	0.0019%	0.0000%		0.0000%
	0.0103%		0.0132%	0.0590%		0.0102%	0.0031%	0.0026%		0.0033%
48	0.0036%	0.0013%	0.0091%	0.0088%	0.0104%	0.0064%	0.0048%	0.0007%	0.0000%	0.0006%
	0.0114%	0.0138%	0.0207%	0.0127%	0.0162%	0.0114%	0.0085%	0.0065%	0.0000%	0.0068%
49	0.0054%		0.0069%		0.0072%	0.0052%		0.0027%		0.0015%
	0.0083%		0.0106%		0.0101%	0.0083%		0.0074%		0.0060%

777 - Inflight - AFT - 47E - BM - Tests 10-12										
	A	B	C	D	E	F	G	J	K	L
45	0.0001%		0.0001%			0.0000%	0.0000%	0.0000%		0.0000%
	0.0004%		0.0003%			0.0000%	0.0000%	0.0000%		0.0004%
46	0.0002%	0.0001%	0.0009%	0.0000%	0.0000%	0.0001%	0.0000%	0.0001%	0.0001%	0.0003%
	0.0008%	0.0012%	0.0015%	0.0004%	0.0004%	0.0002%	0.0002%	0.0002%	0.0004%	0.0004%
47	0.0014%		0.0024%	0.0187%	100.0000%	0.0009%	0.0003%	0.0001%		0.0002%
	0.0044%		0.0042%	0.0543%		0.0013%	0.0011%	0.0004%		0.0005%
48	0.0045%	0.0044%	0.0052%	0.0087%	0.0069%	0.0041%	0.0026%	0.0008%	0.0009%	0.0008%
	0.0065%	0.0059%	0.0119%	0.0114%	0.0169%	0.0098%	0.0066%	0.0023%	0.0017%	0.0019%
49	0.0056%		0.0070%		0.0077%	0.0035%		0.0029%		0.0020%
	0.0075%		0.0117%		0.0102%	0.0060%		0.0049%		0.0029%

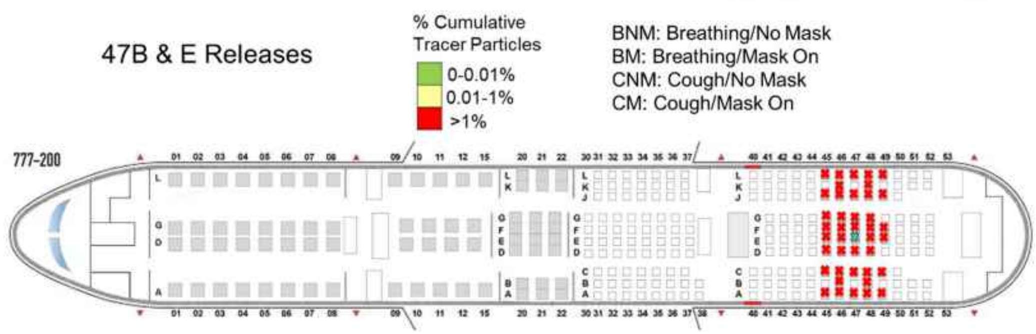


Figure 13. 777-200 Inflight Data – AFT Section

(95% Confidence Intervals applied, n=3)

777 - AFT - 47A - BNM

	A	B	C	D	E	F	G	J	K	L
45	0.0012%		0.0007%	0.0017%	0.0007%	0.0012%	0.0015%	0.0015%		
46	0.0048%	0.0050%	0.0047%	0.0016%	0.0073%	0.0039%		0.0022%	0.0050%	0.0059%
47	100.0000%	0.0130%	0.0145%	0.0145%	0.0166%	0.0200%	0.0068%	0.0080%		0.0094%
48	0.0100%	0.0133%	0.0142%	0.0150%	0.0185%	0.0164%	0.0188%	0.0120%	0.0113%	0.0133%
49	0.0077%		0.0122%		0.0112%	0.0104%		0.0111%		0.0080%

777 - AFT - 47B - BNM

	A	B	C	D	E	F	G	J	K	L
45	0.0007%		0.0005%	0.0000%	0.0003%	0.0005%	0.0008%	0.0006%		
46	0.0032%	0.0029%	0.0036%	0.0010%	0.0030%	0.0011%		0.0011%	0.0023%	0.0028%
47	0.0314%	100.0000%	0.0102%	0.0081%	0.0103%	0.0165%	0.0097%	0.0040%		0.0067%
48	0.0100%	0.0115%	0.0129%	0.0152%	0.0193%	0.0198%	0.0228%	0.0136%	0.0114%	0.0130%
49	0.0082%		0.0125%		0.0116%	0.0125%		0.0147%		0.0110%

777 - AFT - 47C - BNM

	A	B	C	D	E	F	G	J	K	L
45	0.0007%		0.0002%	0.0000%	0.0006%	0.0009%	0.0010%	0.0016%		
46	0.0024%	0.0027%	0.0036%	0.0014%	0.0042%	0.0024%		0.0015%	0.0042%	0.0057%
47	0.0149%	0.0466%	100.0000%	0.0119%	0.0155%	0.0194%	0.0065%	0.0048%		0.0082%
48	0.0116%	0.0143%	0.0158%	0.0228%	0.0297%	0.0244%	0.0236%	0.0136%	0.0112%	0.0142%
49	0.0108%		0.0116%		0.0181%	0.0160%		0.0137%		0.0100%

777 - AFT - 47D - BNM

	A	B	C	D	E	F	G	J	K	L
45	0.0011%		0.0006%	0.0012%	0.0002%	0.0005%	0.0009%	0.0009%		0.0019%
46	0.0038%	0.0045%	0.0047%	0.0010%	0.0038%	0.0011%		0.0012%	0.0027%	0.0033%
47	0.0368%	0.0520%	0.0876%	100.0000%	0.0162%	0.0173%	0.0071%	0.0052%		0.0073%
48	0.0179%	0.0305%	0.0326%	0.0294%	0.0361%	0.0285%	0.0308%	0.0185%	0.0143%	0.0156%
49	0.0148%		0.0249%		0.0261%	0.0227%		0.0198%		0.0147%

777 - AFT - 47E - BNM

	A	B	C	D	E	F	G	J	K	L
45	0.0011%		0.0006%	0.0010%	0.0002%	0.0004%	0.0007%	0.0006%		0.0017%
46	0.0054%	0.0057%	0.0062%	0.0016%	0.0026%	0.0011%		0.0010%	0.0017%	0.0030%
47	0.0254%	0.0465%	0.0481%	0.0504%	100.0000%	0.0131%	0.0074%	0.0031%		0.0055%
48	0.0217%	0.0350%	0.0251%	0.0204%	0.0249%	0.0066%	0.0214%	0.0114%	0.0094%	0.0103%
49	0.0118%		0.0188%		0.0202%	0.0209%		0.0145%		0.0115%

777 - AFT - 47F - BNM

	A	B	C	D	E	F	G	J	K	L
45	0.0094%		0.0044%	0.0089%	0.0017%	0.0023%	0.0039%	0.0026%		0.0049%
46	0.0382%	0.0361%	0.0354%	0.0071%	0.0090%	0.0049%		0.0040%	0.0062%	0.0083%
47	0.0361%	0.0310%		0.0217%	0.0183%	100.0000%	0.0123%	0.0092%		0.0139%
48	0.0154%	0.0201%	0.0192%	0.0190%	0.0221%	0.0190%	0.0209%	0.0148%	0.0149%	0.0170%
49	0.0107%		0.0166%		0.0162%	0.0160%		0.0154%		0.0104%

777 - AFT - 47G - BNM

	A	B	C	D	E	F	G	J	K	L
45	0.0010%		0.0007%	0.0013%	0.0004%	0.0006%	0.0012%	0.0009%		0.0023%
46	0.0040%	0.0033%	0.0030%	0.0013%	0.0024%	0.0012%		0.0014%	0.0045%	0.0076%
47	0.0116%	0.0108%		0.0063%	0.0069%	0.0135%	100.0000%	0.0189%		0.0434%
48	0.0107%	0.0111%	0.0128%	0.0120%	0.0124%	0.0120%	0.0222%	0.0310%	0.0481%	0.0505%
49	0.0092%		0.0136%		0.0119%	0.0141%		0.0215%		0.0134%

777 - AFT - 47J - BNM

	A	B	C	D	E	F	G	J	K	L
45	0.0009%		0.0005%	0.0010%	0.0007%	0.0010%	0.0014%	0.0011%		0.0027%
46	0.0042%	0.0043%	0.0038%	0.0020%	0.0041%	0.0021%		0.0018%	0.0057%	0.0065%
47	0.0152%	0.0134%		0.0083%	0.0127%		0.0506%	100.0000%		0.0308%
48	0.0108%	0.0132%	0.0146%	0.0128%	0.0145%	0.0138%	0.0206%	0.0300%	0.0265%	0.0268%
49	0.0086%		0.0128%		0.0105%	0.0129%		0.0261%		0.0139%

777 - AFT - 47K - BNM

	A	B	C	D	E	F	G	J	K	L
45	0.0021%		0.0009%	0.0021%	0.0005%	0.0011%	0.0021%	0.0015%		0.0036%
46	0.0072%	0.0062%	0.0057%	0.0027%	0.0053%	0.0023%		0.0029%	0.0066%	0.0082%
47	0.0146%	0.0137%		0.0095%	0.0143%		0.0413%	0.0137%	100.0000%	0.0257%
48	0.0094%	0.0124%	0.0122%	0.0120%	0.0139%	0.0118%	0.0158%	0.0167%	0.0220%	0.0206%
49	0.0070%		0.0105%		0.0098%	0.0108%		0.0156%		0.0092%

777 - AFT - 47L - BNM

	A	B	C	D	E	F	G	J	K	L
45	0.0025%		0.0011%	0.0024%	0.0011%	0.0017%	0.0027%	0.0023%		0.0054%
46	0.0079%	0.0068%	0.0062%	0.0033%	0.0077%	0.0028%		0.0031%	0.0069%	0.0088%
47	0.0225%	0.0199%		0.0142%	0.0215%		0.0340%	0.0134%	0.0238%	100.0000%
48	0.0135%	0.0170%	0.0184%	0.0187%	0.0207%	0.0178%	0.0310%	0.0229%	0.0226%	0.0255%
49	0.0118%		0.0160%		0.0141%	0.0162%		0.0241%		0.0142%

Seat Releases: 47A, 47B, 47C, 47D, 47E, 47F, 47G, 47J, 47K & 47L

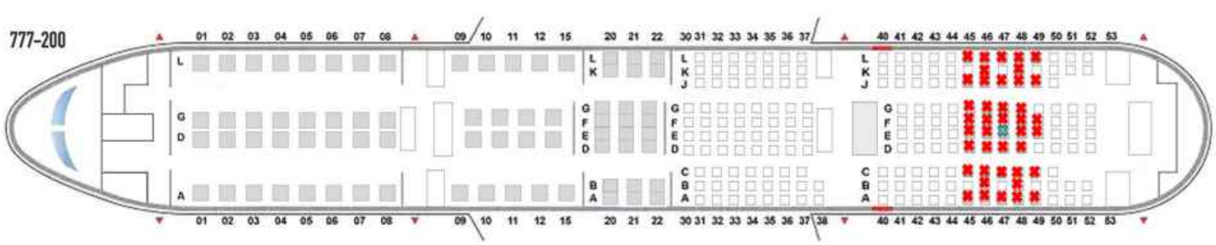


Figure 14. 777-200 Hangar "Inflight" Data – AFT Section

767-FWD-MID-Terminal-18E-BNM
Gaspers On/Blankets On/Ground Air

	A	B	D	E	F	K	L
10	0.0019%				0.0022%		0.0017%
16		0.0022%	0.0026%	0.0027%	0.0027%	0.0026%	0.0021%
17	0.0023%	0.0024%	0.0026%	0.0036%	0.0039%		0.0033%
18	0.0019%	0.0016%	0.0031%	100.0000%	0.0066%	0.0032%	0.0029%
19	0.0002%	0.0002%	0.0001%	0.0003%	0.0013%		0.0003%
20	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0001%	0.0002%
21	0.0000%	0.0000%				0.0000%	0.0000%
22				0.0000%			

767-FWD-MID-Terminal-18E-BNM
Gaspers On/Blankets On/PACS On

	A	B	D	E	F	K	L
10	0.0055%				0.0071%		0.0050%
16		0.0068%	0.0082%	0.0075%	0.0076%	0.0064%	0.0055%
17	0.0074%	0.0078%	0.0084%	0.0102%	0.0122%		0.0066%
18	0.0078%	0.0064%	0.0122%	100.0000%	0.0303%	0.0074%	0.0081%
19	0.0018%	0.0017%	0.0010%	0.0022%	0.0043%		0.0026%
20	0.0000%	0.0004%	0.0004%	0.0007%	0.0007%	0.0017%	0.0020%
21	0.0000%	0.0000%				0.0005%	0.0005%
22				0.0000%			

767-FWD-MID-Terminal-18E-BNM
Gaspers On/Blankets Off/PACS On

	A	B	D	E	F	K	L
10	0.0049%				0.0061%		0.0062%
16		0.0060%	0.0076%	0.0087%	0.0089%	0.0085%	0.0069%
17	0.0058%	0.0058%	0.0075%	0.0107%	0.0123%		0.0092%
18	0.0045%	0.0025%	0.0060%	100.0000%	0.0344%	0.0093%	0.0088%
19	0.0006%	0.0005%	0.0007%	0.0042%	0.0093%		0.0021%
20	0.0000%	0.0000%	0.0004%	0.0004%	0.0004%	0.0010%	0.0020%
21	0.0000%	0.0000%				0.0004%	0.0003%
22				0.0000%			

767-FWD-MID-Terminal-18E-BNM
Gaspers Off/Blankets Off/PACS On

	A	B	D	E	F	K	L
10	0.0023%				0.0026%		0.0040%
16	0.0000%	0.0025%	0.0030%	0.0028%	0.0058%	0.0058%	0.0054%
17	0.0030%	0.0029%	0.0021%	0.0019%	0.0053%		0.0071%
18	0.0046%	0.0029%	0.0002%	100.0000%	0.0005%	0.0052%	0.0085%
19	0.0013%	0.0010%	0.0000%	0.0000%	0.0000%		0.0001%
20	0.0001%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
21	0.0000%	0.0000%				0.0000%	0.0000%
22				0.0000%			

18E Releases

% Cumulative Tracer Particles
- 0-0.01%
- 0.01-1%
- >1%

BNM: Breathing/No Mask
BM: Breathing/Mask On
CNM: Cough/No Mask
CM: Cough/Mask On

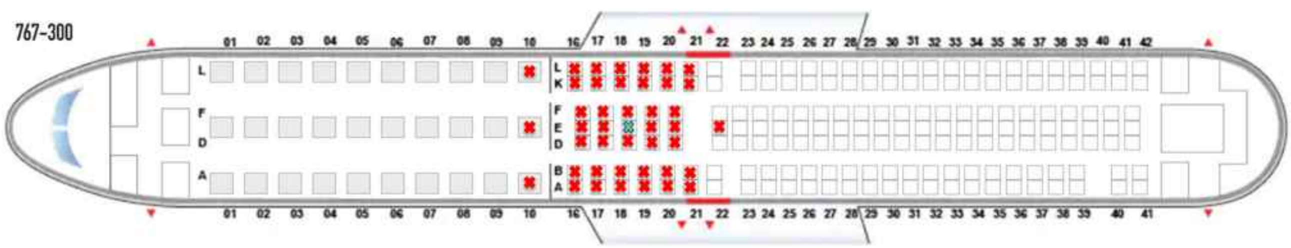


Figure 15. 767-300 Terminal Data – Cooling Configuration Comparison

777 - AFT - 47K - BNM Gaspers Off

	A	B	C	D	E	F	G	J	K	L
45	0.0009%		0.0012%		0.0002%	0.0002%	0.0002%	0.0004%		0.0006%
46	0.0031%	0.0029%	0.0047%	0.0008%	0.0008%	0.0016%	0.0015%	0.0007%	0.0044%	0.0032%
47	0.0125%		0.0233%	0.0039%	0.0042%	0.0033%	0.0007%	0.0023%	100.0000%	0.0055%
48	0.0081%	0.0077%	0.0098%	0.0106%	0.0138%	0.0136%	0.0205%	0.0131%	0.0117%	
49	0.0072%		0.0091%		0.0099%	0.0165%		0.0119%		0.0187%

777 - AFT - 47K - BNM Gaspers On

	A	B	C	D	E	F	G	J	K	L
45	0.0010%		0.0010%		0.0007%	0.0017%	0.0025%	0.0020%		0.0020%
46	0.0024%	0.0017%	0.0018%	0.0029%	0.0030%	0.0048%	0.0067%	0.0033%	0.0028%	0.0029%
47	0.0029%		0.0026%	0.0030%	0.0036%	0.0072%	0.0161%	0.0316%	100.0000%	0.0136%
48	0.0037%	0.0039%	0.0039%	0.0054%	0.0090%	0.0098%	0.0138%	0.0225%	0.0294%	
49	0.0038%		0.0045%		0.0060%	0.0147%		0.0226%		0.0221%

777 - AFT - 47K - BNM Gaspers Down

	A	B	C	D	E	F	G	J	K	L
45	0.0022%		0.0017%		0.0015%	0.0015%	0.0017%	0.0037%		0.0025%
46	0.0026%	0.0026%	0.0030%	0.0030%	0.0036%	0.0042%	0.0043%	0.0087%	0.0092%	0.0078%
47	0.0041%		0.0046%	0.0059%	0.0079%	0.0115%	0.0138%	0.0494%	100.0000%	0.0715%
48	0.0047%	0.0054%	0.0057%	0.0067%	0.0103%	0.0107%	0.0141%	0.0342%	0.0402%	
49	0.0052%		0.0064%		0.0071%	0.0134%		0.0112%		0.0158%

37K Release

% Cumulative Tracer Particles
- 0-0.01%
- 0.01-1%
- >1%

BNM: Breathing/No Mask
BM: Breathing/Mask On
CNM: Cough/No Mask
CM: Cough/Mask On

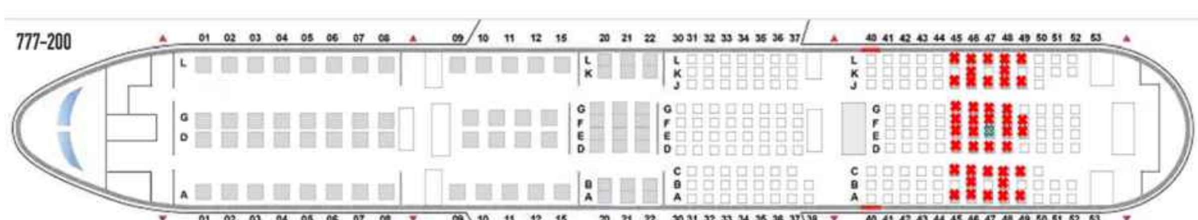


Figure 16. 777-200 Inflight Data – AFT Section – Gasper Condition Comparison
Note: Gaspers on/down only in Seats J, K & L for these tests

767 - Inflight AFT - 37E - BNM Tests 7-9

	A	B	D	E	F	K	L
34			0.0000%		0.0001%		
			0.0005%		0.0002%		
35	0.0000%	0.0000%	0.0005%	0.0003%	0.0001%		0.0000%
	0.0000%	0.0000%	0.0010%	0.0008%	0.0005%		0.0000%
36	0.0002%	0.0002%	0.0025%	0.0007%	0.0005%	0.0002%	0.0002%
	0.0004%	0.0004%	0.0042%	0.0025%	0.0015%	0.0006%	0.0006%
37	0.0008%	0.0005%	0.0060%	100.0000%	0.0027%	0.0005%	0.0005%
	0.0016%	0.0011%	0.0078%		0.0073%	0.0015%	0.0016%
38	0.0026%	0.0038%	0.0096%	0.0062%	0.0045%	0.0033%	0.0029%
	0.0075%	0.0075%	0.0134%	0.0108%	0.0110%	0.0054%	0.0057%
39	0.0120%		0.0084%	0.0077%			0.0063%
	0.0143%		0.0135%	0.0097%			0.0120%
40	0.0058%	0.0055%	0.0054%		0.0064%	0.0057%	0.0052%
	0.0083%	0.0066%	0.0071%		0.0084%	0.0092%	0.0074%
41	0.0048%						0.0054%
	0.0057%						0.0075%

767 - Inflight AFT - 37E - BM Tests 10-12

	A	B	D	E	F	K	L
34			0.0001%		0.0000%		
			0.0003%		0.0002%		
35	0.0000%	0.0000%	0.0002%	0.0002%	0.0001%		0.0000%
	0.0000%	0.0000%	0.0011%	0.0005%	0.0003%		0.0000%
36	0.0001%	0.0001%	0.0021%	0.0007%	0.0003%	0.0001%	0.0001%
	0.0004%	0.0004%	0.0031%	0.0011%	0.0009%	0.0005%	0.0004%
37	0.0005%	0.0003%	0.0042%	100.0000%	0.0032%	0.0003%	0.0004%
	0.0010%	0.0008%	0.0057%		0.0045%	0.0010%	0.0011%
38	0.0018%	0.0015%	0.0063%	0.0063%	0.0048%	0.0025%	0.0024%
	0.0044%	0.0057%	0.0098%	0.0069%	0.0078%	0.0051%	0.0045%
39	0.0086%		0.0064%	0.0065%			0.0070%
	0.0110%		0.0102%	0.0070%			0.0083%
40	0.0051%	0.0044%	0.0046%		0.0057%	0.0056%	0.0048%
	0.0056%	0.0052%	0.0052%		0.0067%	0.0068%	0.0054%
41	0.0042%						0.0047%
	0.0043%						0.0055%

767 - Inflight AFT - 37E - CNM Tests 13-15,19

	A	B	D	E	F	K	L
34			0.0001%		0.0000%		
			0.0007%		0.0005%		
35	0.0001%	0.0000%	0.0007%	0.0003%	0.0002%		0.0000%
	0.0003%	0.0002%	0.0016%	0.0018%	0.0015%		0.0003%
36	0.0002%	0.0002%	0.0025%	0.0013%	0.0008%	0.0003%	0.0002%
	0.0008%	0.0008%	0.0040%	0.0039%	0.0050%	0.0020%	0.0018%
37	0.0012%	0.0006%	0.0041%	100.0000%	0.0061%	0.0006%	0.0013%
	0.0020%	0.0015%	0.0060%		0.0113%	0.0061%	0.0063%
38	0.0041%	0.0037%	0.0050%	0.0076%	0.0080%	0.0066%	0.0080%
	0.0054%	0.0051%	0.0076%	0.0104%	0.0106%	0.0121%	0.0158%
39	0.0053%		0.0048%	0.0059%			0.0079%
	0.0080%		0.0072%	0.0066%			0.0117%
40	0.0046%	0.0044%	0.0039%		0.0057%	0.0058%	0.0046%
	0.0052%	0.0045%	0.0047%		0.0071%	0.0096%	0.0070%
41	0.0039%						0.0046%
	0.0042%						0.0064%

767 - Inflight AFT - 37E - CM Tests 16-18

	A	B	D	E	F	K	L
34			0.0000%		0.0000%		
			0.0000%		0.0000%		
35	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%		0.0000%
	0.0000%	0.0000%	0.0002%	0.0000%	0.0000%		0.0000%
36	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
	0.0000%	0.0000%	0.0005%	0.0003%	0.0003%	0.0000%	0.0000%
37	0.0000%	0.0000%	0.0003%	100.0000%	0.0002%	0.0000%	0.0000%
	0.0003%	0.0002%	0.0010%		0.0005%	0.0003%	0.0000%
38	0.0003%	0.0003%	0.0007%	0.0003%	0.0002%	0.0000%	0.0000%
	0.0006%	0.0007%	0.0015%	0.0014%	0.0014%	0.0011%	0.0011%
39	0.0010%		0.0006%	0.0007%			0.0004%
	0.0015%		0.0014%	0.0011%			0.0016%
40	0.0006%	0.0005%	0.0006%		0.0006%	0.0006%	0.0004%
	0.0009%	0.0009%	0.0008%		0.0010%	0.0010%	0.0009%
41	0.0006%						0.0006%
	0.0007%						0.0008%

37E Release

% Cumulative Tracer Particles
- 0-0.01%
- 0.01-1%
- >1%

BNM: Breathing/No Mask
BM: Breathing/Mask On
CNM: Cough/No Mask
CM: Cough/Mask On

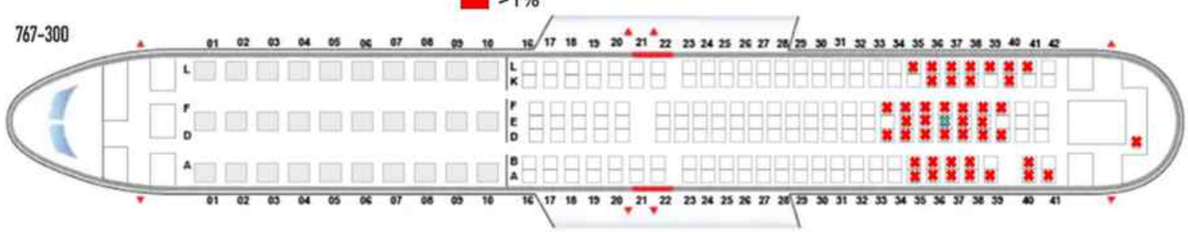


Figure 17. 767-300 Inflight Data – AFT Section – Breathing/Coughing Mask/No Mask

(95% Confidence Intervals applied, n=3)

777-200	Breathing Zone Penetration BNM		Breathing Zone Penetration BM	
	MAX	AVG	MAX	AVG
Terminal				
AFT	0.018%	0.005%		
MID-AFT	0.082%	0.012%	0.050%	0.009%
FWD-MID	0.012%	0.001%	0.008%	0.001%
Hangar "Inflight"				
AFT	0.069%	0.010%		
MID-AFT	0.118%	0.013%		
FWD-MID	0.120%	0.004%		
FWD	0.046%	0.003%		
Inflight				
AFT	0.072%	0.007%	0.042%	0.004%
MID-AFT	0.215%	0.008%	0.074%	0.005%
FWD-MID	0.029%	0.002%	0.020%	0.001%
FWD	0.027%	0.002%	0.013%	0.000%

Figure 18. 777-200 Aerosol Penetration for Measured Breathing Zone
(BNM-Breathing no Mask BM-Breathing with Mask)

767-300	Breathing Zone Penetration BNM		Breathing Zone Penetration BM		Breathing Zone Penetration CNM		Breathing Zone Penetration CM	
	MAX	AVG	MAX	AVG	MAX	AVG	MAX	AVG
Terminal								
AFT	0.010%	0.010%	0.009%	0.008%				
FWD-MID	0.036%	0.004%	0.009%	0.002%				
FWD	0.014%	0.002%	0.011%	0.002%				
Hangar "Inflight"								
AFT	0.115%	0.011%						
FWD-MID	0.067%	0.003%						
FWD	0.066%	0.004%						
Inflight								
AFT	0.036%	0.005%	0.031%	0.004%	0.041%	0.006%	0.002%	0.000%
FWD-MID	0.044%	0.005%	0.037%	0.004%	0.065%	0.004%	0.002%	0.000%
FWD	0.016%	0.003%	0.012%	0.002%	0.024%	0.003%	0.002%	0.000%

Figure 19. 767-300 Aerosol Penetration for Measured Breathing Zones
(BNM-Breathing no Mask BM-Breathing with Mask CNM-Cough no Mask CM-Cough with Mask)

777 In-Flight Testing – DNA-tagged Tracers

Clear trends emerge in both the collected aerosol data and the surface samples. In the case of air samples, the collected fraction of particles aerosolized compares well with the real-time fluorescent tracer, ranging from undetectable to 0.03% in economy sections closest to the release point (Figure 20). The highest collected aerosol concentration is always located closest to the release point of that DNA-tagged bead, with lower risks forward of a release than aft of the release. Low concentrations (<.004% on average) of tracer particles were present in the aft galley in both of the economy seat release locations.

Figure 20. 777-200 DNA Tagged Tracer Particle Maps

Surface samples, in the arm rests and seat backs of the seats closest to each release location (Figure 20 & Figure 21) were scaled from their size to a standard square foot for comparison with the total number of tracer particles released. This scaling which includes integrating to a larger surface areas had less than 0.06% of tracer particles settle out during testing, with the highest concentration on the surfaces closest to each release location, especially the flat surfaces, such as arm rests, when compared to the more vertical surfaces of the seatbacks and inflight entertainment (IFE) systems. The low overall deposition leads to higher 95% confidence intervals, as based on standard error (Figure 21).

Seat	Location	Percent of Released Particles in 1 Ft2 (Surface Sample) or Integrated Collection at a Given Seat (Aerosol)							
		FWD	±95% CI	MID-FWD	±95% CI	MID-AFT	±95% CI	AFT	±95% CI
5D	Center Above IFE	0.001%	0.002%	0.001%	0.003%	0.000%	0.000%	0.029%	0.059%
5D	Left Arm Rest	0.001%	0.001%	0.001%	0.002%	0.000%	0.000%	0.020%	0.027%
5D	Right Arm Rest	0.003%	0.007%	0.001%	0.002%	0.000%	0.000%	0.011%	0.021%
11D	Center Above IFE	0.000%	0.000%	0.002%	0.004%	0.000%	0.000%	0.018%	0.044%
11D	Left Arm Rest	0.000%	0.000%	0.001%	0.003%	0.000%	0.001%	0.006%	0.006%
11D	Right Arm Rest	0.000%	0.000%	0.017%	0.023%	0.000%	0.000%	0.035%	0.100%
33D	Center Above IFE	0.000%	0.001%	0.001%	0.003%	0.000%	0.002%	0.017%	0.027%
33E	Center Below IFE	0.000%	0.000%	0.001%	0.002%	0.001%	0.002%	0.055%	0.175%
33E	Left Arm Rest	0.000%	0.001%	0.002%	0.004%	0.018%	0.060%	0.046%	0.148%
33E	Right Arm Rest	0.000%	0.000%	0.001%	0.002%	0.001%	0.002%	0.013%	0.017%
47E	Center Below IFE	0.000%	0.000%	0.000%	#DIV/0!	0.001%	0.001%	0.022%	0.065%
47E	Left Arm Rest	0.000%	0.000%	0.000%	#DIV/0!	0.000%	0.000%	0.008%	0.009%
47E	Right Arm Rest	0.000%	0.000%	0.000%	#DIV/0!	0.001%	0.001%	0.022%	0.045%
8D	Aerosol	0.000%	0.000%	0.000%	0.001%	0.000%	0.000%	0.000%	0.000%
12D	Aerosol	0.000%	0.000%	0.004%	0.008%	0.001%	0.001%	0.000%	0.000%
36E	Aerosol	0.000%	0.000%	0.000%	0.000%	0.030%	0.093%	0.000%	0.000%
49D	Aerosol	0.000%	0.000%	0.000%	0.000%	0.007%	0.017%	0.001%	0.002%
Rear Galley	Aerosol	0.000%	0.001%	0.000%	0.000%	0.002%	0.006%	0.001%	0.002%

Figure 21. 777-200 DNA-Tagged Tracer Results (n=3), 95% CI based on standard error

767 In-Flight Testing – DNA-tagged Tracers Results

The DNA-tagged tracer releases completed on the 777 were duplicated on the 767, albeit at three locations instead of four for the smaller airframe. Surface samples again targeted the high-touch and easily contaminated surfaces such as arm rests and seat backs.

Similar to the 777, the air samplers agree with the fluorescent real-time releases, with the highest number of particles nearest each release location, and the overall percentage of particles compared to the chamber characterization consistently below 0.02% located 3 rows away (Figure 22). Compared to the 777, the 767 consistently had higher air concentrations in the aft galley, potentially because of the location of the outflow valve in the aft of the plane.

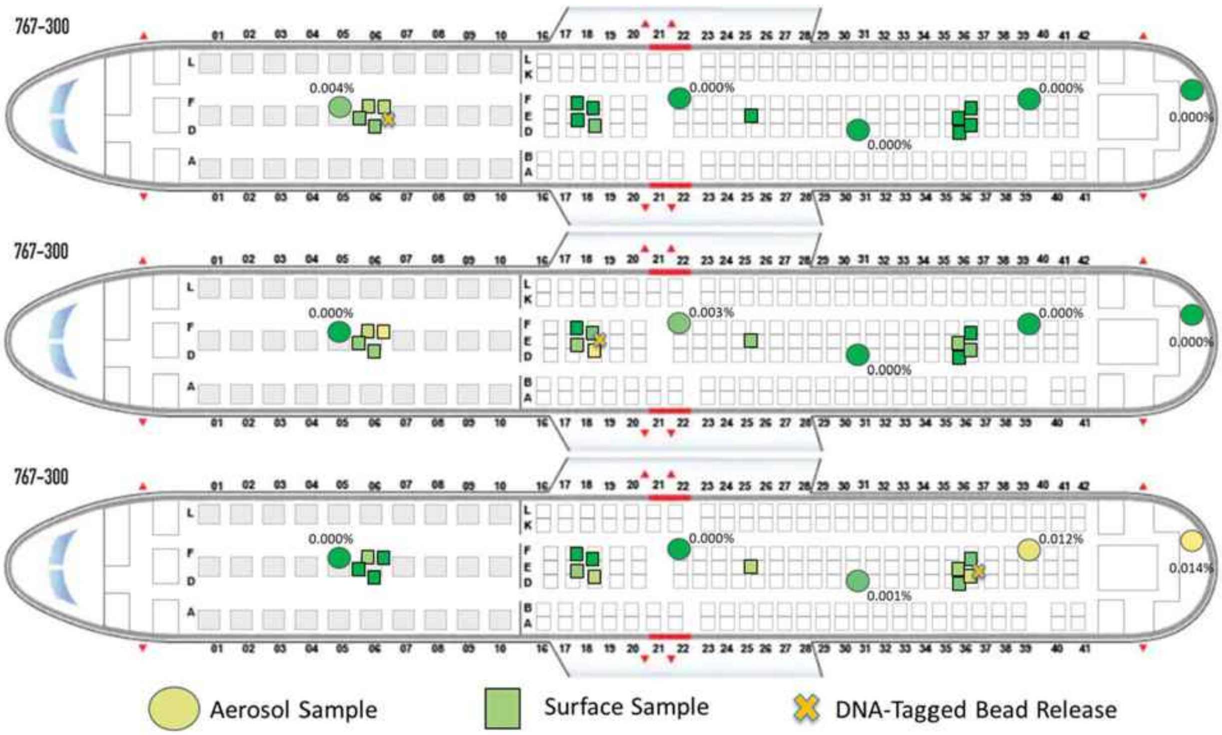


Figure 22. 767-300 DNA-Tagged Tracer Particle Maps

The number of particles on contaminated surfaces is again scaled to a standard square foot, and remains low by aerosol deposition, with a maximum below .005%. Arm rests and table tops closest to the release location are consistently the highest level of contamination for each release location. Confidence intervals are large for surface samples due to low overall deposition and resulting signal (Figure 23).

Seat	Location	Percent of Released Particles in 1 Ft2 (Surface Sample) or Integrated During Release at a Given Seat (Aerosol) FWD	±95% CI	MID	±95% CI	AFT	±95% CI
6D	Left Arm Rest	0.001%	0.002%	0.002%	0.003%	0.000%	0.000%
6D	Center Above IFE	0.001%	0.001%	0.001%	0.003%	0.000%	0.000%
6D	Right Arm Rest	0.003%	0.009%	0.003%	0.008%	0.002%	0.008%
6D	Marble Table	0.003%	0.004%	0.005%	0.005%	0.000%	0.001%
18E	Left Arm Rest	0.001%	0.001%	0.005%	0.012%	0.003%	0.009%
18E	Center Above IFE	0.000%	0.001%	0.002%	0.003%	0.002%	0.006%
18E	Right Arm Rest	0.000%	0.001%	0.001%	0.003%	0.000%	0.001%
18F	Center Below IFE	0.000%	0.000%	0.001%	0.002%	0.000%	0.002%
26E	Tray Table	0.000%	0.001%	0.002%	0.003%	0.003%	0.008%
37D	Center Above IFE	0.000%	0.001%	0.000%	0.000%	0.001%	0.003%
37E	Left Arm Rest	0.000%	0.001%	0.001%	0.002%	0.004%	0.005%
37E	Center Below IFE	0.000%	0.001%	0.002%	0.007%	0.002%	0.006%
37E	Right Arm Rest	0.000%	0.001%	0.001%	0.002%	0.001%	0.001%
5F	Aerosol	0.004%	0.012%	0.000%	0.000%	0.000%	0.000%
22F	Aerosol	0.000%	0.000%	0.000%	0.001%	0.000%	0.001%
31D	Aerosol	0.000%	0.000%	0.004%	0.008%	0.001%	0.004%
40F	Aerosol	0.000%	0.000%	0.000%	0.000%	0.012%	0.016%
Rear Galley	Aerosol	0.000%	0.000%	0.000%	0.000%	0.014%	0.001%

Figure 23. 767-300 DNA-Tagged Tracer Results (n=3), 95% CI based on standard error

Infectious Model

Using the 1000 virion infectious dose assumption and breathing model described previously, results in theoretical calculations of zero aerosol-acquired cases in a 12 hour flight (Note: penetration data for BNM conditions used). Results demonstrate a large number of flight hours are required for cumulative inhalation of an infectious dose of 1,000 virions for both airframes. Specifically, the time required to be exposed to an infectious dose is a minimum of 54 hours when sitting next to an index patient in the economy section of the 777, and in all other airframe (767 and 777) seats examined, over 100. Overall maximum and average transmission likelihoods and the hours required for exposure to a theoretical infectious dose (Figures 24-27).

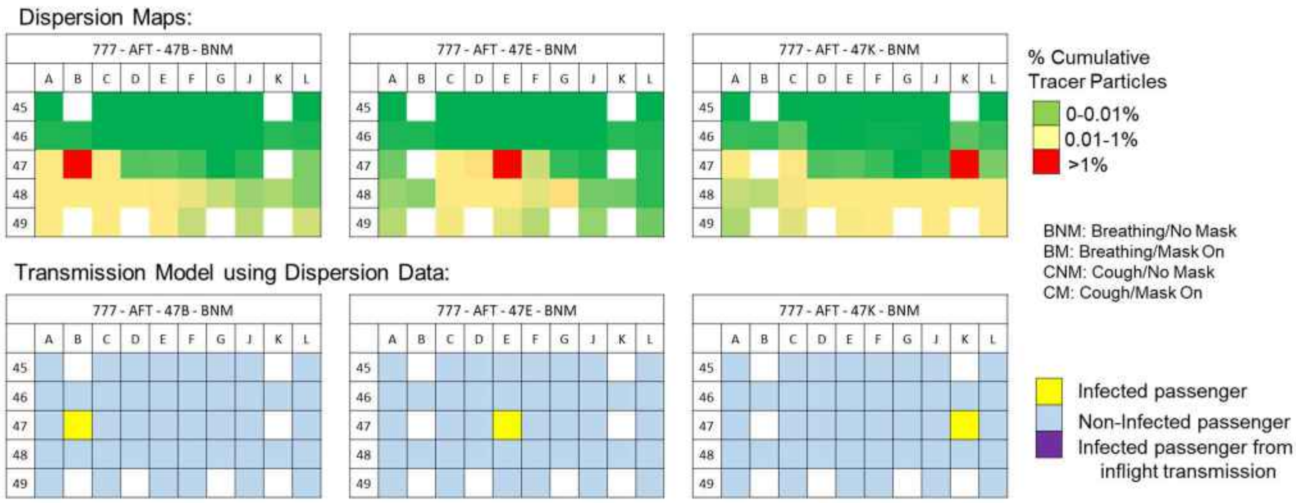
767-300	Breathing Zone Penetration BNM		Breathing Zone Penetration BM		Breathing Zone Penetration CNM		Breathing Zone Penetration CM		**Exposure from single infected passenger MAX**	Assumption: 4,000 virions/hr shedding rate	**Exposure from single infected passenger AVG**	Assumption: 4,000 virions/hr shedding rate
	MAX	AVG	MAX	AVG	MAX	AVG	MAX	AVG	# virions inhaled per hour at 7.5 lpm	**# flight hours to inhale 1,000 virions**	# virions inhaled per hour at 7.5 lpm	**# flight hours to inhale 1,000 virions**
Terminal												
AFT	0.010%	0.010%	0.009%	0.008%					0.86	**1,165**	0.82	**1,213**
FWD-MID	0.036%	0.004%	0.009%	0.002%					3.04	**329**	0.30	**3,288**
FWD	0.014%	0.002%	0.011%	0.002%					1.16	**865**	0.21	**4,752**
Hangar "Inflight"												
AFT	0.115%	0.011%							9.82	**102**	0.91	**1,099**
FWD-MID	0.067%	0.003%							5.73	**175**	0.26	**3,910**
FWD	0.066%	0.004%							5.68	**176**	0.34	**2,934**
Inflight												
AFT	0.036%	0.005%	0.031%	0.004%	0.041%	0.006%	0.002%	0.000%	3.10	**323**	0.44	**2,297**
FWD-MID	0.044%	0.005%	0.037%	0.004%	0.065%	0.004%	0.002%	0.000%	3.78	**264**	0.39	**2,591**
FWD	0.016%	0.003%	0.012%	0.002%	0.024%	0.003%	0.002%	0.000%	1.34	**744**	0.24	**4,179**

Figure 24. 777-200 Transmission Model Calculations
(BNM-Breathing no Mask BM-Breathing with Mask)

777-200	Breathing Zone Penetration BNM		Breathing Zone Penetration BM		**Exposure from single infected passenger MAX**	Assumption: 4,000 virions/hr shedding rate	**Exposure from single infected passenger AVG**	Assumption: 4,000 virions/hr shedding rate
	MAX	AVG	MAX	AVG	# virions inhaled per hour at 7.5 lpm	**# flight hours to inhale 1,000 virions**	# virions inhaled per hour at 7.5 lpm	**# flight hours to inhale 1,000 virions**
Terminal								
AFT	0.018%	0.005%			1.51	**662**	0.45	**2,200**
MID-AFT	0.082%	0.012%	0.050%	0.009%	6.98	**143**	1.02	**977**
FWD-MID	0.012%	0.001%	0.008%	0.001%	1.02	**977**	0.08	**12,002**
Hangar "Inflight"								
AFT	0.069%	0.010%			5.89	**170**	0.89	**1,125**
MID-AFT	0.118%	0.013%			10.06	**99**	1.15	**870**
FWD-MID	0.120%	0.004%			10.27	**97**	0.31	**3,274**
FWD	0.046%	0.003%			3.94	**254**	0.29	**3,424**
Inflight								
AFT	0.072%	0.007%	0.042%	0.004%	6.12	**163**	0.60	**1,668**
MID-AFT	0.215%	0.008%	0.074%	0.005%	18.43	**54**	0.71	**1,400**
FWD-MID	0.029%	0.002%	0.020%	0.001%	2.45	**408**	0.13	**7,627**
FWD	0.027%	0.002%	0.013%	0.000%	2.32	**430**	0.19	**5,266**

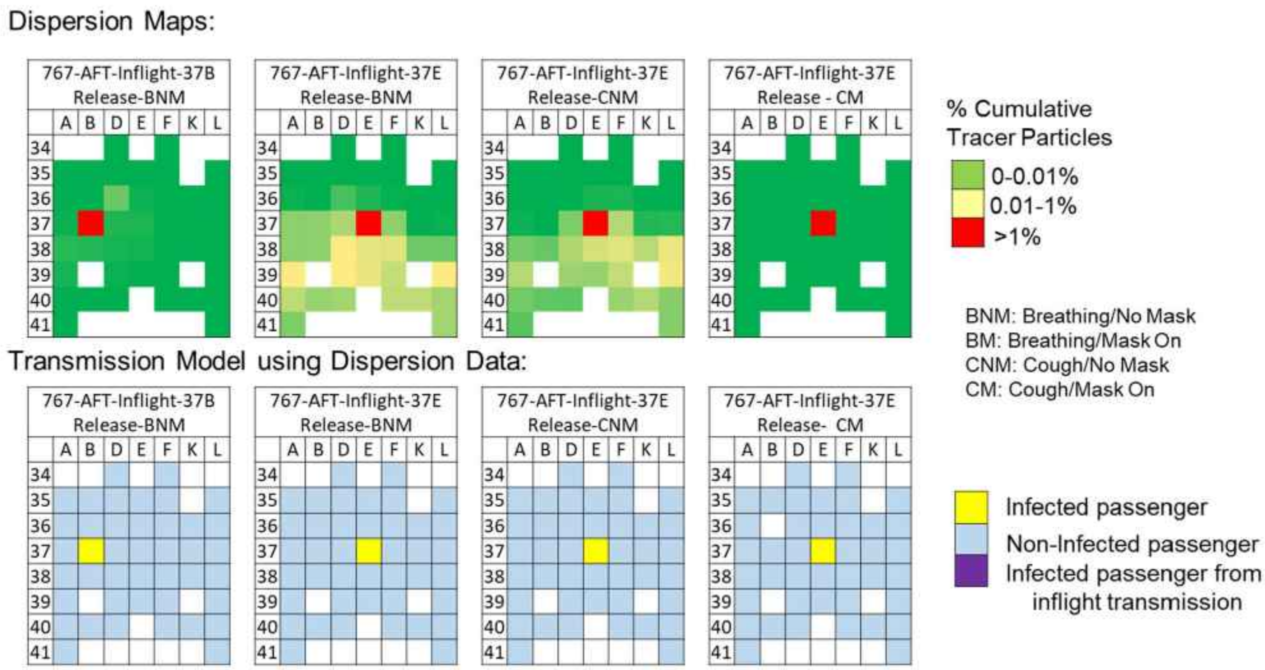
Figure 25. 767-300 Transmission Model Calculations

(BNM-Breathing no Mask BM-Breathing with Mask CNM-Cough no Mask CM-Cough with Mask)



Model Parameters: 12 hour flight – 4,000 virions/hour shed rate – 1,000 virion infectious dose

Figure 26. 777-200 12 Hour Flight - Transmission Model Calculations



Model Parameters: 12 hour flight – 4,000 virions/hour shed rate – 1,000 virion infectious dose

Figure 27. 777-200 12 Hour Flight - Transmission Model Calculations

Discussion & Conclusions – Aerosol Risk of Exposure on Commercial Airframes

Overall, rapid mixing, dilution and removal limit exposure risk for aerosol contaminants at 1 and 3 µm in all tested seat sections of the Boeing 767 and Boeing 777 wide body aircraft. The maximum exposure in a nearby seat of 0.3% of a characterized release, equates to a 99.7% reduction from an aerosolized source of contamination such as SARS-CoV-2. Converting to a reduction factor (how many particles were counted in the characterization vs the breathing zone of the seat), this corresponds to a reduction of 333+. Across the further ~40 seats nearby the simulated infected patient there is average reduction of 99.99% of aerosols, or a reduction factor of 10,000+.

For the 777 and 767, at 100% seating capacity transmission model calculations with a 4,000 viruses/hour shedding rate and 1,000 virus infectious dose show no inflight aerosol transmission for 12 hour flights. The data presented herein couples well with existing modeling and epidemiologic studies of commercial airframe transmission. No secondary cases were traced on a 350-person 15-hour flight from Guangzhou to Toronto, which included a symptomatic (coughing), PCR-positive patient, and his wife, who tested positive a day after landing (Schwartz, et al. 2020). Similarly, surface contamination, via the aerosol route is minimized by the rapid removal of contaminants before settling can occur.

In terms of comparison with other common locations containing COVID-positive personnel, the air exchange rate onboard the Boeing 767 and 777 airframes was significantly higher. Using the CDC airborne contaminant removal table, and our experimental data, the 767 and 777 both removed particulate 15 times faster than a home (as also referenced in Figure 11), and 5 to 6 times faster than recommended design specifications for modern hospital operating or patient isolation rooms (Figure 28).

Air Exchanges & Time to Remove Airborne-Contaminant*		
Building Type	**Air Changes per Hour (ACH)***	**Time (mins.) Required for Removal 99.9% efficiency**
Typical Single Family Home (Low Estimate)	2	207
Typical Single Family Home	4	104
Typical Single Family Home (High Estimate)	6	69
Standard for Hospital Operating Rooms and Isolation Units[ł]	12	35
Boeing 767-200 As Tested[§]	32	6[§]
Boeing 777-300 As Tested[§]	35	6[§]

* Adapted from CDC: https://www.cdc.gov/infectioncontrol/guidelines/environmental/appendix/air.html#tableb1

ł Recommended in ASHRAE / ASHE STANDARD Ventilation of Health Care Facilities (Vol. 4723)

§ Experimentally determined during this report

Figure 28. Comparison of Air Exchange Rates and the Boeing 767 and 777 Airframes Tested

Limitations & Assumptions

Testing focused on aerosol transport and smaller 1 to 3 µm particulate. Larger droplets (50 to 100s of µm) generated and co-released with smaller modes when talking, coughing, or sneezing introduce an alternative transmission mechanism, which face masks have been shown to statistically reduce in other literature (Leung, et al. 2020; Macintyre, et al. 2020). Testing assumes that mask wearing is continuous, and that the number of infected personnel is low. Since modeling and particulate generation assumed low numbers of infected passengers, large numbers of index patients, for instance a unit exposed together and deploying together, will increase risk. As an example, in another epidemiological study, 102 passengers traveled 4.66 hours from Tel Aviv, Israel to Frankfurt, Germany with 7 patients from a tourist group whom index patients who tested positive upon arrival. In this case, two in-air transmissions were possible, with both seated within 2 rows of an index case (Hoehl, et al. 2020).

Contamination of surfaces via non-aerosol routes (large droplets or fecal contamination) is more likely in lavatories and other common areas, and is not tested here. These alternative routes of exposure are more challenging to predict because of uncertainty in human behavior (Bae, et al., 2020). Testing did not include substantial movement throughout the plane or in the airport, lounge, or jetway, where air change rates and human interactions will vary. Similarly, the mannequin remained facing forward, uncertainty in human behavior with conversations and behavior may change the risk and directionality in the closest seats to an index patient, especially for large droplets.

Recommendations

Given the data captured during this most recent round of testing, and coupled with existing literature and a growing consensus on COVID-19 risks, the following recommendations regarding troop transport on commercial airlines can be conveyed.

- For the 777 and 767, at 100% seating capacity transmission model calculations with a 4,000 viruses/hour shedding rate and 1,000 virus infectious dose show a minimum 54 flight hours required to produce inflight infection from aerosol transmission.
- Aerosol exposure risk is minimal even during long duration flights, but typically highest in the row of an index patient. Rows in front and behind the index patient have the next highest risk on average.
- While there is a measurable difference in middle vs aisle or window seat, there is no practical difference at these high overall reduction levels.
- As testing did not incorporate large droplet contamination, recommend continued disinfectant cleaning and mask-wearing, or testing this transmission mechanism in an alternative methodology.
- The benefit of commercial airframes, and the validity of these recommendations relies on the combination of a HEPA-filtration recirculation system and the high air-exchange rate, which is not matched by other indoor venues, including most hospital and biosafety-level 3 laboratories.
- Overhead gasper supply (on or off) does not make a significant impact on aerosol risk and could continue to be used primarily for traveler comfort.
- Contact tracing should be limited, and is unlikely to be necessary for aerosol transmission, but may be necessary for large droplet transmission in the seats immediately neighboring an infectious passenger, or from uncertainty in human behavior (i.e., talking to a neighboring passenger while eating or drinking without a mask, which is not tested here).
- Flight deck exposure risk is extremely unlikely, as the ECS system supplies separate air to this portion of the aircraft.

Additionally, during boarding and deboarding, the following recommendations should be considered:

- Keeping air supply and recirculation mode (HEPA-Filtration) operating is critical. Ground supply and APU behave similarly, but there is likely more uncertainty with variations in ground supply flow rates and suppliers, since the test team was only able to test the single provided system.
- Jetway exposure risk from an infected person already sitting in the airframe was low with reductions for the 777 and 767 terminal of 99.999%.

- Loading passengers in smaller groups and allowing distance on the jetway is likely beneficial to maintaining social distancing guidelines, but simulated infected personnel within these jetways was not tested.

References

April, J., Furuse, Y., Sando, E., Tsuchiya, N., Miyahara, R., Yasuda, I., … Jindai, K. (2020). Clusters of Coronavirus Disease in Communities , *26*(9), 13–16.

Bae, S. H., Shin, H., Koo, H.-Y., Lee, S. W., Yang, J. M., & Yon, D. K. (2020). Asymptomatic Transmission of SARS-CoV-2 on Evacuation Flight. *Emerging Infectious Disease Journal*, *26*(11). https://doi.org/10.3201/eid2611.203353

Basu, S. (2020). Exposure to a COVID-19 carrier: transmission trends in respiratory tract and estimation of infectious dose. *MedRxiv*, 2020.07.27.20162362. https://doi.org/10.1101/2020.07.27.20162362

Barnett, A. (2020). Covid-19 Risk Among Airline Passengers Should the Middle Seat Stay Empty. *Medrxiv*, 1–11. https://doi.org/10.1101/2020.07.02.20143826

Centers for Disease Control (CDC). (2019). Guidelines for Environmental Infection Control in Health-Care Facilities (2003), Appendix B. Air. Table B.1. Air changes/hour (ACH) and time required for airborne-contaminant removal by efficiency. < https://www.cdc.gov/infectioncontrol/guidelines/environmental/appendix/air.html#b1 >

DeFreez, R. (2009). LIF bio-aerosol threat triggers: then and now. *Optically Based Biological and Chemical Detection for Defence V*, *7484*(June), 74840H. https://doi.org/10.1117/12.835088

de Sousa, N. R., Shen, L., Silcott, D., Call, C. J., & Rothfuchs, A. G. (2020). Operative and technical modifications to the Coriolis μ air sampler that improve sample recovery and biosafety during microbiological air sampling. *BioRxiv*, 2020.02.11.943662. https://doi.org/10.1101/2020.02.11.943662

Gupta, J. K., Lin, C. H., & Chen, Q. (2011). Transport of expiratory droplets in an aircraft cabin. *Indoor Air*, *21*(1), 3–11. https://doi.org/10.1111/j.1600-0668.2010.00676.x

Hermans, R. D., Langowski, P. H., Ninomura, P. T., Seth, A. K., Cohen, T., Shaughnessy, D. E., … Newman, H. M. (2008). *ASHRAE / ASHE STANDARD Ventilation of Health Care Facilities* (Vol. 4723).

Hoehl, S., Karaca, O., Kohmer, N., Westhaus, S., Graf, J., Goetsch, U., & Ciesek, S. (2020). Assessment of SARS-CoV-2 Transmission on an International Flight and Among a Tourist Group. *JAMA Network Open*, *3*(8), e2018044. https://doi.org/10.1001/jamanetworkopen.2020.18044

Lednicky, J. A., Lauzardo, M., Fan, Z. H., Jutla, A. S., Tilly, T. B., Gangwar, M., … Wu, C.-Y. (2020). Viable SARS-CoV-2 in the air of a hospital room with COVID-19 patients. *MedRxiv*, 2020.08.03.20167395. https://doi.org/10.1101/2020.08.03.20167395

Leung, N. H. L., Chu, D. K. W., Shiu, E. Y. C., Chan, K., Mcdevitt, J. J., Hau, B. J. P., Cowling, B. J. (2020). Respiratory virus shedding in exhaled breath and efficacy of face masks. *Nature Medicine*, *26*(May). https://doi.org/10.1038/s41591-020-0843-2

Liu, Y., Ning, Z., Chen, Y., Guo, M., Liu, Y., Gali, N. K., … Lan, K. (2020). Aerodynamic analysis of SARS-CoV-2 in two Wuhan hospitals. *Nature*, *582*(7813), 557–560. https://doi.org/10.1038/s41586-020-2271-3

Macintyre, C. R., & Ahmad, A. (2020). International Journal of Nursing Studies A rapid systematic review of the efficacy of face masks and respirators against coronaviruses and other respiratory transmissible viruses for the community , healthcare workers and sick patients. *International Journal of Nursing Studies*, *108*, 103629. https://doi.org/10.1016/j.ijnurstu.2020.103629

McKinsey & Company. (2020). *Survey: In thed US, people say their use of masks may endure*. *McKinsey & Company*.

Morawska, L., Johnson, G. R., Ristovski, Z. D., Hargreaves, M., Mengersen, K., Corbett, S., … Katoshevski, D. (2009). Size distribution and sites of origin of droplets expelled from the human respiratory tract during expiratory activities. *Journal of Aerosol Science*, *40*(3), 256–269. https://doi.org/10.1016/j.jaerosci.2008.11.002

Parks, S. R. (5AD). An assessment of the Sartorius MD8 microbiological air sampler. *Journal of Applied Bacteriology*, *80*(5), 529–534. https://doi.org/10.1111/j.1365-2672.1996.tb03252.x

Santarpia, J. L., Rivera, D. N., Herrera, V. L., Morwitzer, M. J., Creager, H. M., Santarpia, G. W., … Lowe, J. J. (2020). Aerosol and surface contamination of SARS-CoV-2 observed in quarantine and isolation care. *Scientific Reports*, *10*(1), 1–8. https://doi.org/10.1038/s41598-020-69286-3

Schroder, I. (2020). COVID-19: A Risk Assessment Perspective. https://doi.org/10.1021/acs.chas.0c00035

Schwartz, K. L., Murti, M., Finkelstein, M., Leis, J. A., Fitzgerald-Husek, A., Bourns, L., … Yaffe, B. (2020). Lack of COVID-19 transmission on an international flight. *Cmaj*, *192*(15), E410. https://doi.org/10.1503/cmaj.75015

Zayas, G., Chiang, M. C., Wong, E., MacDonald, F., Lange, C. F., Senthilselvan, A., & King, M. (2012). Cough aerosol in healthy participants: Fundamental knowledge to optimize droplet-spread infectious respiratory disease management. *BMC Pulmonary Medicine*, *12*(March). https://doi.org/10.1186/1471-2466-12-11

Appendix A – Airframe Test Tables

8/24/2020	777 Hangar Testing			
Inflight Tests	Airframe Section	Row/Seat Location	Gaspers	Mannequin Mask
Test 1	AFT	47A	OFF	OFF
Test 2	AFT	47A	OFF	OFF
Test 3	AFT	47B	OFF	OFF
Test 4	AFT	47B	OFF	OFF
Test 5	AFT	47C	OFF	OFF
Test 6	AFT	47C	OFF	OFF
Test 7	AFT	47D	OFF	OFF
Test 8	AFT	47D	OFF	OFF
Test 9	AFT	47E	OFF	OFF
Test 10	AFT	47E	OFF	OFF
Test 11	AFT	47F	OFF	OFF
Test 12	AFT	47F	OFF	OFF
Test 13	AFT	47G	OFF	OFF
Test 14	AFT	47G	OFF	OFF
Test 15	AFT	47J	OFF	OFF
Test 16	AFT	47J	OFF	OFF
Test 17	AFT	47K	OFF	OFF
Test 18	AFT	47K	OFF	OFF
Test 19	AFT	47L	OFF	OFF
Test 20	AFT	47L	OFF	OFF
Test 21	FWD	5A	OFF	OFF
Test 22	FWD	5D	OFF	OFF
Test 23	FWD	5G	OFF	OFF
Test 24	FWD	5L	OFF	OFF
Test 26	FWD-MID	11A	OFF	OFF
Test 27	FWD-MID	11D	OFF	OFF
Test 28	FWD-MID	11G	OFF	OFF
Test 29	FWD-MID	11L	OFF	OFF
Test 30	MID-AFT	33A	OFF	OFF
Test 31	MID-AFT	33B	OFF	OFF
Test 32	MID-AFT	33C	OFF	OFF
Test 33	MID-AFT	33D	OFF	OFF
Test 34	MID-AFT	33E	OFF	OFF
Test 35	MID-AFT	33F	OFF	OFF
Test 36	MID-AFT	33G	OFF	OFF
Test 37	MID-AFT	33J	OFF	OFF
Test 38	MID-AFT	33K	OFF	OFF
Test 39	MID-AFT	33L	OFF	OFF

8/28/2020	767 Hangar Testing			
Inflight Tests	Airframe Section	Row/Seat Location	Gaspers	Mannequin Mask
Test 1	AFT	37A	OFF	OFF
Test 2	AFT	37A	OFF	OFF
Test 3	AFT	37A	OFF	OFF
Test 4	AFT	37B	OFF	OFF
Test 5	AFT	37B	OFF	OFF
Test 6	AFT	37B	OFF	OFF
Test 7	AFT	37D	OFF	OFF
Test 8	AFT	37D	OFF	OFF
Test 9	AFT	37D	OFF	OFF
Test 10	AFT	37E	OFF	OFF
Test 11	AFT	37E	OFF	OFF
Test 12	AFT	37E	OFF	OFF
Test 13	AFT	37F	OFF	OFF
Test 14	AFT	37F	OFF	OFF
Test 15	AFT	37F	OFF	OFF
Test 16	AFT	37K	OFF	OFF
Test 17	AFT	37K	OFF	OFF
Test 18	AFT	37K	OFF	OFF
Test 19	AFT	37L	OFF	OFF
Test 20	AFT	37L	OFF	OFF
Test 21	AFT	37L	OFF	OFF
Test 22	FWD	5A	OFF	OFF
Test 23	FWD	5A	OFF	OFF
Test 24	FWD	5A	OFF	OFF
Test 26	FWD	7A	OFF	OFF
Test 27	FWD	7A	OFF	OFF
Test 28	FWD	6D	OFF	OFF
Test 29	FWD	6D	OFF	OFF
Test 30	FWD	6D	OFF	OFF
Test 31	FWD	5L	OFF	OFF
Test 32	FWD	5L	OFF	OFF
Test 33	FWD	5L	OFF	OFF
Test 34	FWD-MID	18A	OFF	OFF
Test 35	FWD-MID	18A	OFF	OFF
Test 36	FWD-MID	18A	OFF	OFF
Test 37	FWD-MID	18B	OFF	OFF
Test 38	FWD-MID	18B	OFF	OFF
Test 39	FWD-MID	18B	OFF	OFF
Test 40	FWD-MID	18D	OFF	OFF
Test 41	FWD-MID	18D	OFF	OFF
Test 42	FWD-MID	18D	OFF	OFF
Test 43	FWD-MID	18E	OFF	OFF
Test 44	FWD-MID	18E	OFF	OFF
Test 45	FWD-MID	18E	OFF	OFF
Test 46	FWD-MID	18F	OFF	OFF
Test 47	FWD-MID	18F	OFF	OFF
Test 48	FWD-MID	18F	OFF	OFF
Test 49	FWD-MID	18K	OFF	OFF
Test 50	FWD-MID	18K	OFF	OFF
Test 51	FWD-MID	18K	OFF	OFF
Test 52	FWD-MID	18L	OFF	OFF
Test 53	FWD-MID	18L	OFF	OFF
Test 54	FWD-MID	18L	OFF	OFF

8/26/2020	777 In-Flight Day 1 Testing			
Inflight Tests	Airframe Section	Row/Seat Location	Gaspers	Mannequin Mask
Test 1	47B	AFT	OFF	OFF
Test 2	47B	AFT	OFF	OFF
Test 3	47B	AFT	OFF	OFF
Test 4	47B	AFT	OFF	ON
Test 5	47B	AFT	OFF	ON
Test 6	47B	AFT	OFF	ON
Test 7	47E	AFT	OFF	OFF
Test 8	47E	AFT	OFF	OFF
Test 9	47E	AFT	OFF	OFF
Test 10	47E	AFT	OFF	ON
Test 11	47E	AFT	OFF	ON
Test 12	47E	AFT	OFF	ON
Test 13	47K	AFT	OFF	OFF
Test 14	47K	AFT	OFF	OFF
Test 15	47K	AFT	ON	OFF
Test 16	47K	AFT	ON	OFF
Test 17	47K	AFT	ON	OFF
Test 18	47K	AFT	ON	OFF
Test 19	33B	MID-AFT	OFF	OFF
Test 20	33B	MID-AFT	OFF	OFF
Test 21	33B	MID-AFT	OFF	OFF
Test 22	33B	MID-AFT	OFF	ON
Test 23	33B	MID-AFT	OFF	ON
Test 24	33B	MID-AFT	OFF	ON
Test 25	33E	MID-AFT	OFF	OFF
Test 26	33E	MID-AFT	OFF	OFF
Test 27	33E	MID-AFT	OFF	OFF
Test 28	33E	MID-AFT	OFF	ON
Test 29	33E	MID-AFT	OFF	ON
Test 30	33E	MID-AFT	OFF	ON
Test 31	33K	MID-AFT	OFF	OFF
Test 32	33K	MID-AFT	OFF	OFF
Test 33	33K	MID-AFT	OFF	OFF

8/27/2020	777 In-Flight Day 2 Testing			
Inflight Tests	Airframe Section	Row/Seat Location	Gaspers	Mannequin Mask
Test 34	FWD-MID	11A	OFF	OFF
Test 35	FWD-MID	11A	OFF	OFF
Test 36	FWD-MID	11A	OFF	OFF
Test 37	FWD-MID	11A	OFF	ON
Test 38	FWD-MID	11A	OFF	ON
Test 39	FWD-MID	11A	OFF	ON
Test 40	FWD-MID	11G	OFF	OFF
Test 41	FWD-MID	11G	OFF	OFF
Test 42	FWD-MID	11G	OFF	OFF
Test 43	FWD-MID	11G	OFF	ON
Test 44	FWD-MID	11G	OFF	ON
Test 45	FWD-MID	11G	OFF	ON
Test 46	FWD-MID	11L	OFF	OFF
Test 47	FWD-MID	11L	OFF	OFF
Test 48	FWD-MID	11L	OFF	OFF
Test 49	FWD-MID	11L	OFF	ON
Test 50	FWD-MID	11L	OFF	ON
Test 51	FWD-MID	11L	OFF	ON
Test 52	FWD	5A	OFF	OFF
Test 53	FWD	5A	OFF	OFF
Test 54	FWD	5A	OFF	OFF
Test 55	FWD	5A	OFF	ON
Test 56	FWD	5A	OFF	ON
Test 57	FWD	5A	OFF	ON
Test 59	FWD	5G	OFF	OFF
Test 60	FWD	5G	OFF	OFF
Test 61	FWD	5G	OFF	OFF
Test 62	FWD	5L	OFF	OFF
Test 63	FWD	5L	OFF	OFF
Test 64	FWD	5L	OFF	OFF

8/25/2020	777 Terminal Testing					
Inflight Tests	Airframe Section	Row/Seat Location	Conditions	Heat Blanket	Gaspers	Mannequin Mask
Test 1	MID-AFT	33E	Ground air on/Recirc off	ON	ON	OFF
Test 2	MID-AFT	33E	Ground air off / Recirc off	ON	OFF	OFF
Test 3	MID-AFT	33E	PACS on / Recirc on	ON	ON	OFF
Test 4	MID-AFT	33E	PACS on / Recirc on	OFF	ON	OFF
Test 5	MID-AFT	33E	PACS on / Recirc on	OFF	OFF	OFF
Test 6	MID-AFT	33E	PACS on / Recirc on	OFF	ON	ON
Test 7	MID-AFT	33E	PACS on / Recirc on	OFF	ON	ON
Test 8	MID-AFT	33E	PACS on / Recirc on	OFF	ON	OFF
Test 9	FWD-MID	11G	PACS on / Recirc on	OFF	OFF	OFF
Test 10	FWD-MID	11G	PACS on / Recirc on	OFF	ON	OFF
Test 11	FWD-MID	11G	PACS on / Recirc on	OFF	ON	OFF
Test 12	FWD-MID	11G	PACS on / Recirc on	OFF	ON	ON
Test 13	FWD-MID	11G	PACS on / Recirc on	OFF	ON	ON
Test 14	FWD-MID	11G	PACS on / Recirc on	OFF	ON	ON
Test 15	FWD-MID	11G	PACS on / Recirc on	OFF	ON	OFF
Test 16	FWD-MID	11G	PACS on / Recirc on	OFF	ON	OFF
Test 17	FWD-MID	11G	PACS on / Recirc on	OFF	ON	OFF
Test 18	FWD-MID	11G	PACS on / Recirc on	OFF	ON	OFF
Test 19	FWD-MID	11G	PACS on / Recirc on	OFF	ON	ON
Test 20	FWD-MID	11G	PACS on / Recirc on	OFF	ON	OFF
Test 21	FWD-MID	11G	PACS on / Recirc on	OFF	ON	ON
Test 22	FWD-MID	11G	PACS on / Recirc on	OFF	ON	OFF
Test 23	FWD-MID	11G	PACS on / Recirc on	OFF	ON	OFF
Test 24	AFT	47E	PACS on / Recirc on	OFF	OFF	OFF
Test 25	AFT	47E	PACS on / Recirc on	OFF	OFF	OFF

8/29/2020	767 Terminal Testing					
Inflight Tests	Airframe Section	Row/Seat Location	Cooling Conditions	Heat Blanket	Gaspers	Mannequin Mask
Test 1	FWD-MID	18E	Ground air ON/ Recirc ON	ON	ON	OFF
Test 2	FWD-MID	18E	Ground air ON/ Recirc ON	ON	ON	OFF
Test 3	FWD-MID	18E	Ground air ON/ Recirc ON	ON	ON	OFF
Test 4	FWD-MID	18E	Ground air ON/ Recirc ON	ON	OFF	OFF
Test 5	FWD-MID	18E	Ground air ON/ Recirc ON	ON	OFF	OFF
Test 6	FWD-MID	18E	Ground air ON/ Recirc ON	ON	OFF	OFF
Test 7	FWD-MID	18E	PACS ON / Recirc ON	ON	ON	OFF
Test 8	FWD-MID	18E	PACS ON / Recirc ON	ON	ON	OFF
Test 9	FWD-MID	18E	PACS ON / Recirc ON	ON	ON	OFF
Test 10	FWD-MID	18E	PACS ON / Recirc ON	OFF	ON	OFF
Test 11	FWD-MID	18E	PACS ON / Recirc ON	OFF	ON	OFF
Test 12	FWD-MID	18E	PACS ON / Recirc ON	OFF	ON	OFF
Test 13	FWD-MID	18E	PACS ON / Recirc ON	OFF	OFF	OFF
Test 14	FWD-MID	18E	PACS ON / Recirc ON	OFF	OFF	OFF
Test 15	FWD-MID	18E	PACS ON / Recirc ON	OFF	OFF	OFF
Test 16	FWD-MID	18E	PACS ON / Recirc ON	OFF	OFF	OFF
Test 17	FWD-MID	18E	PACS ON / Recirc ON	OFF	OFF	OFF
Test 18	FWD-MID	18E	PACS ON / Recirc ON	OFF	OFF	ON
Test 19	FWD-MID	18E	PACS ON / Recirc ON	OFF	OFF	ON
Test 20	FWD-MID	18E	PACS ON / Recirc ON	OFF	OFF	ON
Test 21	FWD	6D	PACS ON / Recirc ON	OFF	ON	OFF
Test 22	FWD	6D	PACS ON / Recirc ON	OFF	ON	OFF
Test 23	FWD	6D	PACS ON / Recirc ON	OFF	ON	OFF
Test 24	FWD	6D	PACS ON / Recirc ON	OFF	ON	OFF
Test 25	FWD	6D	PACS ON / Recirc ON	OFF	ON	ON
Test 26	FWD	6D	PACS ON / Recirc ON	OFF	ON	ON
Test 27	FWD	6D	PACS ON / Recirc ON	OFF	ON	ON
Test 28	AFT	37E	PACS ON / Recirc ON	OFF	ON	OFF
Test 29	AFT	37E	PACS ON / Recirc ON	OFF	ON	OFF
Test 30	AFT	37E	PACS ON / Recirc ON	OFF	ON	OFF
Test 31	AFT	37E	PACS ON / Recirc ON	OFF	ON	ON
Test 32	AFT	37E	PACS ON / Recirc ON	OFF	ON	ON
Test 33	AFT	37E	PACS ON / Recirc ON	OFF	ON	ON

8/30/2020	767 In-Flight Day 1 Testing				
Inflight Tests	Airframe Section	Row/Seat Location	Test Type	Gaspers	Mannequin Mask
Test 1	AFT	37B	Breathing	OFF	OFF
Test 2	AFT	37B	Breathing	OFF	OFF
Test 3	AFT	37B	Breathing	OFF	OFF
Test 4	AFT	37B	Breathing	OFF	ON
Test 5	AFT	37B	Breathing	OFF	ON
Test 6	AFT	37B	Breathing	OFF	ON
Test 7	AFT	37E	Breathing	OFF	OFF
Test 8	AFT	37E	Breathing	OFF	OFF
Test 9	AFT	37E	Breathing	OFF	OFF
Test 10	AFT	37E	Breathing	OFF	ON
Test 11	AFT	37E	Breathing	OFF	ON
Test 12	AFT	37E	Breathing	OFF	ON
Test 13	AFT	37E	Coughing	OFF	OFF
Test 14	AFT	37E	Coughing	OFF	OFF
Test 15	AFT	37E	Coughing	OFF	OFF
Test 16	AFT	37E	Coughing	OFF	ON
Test 17	AFT	37E	Coughing	OFF	ON
Test 18	AFT	37E	Coughing	OFF	ON
Test 19	AFT	37E	Coughing	OFF	OFF
Test 20	AFT	37K	Breathing	OFF	OFF
Test 21	AFT	37K	Breathing	OFF	OFF
Test 22	AFT	37K	Breathing	OFF	OFF
Test 23	AFT	37K	Breathing	OFF	ON
Test 24	AFT	37K	Breathing	OFF	ON
Test 25	AFT	37K	Breathing	OFF	ON
Test 26	AFT	37K	Coughing	OFF	OFF
Test 27	AFT	37K	Coughing	OFF	OFF
Test 28	AFT	37K	Coughing	OFF	OFF
Test 29	AFT	37K	Coughing	OFF	ON
Test 30	AFT	37K	Coughing	OFF	ON
Test 31	AFT	37K	Coughing	OFF	ON
Test 32	FWD-MID	18A	Breathing	OFF	OFF
Test 33	FWD-MID	18A	Breathing	OFF	OFF
Test 34	FWD-MID	18A	Breathing	OFF	OFF
Test 35	FWD-MID	18A	Breathing	OFF	ON
Test 36	FWD-MID	18A	Breathing	OFF	ON
Test 37	FWD-MID	18A	Breathing	OFF	ON
Test 38	FWD-MID	18A	Coughing	OFF	OFF
Test 39	FWD-MID	18A	Coughing	OFF	OFF
Test 40	FWD-MID	18A	Coughing	OFF	OFF
Test 41	FWD-MID	18A	Coughing	OFF	ON
Test 42	FWD-MID	18A	Coughing	OFF	ON
Test 43	FWD-MID	18A	Breathing	OFF	ON
Test 44	FWD-MID	18E	Breathing	OFF	OFF
Test 45	FWD-MID	18E	Breathing	OFF	OFF
Test 46	FWD-MID	18E	Breathing	OFF	OFF
Test 47	FWD-MID	18E	Breathing	OFF	ON

8/31/2020	767 In-Flight Day 2 Testing				
Inflight Tests	Airframe Section	Row/Seat Location	Test Type	Gaspers	Mannequin Mask
Test 48	FWD-MID	18E	Breathing	OFF	ON
Test 49	FWD-MID	18E	Breathing	OFF	ON
Test 50	FWD-MID	18L	Breathing	OFF	OFF
Test 51	FWD-MID	18L	Breathing	OFF	OFF
Test 52	FWD-MID	18L	Breathing	OFF	OFF
Test 53	FWD-MID	18L	Breathing	OFF	ON
Test 54	FWD-MID	18L	Breathing	OFF	ON
Test 55	FWD-MID	18L	Breathing	OFF	ON
Test 56	FWD	6A	Breathing	OFF	OFF
Test 57	FWD	6A	Breathing	OFF	OFF
Test 58	FWD	6A	Breathing	OFF	OFF
Test 59	FWD	6A	Breathing	OFF	ON
Test 60	FWD	6A	Breathing	OFF	ON
Test 61	FWD	6A	Breathing	OFF	ON
Test 62	FWD	6A	Coughing	OFF	OFF
Test 63	FWD	6A	Coughing	OFF	OFF
Test 64	FWD	6A	Coughing	OFF	OFF
Test 65	FWD	6A	Coughing	OFF	ON
Test 66	FWD	6A	Coughing	OFF	ON
Test 67	FWD	6A	Coughing	OFF	ON
Test 68	FWD	6D	Breathing	OFF	OFF
Test 69	FWD	6D	Breathing	OFF	OFF
Test 70	FWD	6D	Breathing	OFF	OFF
Test 71	FWD	6D	Breathing	OFF	ON
Test 72	FWD	6D	Breathing	OFF	ON
Test 73	FWD	6D	Breathing	OFF	ON
Test 74	FWD	6L	Breathing	OFF	OFF
Test 75	FWD	6L	Breathing	OFF	OFF
Test 76	FWD	6L	Breathing	OFF	OFF
Test 77	FWD	6L	Breathing	OFF	ON
Test 78	FWD	6L	Breathing	OFF	ON
Test 79	FWD	6L	Breathing	OFF	ON
Test 80	FWD	6L	Coughing	OFF	OFF
Test 81	FWD	6L	Coughing	OFF	ON
Test 82	FWD	6L	Coughing	OFF	OFF
Test 83	FWD	6L	Coughing	OFF	ON
Test 84	FWD	6L	Coughing	OFF	OFF
Test 85	FWD	6L	Coughing	OFF	ON

Appendix B – Airframe Breathing Zone Penetration Maps

777 Inflight – AFT Section

95% CI based on standard error (n=3)

777 - Inflight - AFT - 47B - BNM - Tests 1-3

	A	B	C	D	E	F	G	J	K	L
45	0.0003%		0.0001%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%		0.0003%
	0.0014%		0.0005%	0.0002%	0.0003%	0.0000%	0.0000%	0.0008%		0.0011%
46	0.0011%	0.0006%	0.0000%	0.0001%	0.0001%	0.0001%	0.0001%	0.0005%	0.0017%	0.0015%
	0.0025%	0.0032%	0.0019%	0.0003%	0.0004%	0.0003%	0.0001%	0.0009%	0.0029%	0.0029%
47	0.0000%	100.0000%	0.0018%	0.0015%	0.0006%	0.0001%	0.0001%	0.0011%		0.0029%
	0.0545%		0.0523%	0.0047%	0.0055%	0.0042%	0.0013%	0.0037%		0.0069%
48	0.0092%	0.0104%	0.0067%	0.0062%	0.0077%	0.0073%	0.0030%	0.0039%	0.0051%	0.0063%
	0.0171%	0.0133%	0.0213%	0.0165%	0.0316%	0.0138%	0.0141%	0.0092%	0.0080%	0.0100%
49	0.0086%		0.0117%		0.0150%	0.0056%		0.0058%		0.0068%
	0.0142%		0.0179%		0.0169%	0.0136%		0.0138%		0.0106%

777 - Inflight - AFT - 47B - BM - Tests 4-6

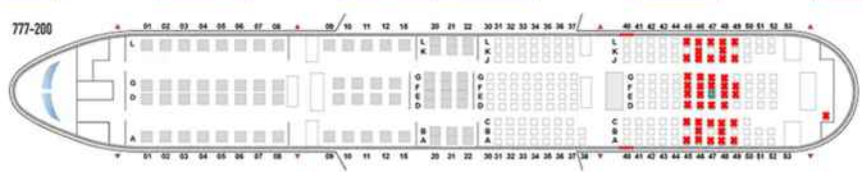
	A	B	C	D	E	F	G	J	K	L
45	0.0003%		0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%		0.0000%
	0.0005%		0.0004%	0.0000%	0.0000%	0.0000%	0.0000%	0.0006%		0.0014%
46	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
	0.0016%	0.0021%	0.0015%	0.0003%	0.0007%	0.0005%	0.0003%	0.0009%	0.0030%	0.0026%
47	0.0017%	100.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%		0.0008%
	0.0079%		0.0393%	0.0000%	0.0056%	0.0041%	0.0028%	0.0047%		0.0040%
48	0.0020%	0.0024%	0.0026%	0.0038%	0.0074%	0.0098%	0.0063%	0.0031%	0.0045%	0.0010%
	0.0129%	0.0113%	0.0126%	0.0095%	0.0154%	0.0140%	0.0130%	0.0070%	0.0054%	0.0131%
49	0.0061%		0.0085%		0.0105%	0.0052%		0.0098%		0.0058%
	0.0089%		0.0108%		0.0128%	0.0110%		0.0109%		0.0091%

777 - Inflight - AFT - 47E - BNM - Tests 7-9

	A	B	C	D	E	F	G	J	K	L
45	0.0005%		0.0003%	0.0000%	0.0001%	0.0000%	0.0000%	0.0001%		0.0001%
	0.0005%		0.0019%	0.0000%	0.0003%	0.0000%	0.0000%	0.0004%		0.0006%
46	0.0011%	0.0025%	0.0066%	0.0008%	0.0000%	0.0000%	0.0003%	0.0000%	0.0000%	0.0007%
	0.0067%	0.0073%	0.0121%	0.0016%	0.0039%	0.0023%	0.0007%	0.0010%	0.0000%	0.0017%
47	0.0030%		0.0082%	0.0379%	100.0000%	0.0017%	0.0019%	0.0000%		0.0000%
	0.0103%		0.0132%	0.0590%		0.0102%	0.0031%	0.0026%		0.0033%
48	0.0036%	0.0013%	0.0091%	0.0088%	0.0104%	0.0064%	0.0048%	0.0007%	0.0000%	0.0006%
	0.0114%	0.0138%	0.0207%	0.0127%	0.0162%	0.0114%	0.0085%	0.0065%	0.0000%	0.0068%
49	0.0054%		0.0069%		0.0072%	0.0052%		0.0027%		0.0015%
	0.0083%		0.0106%		0.0101%	0.0083%		0.0074%		0.0060%

777 - Inflight - AFT - 47E - BNM - Tests 10-12

	A	B	C	D	E	F	G	J	K	L
45	0.0001%		0.0001%			0.0000%	0.0000%	0.0000%		0.0000%
	0.0004%		0.0003%			0.0000%	0.0000%	0.0000%		0.0004%
46	0.0002%	0.0001%	0.0009%	0.0000%	0.0000%	0.0001%	0.0000%	0.0001%	0.0001%	0.0003%
	0.0008%	0.0012%	0.0015%	0.0004%	0.0004%	0.0002%	0.0002%	0.0002%	0.0004%	0.0004%
47	0.0014%		0.0024%	0.0187%	100.0000%	0.0009%	0.0003%	0.0001%		0.0002%
	0.0044%		0.0042%	0.0543%		0.0013%	0.0011%	0.0004%		0.0005%
48	0.0045%	0.0044%	0.0052%	0.0087%	0.0069%	0.0041%	0.0026%	0.0008%	0.0009%	0.0008%
	0.0065%	0.0059%	0.0119%	0.0114%	0.0169%	0.0098%	0.0066%	0.0023%	0.0017%	0.0019%
49	0.0056%		0.0070%		0.0077%	0.0035%		0.0029%		0.0020%
	0.0075%		0.0117%		0.0102%	0.0060%		0.0049%		0.0029%



777 Inflight – MID-AFT Section

95% CI based on standard error (n=3)

777 - Inflight MID-AFT - 33B - BNM Tests 19-21

	A	B	C	D	E	F	G	J	K	L
31	0.0000%	0.0000%				0.0000%		0.0000%	0.0001%	0.0000%
	0.0000%	0.0000%				0.0000%		0.0004%	0.0004%	0.0005%
32	0.0000%		0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0001%		0.0001%
	0.0011%		0.0006%	0.0003%	0.0004%	0.0003%	0.0003%	0.0004%		0.0007%
33	0.0733%	100.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0001%	0.0002%	0.0001%
	0.2667%		0.0214%	0.0093%	0.0009%	0.0008%	0.0006%	0.0007%	0.0012%	0.0014%
34	0.0178%			0.0000%	0.0000%	0.0000%	0.0000%	0.0000%		0.0003%
	0.0334%			0.0029%	0.0035%	0.0036%	0.0024%	0.0012%		0.0016%
35	0.0072%	0.0018%	0.0001%	0.0000%	0.0001%		0.0008%	0.0001%	0.0005%	0.0002%
	0.0084%	0.0089%	0.0050%	0.0053%	0.0052%		0.0025%	0.0028%	0.0022%	0.0025%

777 - Inflight MID-AFT - 33B - BM Tests 22-24

	A	B	C	D	E	F	G	J	K	L
31	0.0000%	0.0001%				0.0000%		0.0001%	0.0000%	0.0000%
	0.0000%	0.0002%				0.0002%		0.0008%	0.0010%	0.0010%
32	0.0001%		0.0003%	0.0002%	0.0002%	0.0002%	0.0002%	0.0002%		0.0003%
	0.0004%		0.0006%	0.0002%	0.0002%	0.0003%	0.0003%	0.0008%		0.0012%
33	0.0000%	100.0000%	0.0005%	0.0000%	0.0009%	0.0005%	0.0005%	0.0006%	0.0009%	0.0009%
	0.0730%		0.0029%	0.0018%	0.0010%	0.0011%	0.0008%	0.0016%	0.0021%	0.0020%
34	0.0041%			0.0012%	0.0014%	0.0008%	0.0013%	0.0010%		0.0015%
	0.0308%			0.0045%	0.0043%	0.0062%	0.0050%	0.0026%		0.0025%
35	0.0053%	0.0049%	0.0046%	0.0049%	0.0051%		0.0031%	0.0023%	0.0022%	0.0015%
	0.0104%	0.0053%	0.0067%	0.0072%	0.0068%		0.0046%	0.0051%	0.0038%	0.0037%

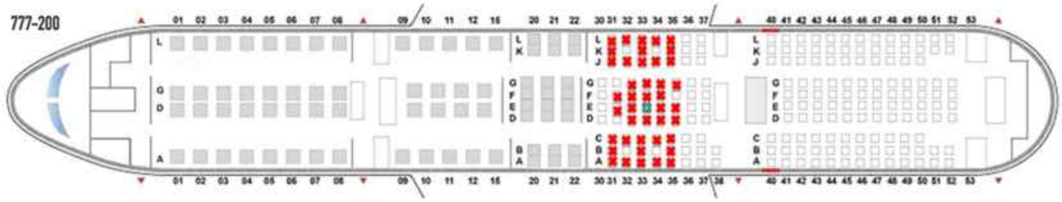
777 - Inflight MID-AFT - 33E - BNM Tests 25-28

	A	B	C	D	E	F	G	J	K	L
31	0.0000%	0.0000%				0.0002%		0.0003%	0.0000%	0.0002%
	0.0000%	0.0004%				0.0006%		0.0015%	0.0013%	0.0021%
32	0.0001%		0.0011%	0.0005%	0.0002%	0.0006%	0.0006%	0.0012%		0.0016%
	0.0011%		0.0045%	0.0026%	0.0037%	0.0031%	0.0024%	0.0033%		0.0036%
33	0.0000%		0.0000%	0.0005%	100.0000%	0.0054%	0.0040%	0.0045%	0.0043%	0.0044%
	0.0134%		0.0695%	0.0029%		0.0124%	0.0074%	0.0079%	0.0062%	0.0065%
34	0.0024%			0.0132%	0.0134%	0.0135%	0.0095%	0.0059%		0.0043%
	0.0201%			0.0273%	0.0218%	0.0174%	0.0117%	0.0079%		0.0082%
35	0.0067%	0.0057%	0.0082%	0.0111%	0.0116%		0.0082%	0.0079%	0.0057%	0.0046%
	0.0134%	0.0119%	0.0142%	0.0169%	0.0131%		0.0106%	0.0107%	0.0076%	0.0078%

33B, 33E Releases

% Cumulative Tracer Particles
- 0-0.01%
- 0.01-1%
- >1%

BNM: Breathing/No Mask
BM: Breathing/Mask On
CNM: Cough/No Mask
CM: Cough/Mask On



777 Inflight – FWD-MID Section

95% CI based on standard error (n=3)

777 - INFLIGHT FWD-MID - 11A - BNM Tests 34-36

	A	B	D	E	F	G	K	L
9	0.0000%		0.0000%			0.0000%		0.0000%
	0.0018%		0.0033%			0.0011%		0.0011%
10	0.0000%		0.0000%			0.0000%		0.0000%
	0.0032%		0.0033%			0.0018%		0.0017%
11	100.0000%		0.0000%			0.0000%		0.0000%
			0.0030%			0.0017%		0.0017%
12	0.0000%					0.0000%		
	0.0411%					0.0007%		
15	0.0000%							
	0.0291%							
20	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
	0.0023%	0.0021%	0.0004%	0.0003%	0.0004%	0.0003%	0.0005%	0.0005%
21	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%		0.0000%
	0.0017%	0.0018%	0.0004%	0.0004%	0.0003%	0.0004%		0.0004%
22	0.0000%		0.0000%	0.0000%	0.0000%	0.0000%		0.0000%
	0.0013%		0.0004%	0.0004%	0.0004%	0.0003%		0.0003%

777 - INFLIGHT FWD-MID - 11A - BM Tests 37-39

	A	B	D	E	F	G	K	L
9	0.0002%		0.0000%			0.0000%		0.0000%
	0.0005%		0.0003%			0.0000%		0.0000%
10	0.0001%		0.0000%			0.0000%		0.0000%
	0.0025%		0.0005%			0.0000%		0.0000%
11	100.0000%		0.0000%			0.0000%		0.0000%
			0.0000%			0.0000%		0.0000%
12	0.0000%					0.0000%		
	0.0004%					0.0002%		
15	0.0000%							
	0.0000%							
20	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
21	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%		0.0000%
	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%		0.0000%
22	0.0000%		0.0000%	0.0000%	0.0000%	0.0000%		0.0000%
	0.0000%		0.0000%	0.0000%	0.0000%	0.0000%		0.0000%

777 - INFLIGHT FWD-MID - 11G - BNM Test 40-42

	A	B	D	E	F	G	K	L
9	0.0007%		0.0022%			0.0000%		0.0000%
	0.0048%		0.0103%			0.0272%		0.0070%
10	0.0013%		0.0064%			0.0071%		0.0006%
	0.0087%		0.0096%			0.0220%		0.0097%
11	0.0050%		0.0018%			100.0000%		0.0098%
	0.0071%		0.0162%					0.0188%
12	0.0039%					0.0002%		0.0159%
	0.0099%					0.0111%		0.0161%
15	0.0023%							0.0016%
	0.0045%							0.0176%
20	0.0005%	0.0000%	0.0006%	0.0004%	0.0003%	0.0003%	0.0000%	0.0003%
	0.0012%	0.0011%	0.0007%	0.0006%	0.0007%	0.0008%	0.0045%	0.0040%
21	0.0000%	0.0002%	0.0003%	0.0000%	0.0000%	0.0001%		0.0005%
	0.0016%	0.0010%	0.0008%	0.0009%	0.0011%	0.0016%		0.0034%
22	0.0001%		0.0000%	0.0001%	0.0001%	0.0000%		0.0004%
	0.0009%		0.0007%	0.0009%	0.0011%	0.0009%		0.0021%

777 - INFLIGHT FWD-MID - 11G - BM Tests 43-45

	A	B	D	E	F	G	K	L
9	0.0016%		0.0006%			0.0011%		0.0002%
	0.0019%		0.0017%			0.0068%		0.0181%
10	0.0000%		0.0007%			0.0012%		0.0154%
	0.0048%		0.0038%			0.0197%		0.0219%
11	0.0016%		0.0033%			100.0000%		0.0053%
	0.0031%		0.0044%					0.0123%
12	0.0015%					0.0048%		0.0041%
	0.0031%					0.0094%		0.0058%
15	0.0004%							0.0021%
	0.0031%							0.0059%
20	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0002%	0.0000%
	0.0023%	0.0015%	0.0020%	0.0017%	0.0018%	0.0017%	0.0014%	0.0030%
21	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%		0.0000%
	0.0019%	0.0010%	0.0009%	0.0008%	0.0007%	0.0018%		0.0022%
22	0.0000%		0.0000%	0.0000%	0.0000%	0.0000%		0.0000%
	0.0009%		0.0005%	0.0007%	0.0009%	0.0006%		0.0012%

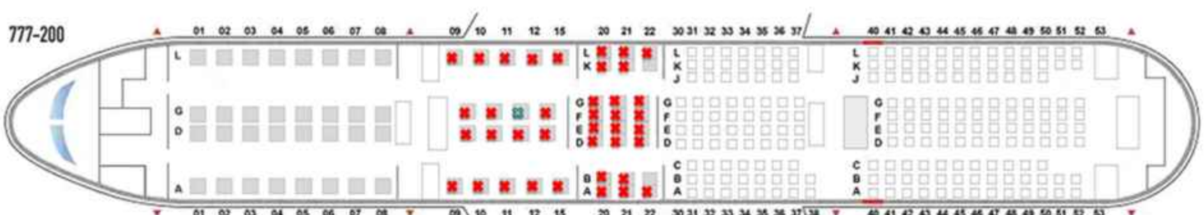
11A, 11G, 11L Releases

777 - INFLIGHT FWD-MID - 11L - BNM Tests 46-48

	A	B	D	E	F	G	K	L
9	0.0000%		0.0000%			0.0000%		0.0000%
	0.0000%		0.0000%			0.0000%		0.0000%
10	0.0000%		0.0000%			0.0000%		0.0000%
	0.0000%		0.0000%			0.0000%		0.0000%
11	0.0000%		0.0000%					100.0000%
	0.0000%		0.0090%					
12	0.0000%					0.0000%		0.0000%
	0.0000%					0.0000%		0.0000%
15	0.0000%							0.0000%
	0.0000%							0.0003%
20	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
21	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%		0.0000%
	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%		0.0000%
22	0.0000%		0.0000%	0.0000%	0.0000%	0.0000%		0.0000%
	0.0000%		0.0000%	0.0000%	0.0000%	0.0000%		0.0000%

% Cumulative Tracer Particles
- 0-0.01%
- 0.01-1%
- >1%

BNM: Breathing/No Mask
BM: Breathing/Mask On
CNM: Cough/No Mask
CM: Cough/Mask On



777 Inflight – FWD Section

95% CI based on standard error (n=3)

777 - Inflight FWD - 5A - BNM Tests 52-54

	A	D	G	L
1	0.0000%	0.0000%	0.0001%	0.0000%
	0.0000%	0.0000%	0.0002%	0.0004%
2	0.0002%	0.0002%	0.0001%	0.0000%
	0.0002%	0.0003%	0.0002%	0.0002%
3	0.0001%	0.0003%	0.0001%	0.0000%
	0.0006%	0.0005%	0.0004%	0.0000%
4	0.0003%		0.0001%	0.0000%
	0.0007%		0.0003%	0.0000%
5	100.0000%	0.0004%		
		0.0006%		
6	0.0001%	0.0004%	0.0001%	0.0001%
	0.0041%	0.0007%	0.0003%	0.0002%
7		0.0001%	0.0001%	0.0000%
		0.0005%	0.0004%	0.0000%
8	0.0002%	0.0001%	0.0000%	0.0000%
	0.0006%	0.0002%	0.0003%	0.0000%
9	0.0000%	0.0000%	0.0000%	0.0000%
	0.0000%	0.0000%	0.0000%	0.0000%
10	0.0000%	0.0000%	0.0000%	0.0000%
	0.0002%	0.0000%	0.0000%	0.0000%

777 - Inflight FWD - 5A - BM Tests 55-57

	A	D	G	L
1	0.0000%	0.0000%	0.0000%	0.0000%
	0.0000%	0.0000%	0.0002%	0.0001%
2	0.0000%	0.0000%	0.0000%	0.0000%
	0.0001%	0.0003%	0.0002%	0.0003%
3	0.0000%	0.0000%	0.0000%	0.0000%
	0.0005%	0.0006%	0.0004%	0.0004%
4	0.0000%		0.0000%	0.0000%
	0.0010%		0.0002%	0.0000%
5	100.0000%	0.0000%		
		0.0006%		
6	0.0000%	0.0000%	0.0000%	0.0000%
	0.0009%	0.0002%	0.0003%	0.0003%
7		0.0000%	0.0000%	0.0000%
		0.0003%	0.0003%	0.0002%
8	0.0000%	0.0000%	0.0000%	0.0000%
	0.0012%	0.0002%	0.0000%	0.0000%
9	0.0000%	0.0000%	0.0000%	0.0000%
	0.0000%	0.0000%	0.0000%	0.0000%
10	0.0000%	0.0000%	0.0000%	0.0000%
	0.0000%	0.0000%	0.0000%	0.0000%

777 - Inflight FWD - 5G - BNM Tests 59-61

	A	D	G	L
1	0.0006%	0.0000%	0.0005%	0.0006%
	0.0043%	0.0045%	0.0059%	0.0074%
2	0.0001%	0.0005%	0.0009%	0.0011%
	0.0070%	0.0092%	0.0150%	0.0139%
3	0.0003%	0.0003%	0.0025%	0.0023%
	0.0081%	0.0000%	0.0281%	0.0285%
4	0.0008%		0.0036%	0.0075%
	0.0088%		0.0035%	0.0072%
5		0.0015%	100.0000%	
		0.0056%		
6	0.0001%	0.0005%	0.0006%	0.0017%
	0.0018%	0.0018%	0.0038%	0.0003%
7		0.0007%	0.0010%	0.0021%
		0.0004%	0.0009%	0.0007%
8	0.0002%	0.0002%	0.0004%	0.0004%
	0.0000%	0.0000%	0.0000%	0.0001%
9	0.0000%	0.0000%	0.0000%	0.0000%
	0.0000%	0.0000%	0.0000%	0.0000%
10	0.0000%	0.0000%	0.0000%	0.0000%
	0.0000%	0.0000%	0.0000%	0.0000%

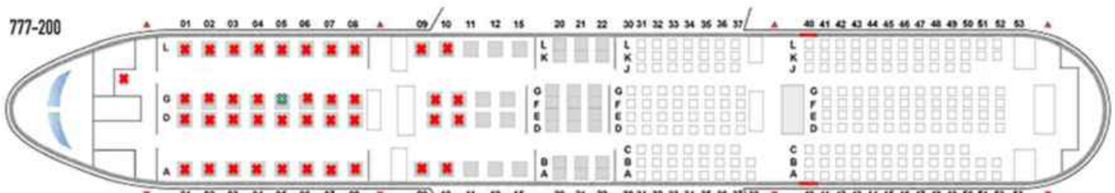
777 - Inflight FWD - 5L - BNM Tests 62-63

	A	D	G	L
1	0.0009%	0.0013%	0.0000%	0.0000%
	0.0065%	0.0051%	0.0072%	0.0105%
2	0.0035%	0.0025%	0.0000%	0.0000%
	0.0077%	0.0096%	0.0230%	0.0158%
3	0.0033%	0.0039%	0.0078%	0.0000%
	0.0069%	0.0000%	0.0234%	0.0283%
4	0.0028%		0.0124%	0.0000%
	0.0050%		0.0024%	0.0055%
5		0.0000%		100.0000%
		0.0025%		
6	0.0004%	0.0008%	0.0018%	0.0008%
	0.0009%	0.0007%	0.0028%	0.0001%
7		0.0001%	0.0000%	0.0000%
		0.0001%	0.0004%	0.0007%
8	0.0000%	0.0000%	0.0000%	0.0000%
	0.0000%	0.0000%	0.0000%	0.0000%
9	0.0000%	0.0000%	0.0000%	0.0000%
	0.0000%	0.0000%	0.0000%	0.0000%
10	0.0000%	0.0000%	0.0000%	0.0000%
	0.0000%	0.0000%	0.0000%	0.0000%

5A, 5G, 5L Releases

% Cumulative Tracer Particles
- 0-0.01%
- 0.01-1%
- >1%

BNM: Breathing/No Mask
BM: Breathing/Mask On
CNM: Cough/No Mask
CM: Cough/Mask On



777 Terminal FWD-MID Section

95% CI based on standard error (n=3)

777 - TERMINAL FWD-MID - 11G - BNM Tests 9-11

	A	B	D	E	F	G	K	L
9	0.0016%		0.0031%			0.0000%		0.0053%
	0.0028%		0.0033%			0.0153%		0.0085%
10	0.0009%		0.0046%			0.0060%		0.0023%
	0.0024%		0.0076%			0.0083%		0.0032%
11			0.0000%			100.0000%		
			0.0175%					
12	0.0000%		0.0013%			0.0000%		0.0000%
	0.0005%		0.0025%			0.0023%		0.0000%
15	0.0000%							0.0000%
	0.0000%							0.0000%
20	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
21	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
22	0.0000%		0.0000%	0.0000%	0.0000%	0.0000%		0.0000%
	0.0000%		0.0000%	0.0000%	0.0000%	0.0000%		0.0000%

777 - TERMINAL FWD-MID - 11G - BM Tests 12-14

	A	B	D	E	F	G	K	L
9	0.0019%		0.0018%			0.0028%		0.0049%
	0.0025%		0.0029%			0.0042%		0.0058%
10	0.0019%		0.0023%			0.0042%		0.0019%
	0.0021%		0.0060%			0.0092%		0.0025%
11			0.0002%			100.0000%		
			0.0096%					
12	0.0002%		0.0013%			0.0000%		0.0000%
	0.0006%		0.0022%			0.0018%		0.0000%
15	0.0000%							0.0000%
	0.0000%							0.0000%
20	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
21	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
22	0.0000%		0.0000%	0.0000%	0.0000%	0.0000%		0.0000%
	0.0000%		0.0000%	0.0000%	0.0000%	0.0000%		0.0000%

777 - TERMINAL FWD-MID - 11G - BNM Tests 15-17

	A	B	D	E	F	G	K	L
9	0.0011%		0.0014%			0.0033%		0.0059%
	0.0023%		0.0023%			0.0039%		0.0107%
10	0.0006%		0.0020%			0.0054%		0.0026%
	0.0019%		0.0046%			0.0094%		0.0035%
11			0.0012%			100.0000%		
			0.0020%					
12	0.0002%		0.0012%			0.0002%		0.0000%
	0.0005%		0.0022%			0.0003%		0.0000%
15	0.0000%							0.0000%
	0.0000%							0.0000%
20	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
21	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
22	0.0000%		0.0000%	0.0000%	0.0000%	0.0000%		0.0000%
	0.0000%		0.0000%	0.0000%	0.0000%	0.0000%		0.0000%

777 - TERMINAL FWD-MID - 11G - BM Tests 18-20

	A	B	D	E	F	G	K	L
9	0.0006%		0.0013%			0.0019%		0.0026%
	0.0012%		0.0015%			0.0025%		0.0053%
10	0.0002%		0.0013%			0.0050%		0.0007%
	0.0009%		0.0041%			0.0065%		0.0007%
11			0.0017%			100.0000%		
			0.0035%					
12	0.0000%		0.0007%			0.0001%		0.0000%
	0.0001%		0.0013%			0.0006%		0.0000%
15	0.0000%							0.0000%
	0.0000%							0.0000%
20	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
21	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
22	0.0000%		0.0000%	0.0000%	0.0000%	0.0000%		0.0000%
	0.0000%		0.0000%	0.0000%	0.0000%	0.0000%		0.0000%

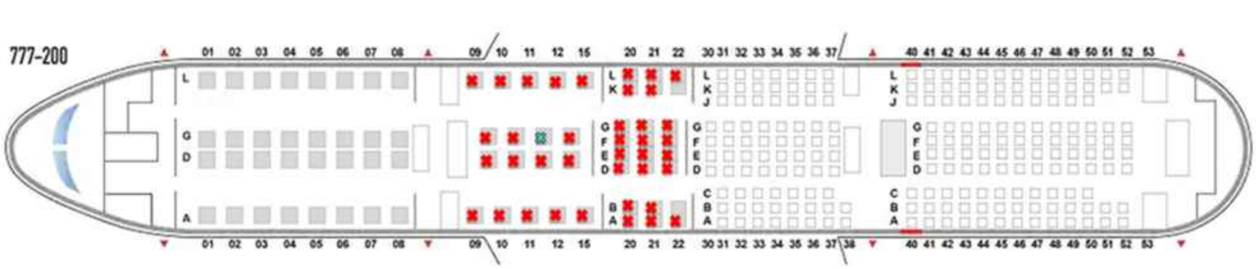
777 - TERMINAL FWD-MID - 11G - BNM Tests 21-23

	A	B	D	E	F	G	K	L
9	0.0000%		0.0000%			0.0000%		0.0000%
	0.0000%		0.0041%			0.0051%		0.0097%
10	0.0002%		0.0000%			0.0000%		0.0003%
	0.0011%		0.0036%			0.0153%		0.0033%
11			0.0000%			100.0000%		
			0.0078%					
12	0.0000%		0.0000%			0.0003%		0.0000%
	0.0002%		0.0007%			0.0004%		0.0000%
15	0.0000%							0.0000%
	0.0000%							0.0000%
20	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
21	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
22	0.0000%		0.0000%	0.0000%	0.0000%	0.0000%		0.0000%
	0.0000%		0.0000%	0.0000%	0.0000%	0.0000%		0.0000%

11G Releases

% Cumulative Tracer Particles
- 0-0.01%
- 0.01-1%
- >1%

BNM: Breathing/No Mask
BM: Breathing/Mask On
CNM: Cough/No Mask
CM: Cough/Mask On



767 Inflight – AFT Section

95% CI based on standard error (n=3)

767 - Inflight AFT - 37B - BNM Tests 1-3

	A	B	D	E	F	K	L
34			0.0001%		0.0001%		
			0.0003%		0.0002%		
35	0.0000%	0.0000%	0.0004%	0.0003%	0.0001%		0.0002%
	0.0002%	0.0000%	0.0011%	0.0006%	0.0005%		0.0005%
36	0.0002%	0.0002%	0.0043%	0.0004%	0.0003%	0.0001%	0.0002%
	0.0005%	0.0004%	0.0060%	0.0017%	0.0008%	0.0007%	0.0006%
37	0.0013%	100.0000%	0.0017%		0.0007%	0.0003%	0.0003%
	0.0015%		0.0023%		0.0012%	0.0010%	0.0010%
38	0.0021%	0.0020%	0.0016%	0.0009%	0.0006%	0.0006%	0.0005%
	0.0026%	0.0025%	0.0019%	0.0018%	0.0011%	0.0011%	0.0014%
39	0.0013%		0.0013%	0.0008%			0.0008%
	0.0019%		0.0015%	0.0012%			0.0012%
40	0.0007%	0.0007%	0.0007%		0.0008%	0.0008%	0.0006%
	0.0011%	0.0008%	0.0008%		0.0011%	0.0012%	0.0009%
41	0.0005%						0.0007%
	0.0009%						0.0010%

767 - Inflight AFT - 37B - BM Tests 4-6

	A	B	D	E	F	K	L
34			0.0001%		0.0000%		
			0.0002%		0.0003%		
35	0.0000%	0.0000%	0.0004%	0.0002%	0.0001%		0.0000%
	0.0002%	0.0000%	0.0007%	0.0003%	0.0002%		0.0000%
36	0.0002%	0.0001%	0.0014%	0.0004%	0.0002%	0.0001%	0.0002%
	0.0003%	0.0003%	0.0024%	0.0005%	0.0003%	0.0002%	0.0003%
37	0.0005%	100.0000%	0.0018%		0.0005%	0.0002%	0.0002%
	0.0005%		0.0020%		0.0007%	0.0004%	0.0004%
38	0.0020%	0.0017%	0.0015%	0.0007%	0.0005%	0.0004%	0.0003%
	0.0033%	0.0034%	0.0022%	0.0014%	0.0008%	0.0006%	0.0009%
39	0.0012%		0.0013%	0.0008%			0.0006%
	0.0021%		0.0025%	0.0014%			0.0011%
40	0.0007%	0.0005%	0.0006%		0.0007%	0.0006%	0.0005%
	0.0012%	0.0010%	0.0010%		0.0013%	0.0009%	0.0009%
41	0.0006%						0.0006%
	0.0008%						0.0010%

767 - Inflight AFT - 37E - BNM Tests 7-9

	A	B	D	E	F	K	L
34			0.0000%		0.0001%		
			0.0005%		0.0002%		
35	0.0000%	0.0000%	0.0005%	0.0003%	0.0001%		0.0000%
	0.0000%	0.0000%	0.0010%	0.0008%	0.0005%		0.0000%
36	0.0002%	0.0002%	0.0025%	0.0007%	0.0005%	0.0002%	0.0002%
	0.0004%	0.0004%	0.0042%	0.0025%	0.0015%	0.0006%	0.0006%
37	0.0008%	0.0005%	0.0060%	100.0000%	0.0027%	0.0005%	0.0005%
	0.0016%	0.0011%	0.0078%		0.0073%	0.0015%	0.0016%
38	0.0026%	0.0038%	0.0096%	0.0062%	0.0045%	0.0033%	0.0029%
	0.0075%	0.0075%	0.0134%	0.0108%	0.0110%	0.0054%	0.0057%
39	0.0120%		0.0084%	0.0077%			0.0063%
	0.0143%		0.0135%	0.0097%			0.0120%
40	0.0058%	0.0055%	0.0054%		0.0064%	0.0057%	0.0052%
	0.0083%	0.0066%	0.0071%		0.0084%	0.0092%	0.0074%
41	0.0048%						0.0054%
	0.0057%						0.0075%

767 - Inflight AFT - 37E - BM Tests 10-12

	A	B	D	E	F	K	L
34			0.0001%		0.0000%		
			0.0003%		0.0002%		
35	0.0000%	0.0000%	0.0002%	0.0002%	0.0001%		0.0000%
	0.0000%	0.0000%	0.0011%	0.0005%	0.0003%		0.0000%
36	0.0001%	0.0001%	0.0021%	0.0007%	0.0003%	0.0001%	0.0001%
	0.0004%	0.0004%	0.0031%	0.0011%	0.0009%	0.0005%	0.0004%
37	0.0005%	0.0003%	0.0042%	100.0000%	0.0032%	0.0003%	0.0004%
	0.0010%	0.0008%	0.0057%		0.0045%	0.0010%	0.0011%
38	0.0018%	0.0015%	0.0063%	0.0063%	0.0048%	0.0025%	0.0024%
	0.0044%	0.0057%	0.0098%	0.0069%	0.0078%	0.0051%	0.0045%
39	0.0086%		0.0064%	0.0065%			0.0070%
	0.0110%		0.0102%	0.0070%			0.0083%
40	0.0051%	0.0044%	0.0046%		0.0057%	0.0056%	0.0048%
	0.0056%	0.0052%	0.0052%		0.0067%	0.0068%	0.0054%
41	0.0042%						0.0047%
	0.0043%						0.0055%

767 - Inflight AFT - 37E - CNM Tests 13-15,19

	A	B	D	E	F	K	L
34			0.0001%		0.0000%		
			0.0007%		0.0005%		
35	0.0001%	0.0000%	0.0007%	0.0003%	0.0002%		0.0000%
	0.0003%	0.0002%	0.0016%	0.0018%	0.0015%		0.0003%
36	0.0002%	0.0002%	0.0025%	0.0013%	0.0008%	0.0003%	0.0002%
	0.0008%	0.0008%	0.0040%	0.0039%	0.0050%	0.0020%	0.0018%
37	0.0012%	0.0006%	0.0041%	100.0000%	0.0061%	0.0006%	0.0013%
	0.0020%	0.0015%	0.0060%		0.0113%	0.0061%	0.0063%
38	0.0041%	0.0037%	0.0050%	0.0076%	0.0080%	0.0066%	0.0080%
	0.0054%	0.0051%	0.0076%	0.0104%	0.0106%	0.0121%	0.0158%
39	0.0053%		0.0048%	0.0059%			0.0079%
	0.0080%		0.0072%	0.0066%			0.0117%
40	0.0046%	0.0044%	0.0039%		0.0057%	0.0058%	0.0046%
	0.0052%	0.0045%	0.0047%		0.0071%	0.0096%	0.0070%
41	0.0039%						0.0046%
	0.0042%						0.0064%

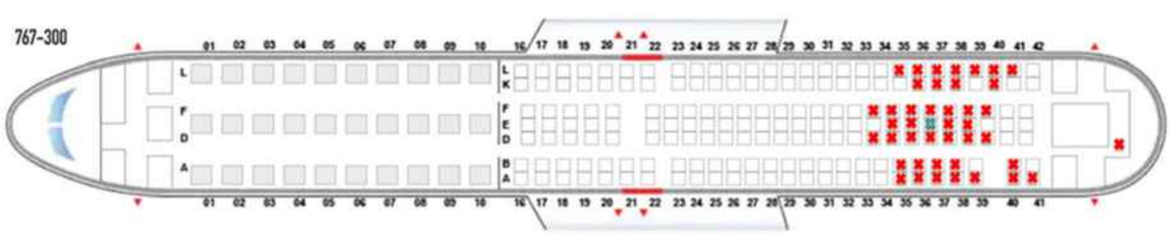
767 - Inflight AFT - 37E - CM Tests 16-18

	A	B	D	E	F	K	L
34			0.0000%		0.0000%		
			0.0000%		0.0000%		
35	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%		0.0000%
	0.0000%	0.0000%	0.0002%	0.0000%	0.0000%		0.0000%
36	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
	0.0000%	0.0000%	0.0005%	0.0003%	0.0003%	0.0000%	0.0000%
37	0.0000%	0.0000%	0.0003%	100.0000%	0.0002%	0.0000%	0.0000%
	0.0003%	0.0002%	0.0010%		0.0005%	0.0003%	0.0000%
38	0.0003%	0.0003%	0.0007%	0.0003%	0.0002%	0.0000%	0.0000%
	0.0006%	0.0007%	0.0015%	0.0014%	0.0014%	0.0011%	0.0011%
39	0.0010%		0.0006%	0.0007%			0.0004%
	0.0015%		0.0014%	0.0011%			0.0016%
40	0.0006%	0.0005%	0.0006%		0.0006%	0.0006%	0.0004%
	0.0009%	0.0009%	0.0008%		0.0010%	0.0010%	0.0009%
41	0.0006%						0.0006%
	0.0007%						0.0008%

37B & 37E Releases

% Cumulative Tracer Particles
- 0-0.01%
- 0.01-1%
- >1%

BNM: Breathing/No Mask
BM: Breathing/Mask On
CNM: Cough/No Mask
CM: Cough/Mask On



767 Inflight – FWD-MID Section

95% CI based on standard error (n=3)

767 - Inflight FWD-MID - 18A - BNM Tests 62-64

	A	B	D	E	F	K	L
10	0.0046%				0.0042%		0.0039%
	0.0078%				0.0064%		0.0044%
16	0.0078%	0.0080%	0.0010%	0.0025%	0.0019%	0.0036%	0.0032%
	0.0110%	0.0113%	0.0174%	0.0057%	0.0049%	0.0040%	0.0041%
17	0.0064%	0.0050%	0.0000%	0.0018%	0.0019%		0.0019%
	0.0137%	0.0181%	0.0120%	0.0025%	0.0024%		0.0028%
18	100.0000%	0.0057%	0.0009%	0.0010%	0.0005%		
		0.0103%	0.0015%	0.0013%	0.0006%		
19	0.0010%	0.0011%	0.0006%	0.0005%	0.0005%	0.0003%	0.0004%
	0.0014%	0.0013%	0.0007%	0.0007%	0.0007%	0.0005%	0.0006%
20		0.0003%	0.0002%	0.0001%	0.0001%	0.0002%	0.0003%
		0.0004%	0.0002%	0.0003%	0.0002%	0.0003%	0.0004%
21	0.0002%	0.0000%				0.0001%	0.0001%
	0.0002%	0.0003%				0.0002%	0.0002%

767 - Inflight FWD-MID - 18A - BM Tests 65-67

	A	B	D	E	F	K	L
10	0.0037%				0.0028%		0.0020%
	0.0052%				0.0053%		0.0035%
16	0.0069%	0.0071%	0.0045%	0.0027%	0.0017%	0.0020%	0.0017%
	0.0088%	0.0087%	0.0048%	0.0029%	0.0039%	0.0031%	0.0029%
17	0.0089%	0.0095%	0.0014%	0.0009%	0.0011%		0.0013%
	0.0116%	0.0126%	0.0041%	0.0019%	0.0018%		0.0018%
18	100.0000%	0.0088%	0.0010%	0.0008%	0.0003%		
		0.0138%	0.0015%	0.0011%	0.0006%		
19	0.0010%	0.0011%	0.0007%	0.0005%	0.0006%	0.0002%	0.0003%
	0.0015%	0.0016%	0.0009%	0.0007%	0.0007%	0.0004%	0.0005%
20		0.0003%	0.0002%	0.0002%	0.0001%	0.0001%	0.0002%
		0.0004%	0.0002%	0.0003%	0.0002%	0.0003%	0.0004%
21	0.0001%	0.0001%				0.0001%	0.0000%
	0.0003%	0.0001%				0.0002%	0.0003%

767 - Inflight FWD-MID - 18A - CNM Tests 68-70

	A	B	D	E	F	K	L
10	0.0042%				0.0036%		0.0029%
	0.0070%				0.0058%		0.0043%
16	0.0078%	0.0081%	0.0000%	0.0016%	0.0009%	0.0024%	0.0022%
	0.0130%	0.0129%	0.0143%	0.0055%	0.0068%	0.0043%	0.0040%
17	0.0102%	0.0116%	0.0011%	0.0011%	0.0015%		0.0017%
	0.0200%	0.0292%	0.0040%	0.0021%	0.0020%		0.0022%
18	100.0000%	0.0035%	0.0005%	0.0005%	0.0002%		
		0.0079%	0.0011%	0.0011%	0.0005%		
19	0.0003%	0.0003%	0.0001%	0.0002%	0.0002%	0.0001%	0.0002%
	0.0013%	0.0014%	0.0008%	0.0006%	0.0006%	0.0004%	0.0004%
20		0.0002%	0.0001%	0.0001%	0.0000%	0.0001%	0.0001%
		0.0003%	0.0002%	0.0002%	0.0002%	0.0002%	0.0004%
21	0.0001%	0.0000%				0.0000%	0.0001%
	0.0002%	0.0000%				0.0002%	0.0002%

767 - Inflight FWD-MID - 18A - CM Tests 71-73

	A	B	D	E	F	K	L
10	0.0003%				0.0002%		0.0001%
	0.0005%				0.0005%		0.0005%
16	0.0003%	0.0003%	0.0002%	0.0000%	0.0000%	0.0000%	0.0000%
	0.0008%	0.0010%	0.0006%	0.0006%	0.0006%	0.0005%	0.0008%
17	0.0005%	0.0002%	0.0001%	0.0000%	0.0000%		0.0000%
	0.0007%	0.0013%	0.0011%	0.0006%	0.0006%		0.0004%
18	100.0000%	0.0005%	0.0000%	0.0000%	0.0000%		
		0.0010%	0.0004%	0.0004%	0.0004%		
19	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
	0.0002%	0.0004%	0.0003%	0.0003%	0.0002%	0.0000%	0.0002%
20		0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
		0.0003%	0.0002%	0.0005%	0.0003%	0.0003%	0.0002%
21	0.0000%	0.0000%				0.0000%	0.0000%
	0.0002%	0.0002%				0.0000%	0.0000%

767 - Inflight FWD-MID - 18E - BNM Tests 74-76

	A	B	D	E	F	K	L
10	0.0027%				0.0025%		0.0027%
	0.0046%				0.0040%		0.0038%
16	0.0055%	0.0052%	0.0046%	0.0041%	0.0032%	0.0041%	0.0038%
	0.0063%	0.0065%	0.0085%	0.0057%	0.0073%	0.0056%	0.0051%
17	0.0062%	0.0062%	0.0060%	0.0060%	0.0071%		0.0052%
	0.0073%	0.0070%	0.0078%	0.0076%	0.0093%		0.0064%
18	0.0073%	0.0073%	0.0054%	100.0000%	0.0052%		
	0.0090%	0.0089%	0.0232%		0.0193%		
19	0.0094%	0.0085%	0.0087%	0.0129%	0.0111%	0.0068%	0.0091%
	0.0124%	0.0125%	0.0156%	0.0206%	0.0239%	0.0103%	0.0118%
20		0.0017%	0.0002%	0.0023%	0.0011%	0.0020%	0.0036%
		0.0059%	0.0044%	0.0061%	0.0017%	0.0032%	0.0046%
21	0.0006%	0.0005%				0.0007%	0.0005%
	0.0020%	0.0016%				0.0011%	0.0010%

767 - Inflight FWD-MID - 18E - BM Tests 77-79

	A	B	D	E	F	K	L
10	0.0015%				0.0011%		0.0012%
	0.0039%				0.0054%		0.0064%
16	0.0009%	0.0010%	0.0046%	0.0033%	0.0038%	0.0016%	0.0017%
	0.0128%	0.0103%	0.0134%	0.0113%	0.0087%	0.0089%	0.0074%
17	0.0014%	0.0000%	0.0058%	0.0023%	0.0047%		0.0037%
	0.0136%	0.0168%	0.0170%	0.0145%	0.0106%		0.0074%
18	0.0018%	0.0004%	0.0041%	100.0000%	0.0059%		
	0.0166%	0.0179%	0.0189%		0.0094%		
19	0.0022%	0.0019%	0.0053%	0.0099%	0.0080%	0.0016%	0.0009%
	0.0241%	0.0277%	0.0336%	0.0271%	0.0195%	0.0097%	0.0121%
20		0.0000%	0.0000%	0.0000%	0.0000%	0.0002%	0.0000%
		0.0116%	0.0087%	0.0113%	0.0051%	0.0037%	0.0059%
21	0.0000%	0.0000%				0.0000%	0.0000%
	0.0032%	0.0041%				0.0024%	0.0019%

% Cumulative Tracer Particles

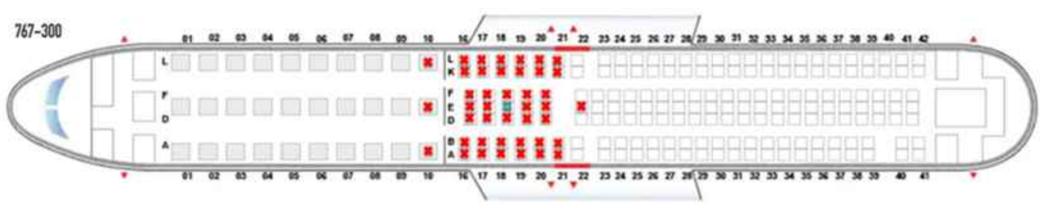
- 0-0.01%
- 0.01-1%
- >1%

BNM: Breathing/No Mask
BM: Breathing/Mask On
CNM: Cough/No Mask
CM: Cough/Mask On

767 - Inflight FWD-MID - 18L - BNM Tests 80-82

	A	B	D	E	F	K	L
10	0.0022%				0.0030%		0.0057%
	0.0030%				0.0035%		0.0074%
16	0.0028%	0.0028%	0.0027%	0.0034%	0.0091%	0.0085%	0.0070%
	0.0044%	0.0040%	0.0046%	0.0048%	0.0098%	0.0105%	0.0092%
17	0.0029%	0.0028%	0.0015%	0.0080%	0.0157%		0.0071%
	0.0057%	0.0051%	0.0057%	0.0154%	0.0228%		0.0092%
18	0.0023%	0.0018%	0.0020%	0.0020%	0.0019%		100.0000%
	0.0054%	0.0045%	0.0030%	0.0067%	0.0023%		
19	0.0012%	0.0012%	0.0016%	0.0011%	0.0005%	0.0004%	0.0004%
	0.0024%	0.0024%	0.0024%	0.0025%	0.0020%	0.0010%	0.0012%
20		0.0006%	0.0003%	0.0003%	0.0002%	0.0001%	0.0002%
		0.0009%	0.0004%	0.0008%	0.0003%	0.0005%	0.0006%
21	0.0002%	0.0002%				0.0001%	0.0001%
	0.0003%	0.0003%				0.0003%	0.0004%

18A, 18E & 18L Releases



767 Inflight – FWD Section

95% CI based on standard error (n=3)

767 - FLIGHT BNM 6A Tests 32-34

	A	B	D	E	F	K	L
1	0.0037%				0.0016%		0.0042%
	0.0038%				0.0030%		0.0048%
2	0.0051%		0.0046%				0.0043%
	0.0054%		0.0047%				0.0048%
3	0.0090%				0.0037%		0.0067%
	0.0102%				0.0042%		0.0079%
4	0.0062%		0.0091%				0.0075%
	0.0080%		0.0138%				0.0082%
5					0.0043%		0.0046%
					0.0049%		0.0060%
6	100.0000%						
7	0.0019%				0.0008%		0.0011%
	0.0032%				0.0022%		0.0016%
8	0.0007%		0.0003%				0.0005%
	0.0018%		0.0009%				0.0009%
9	0.0003%				0.0003%		0.0003%
	0.0006%				0.0005%		0.0004%
10	0.0002%		0.0002%				0.0002%
	0.0004%		0.0004%				0.0003%
16	0.0001%	0.0000%	0.0001%	0.0001%	0.0000%	0.0001%	0.0000%
	0.0002%	0.0002%	0.0002%	0.0002%	0.0000%	0.0001%	0.0002%
17		0.0000%				0.0000%	
		0.0000%				0.0000%	
18							0.0000%
							0.0000%

767 - FLIGHT BM 6A Tests 35-37

	A	B	D	E	F	K	L
1	0.0025%				0.0017%		0.0028%
	0.0032%				0.0020%		0.0039%
2	0.0034%		0.0029%				0.0027%
	0.0042%		0.0040%				0.0036%
3	0.0069%				0.0023%		0.0039%
	0.0080%				0.0033%		0.0061%
4	0.0075%		0.0068%				0.0039%
	0.0110%		0.0087%				0.0060%
5					0.0026%		0.0028%
					0.0050%		0.0058%
6	100.0000%						
7	0.0027%				0.0012%		0.0004%
	0.0045%				0.0025%		0.0028%
8	0.0012%		0.0005%				0.0006%
	0.0021%		0.0012%				0.0010%
9	0.0004%				0.0004%		0.0004%
	0.0008%				0.0006%		0.0005%
10	0.0003%		0.0003%				0.0002%
	0.0004%		0.0005%				0.0005%
16	0.0001%	0.0001%	0.0001%	0.0001%	0.0000%	0.0001%	0.0000%
	0.0002%	0.0002%	0.0003%	0.0002%	0.0000%	0.0002%	0.0003%
17		0.0000%				0.0000%	
		0.0000%				0.0000%	
18							0.0000%
							0.0000%

767 - FLIGHT CNM 6A Tests 38-40

	A	B	D	E	F	K	L
1	0.0046%				0.0028%		0.0056%
	0.0054%				0.0036%		0.0062%
2	0.0065%		0.0051%				0.0051%
	0.0071%		0.0073%				0.0063%
3	0.0140%				0.0042%		0.0067%
	0.0154%				0.0054%		0.0107%
4	0.0065%		0.0124%				0.0054%
	0.0272%		0.0160%				0.0121%
5					0.0045%		0.0040%
					0.0062%		0.0074%
6	100.0000%						
7	0.0017%				0.0016%		0.0008%
	0.0058%				0.0026%		0.0023%
8	0.0012%		0.0004%				0.0006%
	0.0025%		0.0015%				0.0011%
9	0.0004%				0.0005%		0.0004%
	0.0009%				0.0007%		0.0006%
10	0.0004%		0.0004%				0.0003%
	0.0005%		0.0006%				0.0005%
16	0.0001%	0.0001%	0.0001%	0.0001%	0.0001%	0.0001%	0.0000%
	0.0003%	0.0002%	0.0003%	0.0002%	0.0002%	0.0002%	0.0002%
17		0.0000%				0.0000%	
		0.0000%				0.0000%	
18							0.0000%
							0.0002%

767 - FLIGHT CM 6A Tests 41-43

	A	B	D	E	F	K	L
1	0.0000%				0.0000%		0.0000%
	0.0006%				0.0010%		0.0007%
2	0.0001%		0.0000%				0.0001%
	0.0006%		0.0008%				0.0006%
3	0.0002%				0.0000%		0.0001%
	0.0010%				0.0009%		0.0007%
4	0.0005%		0.0002%				0.0001%
	0.0009%		0.0010%				0.0007%
5					0.0000%		0.0002%
					0.0009%		0.0007%
6	100.0000%						
7	0.0002%				0.0000%		0.0000%
	0.0005%				0.0006%		0.0004%
8	0.0000%		0.0000%				0.0000%
	0.0004%		0.0003%				0.0003%
9	0.0000%				0.0000%		0.0000%
	0.0003%				0.0003%		0.0002%
10	0.0000%		0.0000%				0.0000%
	0.0002%		0.0003%				0.0023%
16	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
	0.0003%	0.0000%	0.0002%	0.0003%	0.0002%	0.0002%	0.0000%
17		0.0000%				0.0000%	
		0.0000%				0.0000%	
18							0.0000%
							0.0000%

767 - FLIGHT BNM 6D Tests 44-46

	A	B	D	E	F	K	L
1	0.0014%				0.0008%		0.0019%
	0.0027%				0.0020%		0.0034%
2	0.0018%		0.0016%				0.0019%
	0.0040%		0.0034%				0.0034%
3	0.0035%				0.0018%		0.0037%
	0.0068%				0.0032%		0.0049%
4	0.0087%		0.0044%				0.0038%
	0.0122%		0.0067%				0.0048%
5					0.0046%		0.0061%
					0.0060%		0.0078%
6			100.0000%				
7	0.0053%				0.0038%		0.0025%
	0.0204%				0.0053%		0.0084%
8	0.0017%		0.0006%				0.0009%
	0.0076%		0.0034%				0.0029%
9	0.0002%				0.0008%		0.0004%
	0.0024%				0.0014%		0.0014%
10	0.0002%		0.0003%				0.0003%
	0.0012%		0.0014%				0.0008%
16	0.0001%	0.0000%	0.0001%	0.0001%	0.0001%	0.0001%	0.0000%
	0.0003%	0.0003%	0.0005%	0.0003%	0.0004%	0.0002%	0.0003%
17		0.0000%				0.0000%	
		0.0000%				0.0000%	
18							0.0000%
							0.0000%

767 - FLIGHT BM 6D Tests 47-49

	A	B	D	E	F	K	L
1	0.0010%				0.0007%		0.0014%
	0.0026%				0.0018%		0.0034%
2	0.0017%		0.0011%				0.0012%
	0.0035%		0.0033%				0.0033%
3	0.0030%				0.0012%		0.0024%
	0.0057%				0.0031%		0.0050%
4	0.0064%		0.0037%				0.0020%
	0.0141%		0.0065%				0.0054%
5					0.0026%		0.0033%
					0.0065%		0.0079%
6			100.0000%				
7	0.0056%				0.0019%		0.0010%
	0.0140%				0.0060%		0.0081%
8	0.0022%		0.0007%				0.0010%
	0.0046%		0.0028%				0.0022%
9	0.0006%				0.0008%		0.0006%
	0.0016%				0.0012%		0.0009%
10	0.0003%		0.0004%				0.0004%
	0.0009%		0.0011%				0.0006%
16	0.0000%	0.0001%	0.0001%	0.0001%	0.0002%	0.0001%	0.0001%
	0.0003%	0.0002%	0.0004%	0.0003%	0.0004%	0.0003%	0.0002%
17		0.0000%				0.0000%	
		0.0000%				0.0000%	
18							0.0000%
							0.0000%

767 Inflight – FWD Section

95% CI based on standard error (n=3)

767 - FLIGHT BNM 6L Tests 50-52

	A	B	D	E	F	K	L
1	0.0025% 0.0041%				0.0017% 0.0031%		0.0035% 0.0053%
2	0.0033% 0.0056%		0.0027% 0.0049%				0.0035% 0.0052%
3	0.0057% 0.0086%				0.0038% 0.0049%		0.0066% 0.0071%
4	0.0058% 0.0098%		0.0062% 0.0088%				0.0066% 0.0086%
5					0.0085% 0.0134%		0.0066% 0.0134%
6							100.0000%
7	0.0017% 0.0052%				0.0034% 0.0109%		0.0015% 0.0048%
8	0.0010% 0.0038%		0.0005% 0.0022%				0.0006% 0.0026%
9	0.0002% 0.0020%				0.0004% 0.0027%		0.0001% 0.0016%
10	0.0002% 0.0013%		0.0003% 0.0014%				0.0002% 0.0012%
16	0.0000% 0.0010%	0.0001% 0.0003%	0.0002% 0.0004%	0.0000% 0.0007%	0.0001% 0.0006%	0.0000% 0.0005%	0.0001% 0.0004%
17		0.0001% 0.0002%				0.0001% 0.0004%	
18							0.0000% 0.0002%

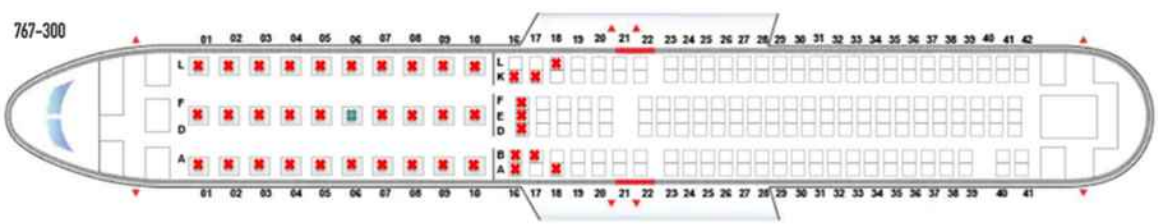
767 - FLIGHT BM 6L Tests 53-55

	A	B	D	E	F	K	L
1	0.0019% 0.0024%				0.0014% 0.0018%		0.0026% 0.0034%
2	0.0028% 0.0033%		0.0020% 0.0028%				0.0025% 0.0031%
3	0.0036% 0.0050%				0.0025% 0.0034%		0.0042% 0.0049%
4	0.0045% 0.0069%		0.0039% 0.0059%				0.0041% 0.0059%
5					0.0070% 0.0083%		0.0067% 0.0078%
6							100.0000%
7	0.0017% 0.0041%				0.0033% 0.0066%		0.0016% 0.0048%
8	0.0008% 0.0032%		0.0005% 0.0016%				0.0008% 0.0018%
9	0.0003% 0.0012%				0.0006% 0.0013%		0.0004% 0.0008%
10	0.0001% 0.0008%		0.0002% 0.0009%				0.0003% 0.0006%
16	0.0000% 0.0004%	0.0001% 0.0002%	0.0001% 0.0003%	0.0000% 0.0004%	0.0001% 0.0003%	0.0000% 0.0003%	0.0000% 0.0003%
17		0.0000% 0.0000%				0.0000% 0.0002%	
18							0.0000% 0.0000%

6A, 6D & 6L Releases

% Cumulative Tracer Particles
- 0-0.01%
- 0.01-1%
- >1%

BNM: Breathing/No Mask
BM: Breathing/Mask On
CNM: Cough/No Mask
CM: Cough/Mask On



767 Hangar "Inflight" AFT Section

95% CI based on standard error (n=3)

767 - Inflight AFT - 37A - BNM Tests 1-3

	A	B	D	E	F	K	L
34			0.0015%		0.0006%		
			0.0046%		0.0014%		
35	0.0020%	0.0035%	0.0026%	0.0006%	0.0016%		0.0012%
	0.0081%	0.0089%	0.0058%	0.0035%	0.0024%		0.0023%
36	0.0040%	0.0069%	0.0058%	0.0045%	0.0044%	0.0027%	0.0026%
	0.0143%	0.0166%	0.0090%	0.0090%	0.0072%	0.0037%	0.0038%
37	100.0000%	0.0801%	0.0182%	0.0125%	0.0075%	0.0030%	0.0008%
		0.1254%	0.0196%	0.0147%	0.0097%	0.0046%	0.0015%
38	0.0236%	0.0239%	0.0192%	0.0154%	0.0056%	0.0036%	0.0048%
	0.0251%	0.0365%	0.0236%	0.0190%	0.0087%	0.0068%	0.0075%
39	0.0162%		0.0131%	0.0085%	0.0054%		0.0072%
	0.0178%		0.0154%	0.0147%	0.0075%		0.0106%
40	0.0071%	0.0057%			0.0058%	0.0059%	0.0050%
	0.0083%	0.0068%			0.0090%	0.0095%	0.0076%
41	0.0060%						0.0054%
	0.0076%						0.0071%

767 - Inflight AFT - 37B - BNM Tests 4-6

	A	B	D	E	F	K	L
34			0.0012%		0.0009%		
			0.0046%		0.0014%		
35	0.0020%	0.0027%	0.0000%	0.0010%	0.0017%		0.0017%
	0.0072%	0.0086%	0.0080%	0.0030%	0.0029%		0.0025%
36	0.0048%	0.0060%	0.0051%	0.0033%	0.0054%	0.0015%	0.0018%
	0.0093%	0.0109%	0.0118%	0.0080%	0.0073%	0.0062%	0.0059%
37	0.0079%	100.0000%	0.0111%	0.0112%	0.0048%	0.0015%	0.0018%
	0.0180%		0.0321%	0.0162%	0.0142%	0.0085%	0.0027%
38	0.0191%		0.0219%	0.0165%	0.0022%	0.0019%	0.0027%
	0.0324%		0.0255%	0.0219%	0.0182%	0.0115%	0.0130%
39	0.0165%		0.0152%	0.0075%	0.0045%		0.0050%
	0.0195%		0.0162%	0.0181%	0.0109%		0.0168%
40	0.0076%	0.0059%			0.0051%	0.0043%	0.0048%
	0.0102%	0.0079%			0.0118%	0.0144%	0.0102%
41	0.0062%						0.0053%
	0.0085%						0.0094%

767 - Hangar AFT - 37D - BNM Tests 7-9

	A	B	D	E	F	K	L
34			0.0042%		0.0008%		
			0.0094%		0.0035%		
35	0.0104%	0.0100%	0.0107%	0.0036%	0.0014%		0.0022%
	0.0119%	0.0132%	0.0164%	0.0051%	0.0042%		0.0035%
36	0.0120%	0.0157%	0.0043%	0.0063%	0.0040%	0.0023%	0.0024%
	0.0169%	0.0205%	0.0057%	0.0114%	0.0057%	0.0043%	0.0043%
37	0.0285%	0.0252%	100.0000%	0.0047%	0.0049%	0.0022%	0.0023%
	0.0345%	0.0305%		0.0125%	0.0060%	0.0048%	0.0027%
38	0.0217%		0.0167%	0.0085%	0.0040%	0.0024%	0.0041%
	0.0299%		0.0171%	0.0166%	0.0062%	0.0056%	0.0061%
39	0.0146%		0.0101%	0.0068%	0.0036%		0.0050%
	0.0170%		0.0155%	0.0098%	0.0055%		0.0070%
40	0.0056%	0.0038%			0.0043%	0.0041%	0.0034%
	0.0072%	0.0068%			0.0057%	0.0063%	0.0053%
41	0.0045%						0.0028%
	0.0068%						0.0062%

767 - AFT - Hangar - 37E - BNM Tests 10-12

	A	B	D	E	F	K	L
34			0.0024%		0.0019%		
			0.0053%		0.0056%		
35	0.0038%	0.0040%	0.0054%	0.0036%	0.0040%		0.0042%
	0.0090%	0.0090%	0.0108%	0.0052%	0.0155%		0.0098%
36	0.0049%	0.0053%	0.0053%	0.0064%	0.0069%	0.0037%	0.0035%
	0.0111%	0.0130%	0.0156%	0.0161%	0.0247%	0.0159%	0.0164%
37	0.0055%	0.0064%	0.0052%	100.0000%	0.0089%	0.0033%	0.0097%
	0.0193%	0.0196%	0.0203%		0.0261%	0.0216%	0.0130%
38	0.0077%		0.0056%	0.0056%	0.0107%	0.0074%	0.0134%
	0.0324%		0.0228%	0.0207%	0.0291%	0.0328%	0.0430%
39	0.0053%		0.0062%	0.0061%	0.0050%		0.0091%
	0.0207%		0.0191%	0.0199%	0.0138%		0.0241%
40	0.0037%	0.0035%			0.0053%	0.0067%	0.0044%
	0.0108%	0.0100%			0.0156%	0.0221%	0.0131%
41	0.0037%						0.0041%
	0.0102%						0.0100%

767 - Hangar AFT - 37F - BNM Tests 13-15

	A	B	D	E	F	K	L
34			0.0024%		0.0035%		
			0.0032%		0.0089%		
35	0.0033%	0.0034%	0.0044%	0.0034%	0.0134%		0.0060%
	0.0046%	0.0046%	0.0049%	0.0084%	0.0195%		0.0157%
36	0.0042%	0.0049%	0.0057%	0.0099%	0.0147%	0.0067%	0.0087%
	0.0059%	0.0065%	0.0097%	0.0113%	0.0182%	0.0271%	0.0283%
37	0.0051%	0.0050%	0.0053%	0.0087%	100.0000%	0.0131%	0.0157%
	0.0085%	0.0082%	0.0075%	0.0100%		0.0320%	0.0192%
38	0.0056%		0.0062%	0.0068%	0.0151%	0.0194%	0.0231%
	0.0100%		0.0088%	0.0087%	0.0205%	0.0285%	0.0318%
39	0.0056%		0.0067%	0.0080%	0.0049%		0.0111%
	0.0079%		0.0087%	0.0130%	0.0093%		0.0153%
40	0.0037%	0.0035%			0.0057%	0.0089%	0.0050%
	0.0055%	0.0050%			0.0097%	0.0143%	0.0078%
41	0.0036%						0.0040%
	0.0052%						0.0058%

767 - Hangar - AFT - 37K - BNM Tests 16-18

	A	B	D	E	F	K	L
34			0.0024%		0.0036%		
			0.0026%		0.0047%		
35	0.0031%	0.0035%	0.0051%	0.0034%	0.0082%		0.0075%
	0.0040%	0.0038%	0.0052%	0.0045%	0.0138%		0.0088%
36	0.0039%	0.0048%	0.0100%	0.0111%	0.0204%	0.0132%	0.0134%
	0.0050%	0.0054%	0.0134%	0.0120%	0.0234%	0.0156%	0.0153%
37	0.0056%	0.0051%	0.0065%	0.0104%	0.0175%	100.0000%	0.0043%
	0.0072%	0.0070%	0.0073%	0.0164%	0.0281%		0.0080%
38	0.0068%		0.0083%	0.0088%	0.0253%	0.0408%	0.0308%
	0.0090%		0.0089%	0.0119%	0.0298%	0.0443%	0.0406%
39	0.0077%		0.0092%	0.0116%	0.0085%		0.0171%
	0.0079%		0.0112%	0.0190%	0.0126%		0.0227%
40	0.0058%	0.0049%			0.0100%	0.0175%	0.0082%
	0.0075%	0.0072%			0.0134%	0.0188%	0.0116%
41	0.0056%						0.0066%
	0.0068%						0.0081%

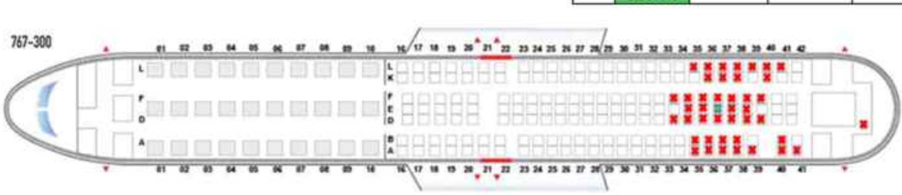
37A, 37B, 37D, 37E
37F, 37K, 37L Releases

767 - Hangar- AFT - 37L - BNM Tests 19-21

	A	B	D	E	F	K	L
34			0.0046%		0.0054%		
			0.0052%		0.0166%		
35	0.0058%	0.0063%	0.0056%	0.0061%	0.0162%		0.0119%
	0.0069%	0.0070%	0.0111%	0.0161%	0.0507%		0.0274%
36	0.0080%	0.0089%	0.0087%	0.0056%	0.0085%	0.0138%	0.0158%
	0.0091%	0.0104%	0.0129%	0.0256%	0.0702%	0.0483%	0.0497%
37	0.0104%	0.0094%	0.0090%	0.0079%	0.0161%	0.0313%	100.0000%
	0.0133%	0.0129%	0.0121%	0.0235%	0.0320%	0.0642%	
38	0.0080%		0.0105%	0.0084%	0.0224%	0.0320%	0.0357%
	0.0161%		0.0133%	0.0151%	0.0277%	0.0440%	0.0394%
39	0.0089%		0.0103%	0.0138%	0.0073%		0.0168%
	0.0125%		0.0144%	0.0193%	0.0119%		0.0197%
40	0.0060%	0.0054%			0.0087%	0.0137%	0.0078%
	0.0081%	0.0076%			0.0129%	0.0205%	0.0100%
41	0.0055%						0.0057%
	0.0077%						0.0084%

% Cumulative Tracer Particles
- 0-0.01%
- 0.01-1%
- >1%

BNM: Breathing/No Mask
BM: Breathing/Mask On
CNM: Cough/No Mask
CM: Cough/Mask On



767 Hangar “Inflight” FWD-MID Section

95% CI based on standard error (n=3)

767 - HANGAR FWD-MID - 18A - BNM Tests 34-36							
	A	B	D	E	F	K	L
10	0.0070%				0.0060%		0.0035%
	0.0094%				0.0104%		0.0040%
16	0.0094%	0.0096%	0.0146%	0.0047%	0.0013%	0.0019%	0.0017%
	0.0171%	0.0161%	0.0228%	0.0202%	0.0026%	0.0041%	0.0036%
17	0.0042%	0.0028%	0.0066%	0.0021%	0.0005%		
	0.0166%	0.0163%	0.0301%	0.0054%	0.0010%		
18	100.0000%	0.0000%	0.0001%	0.0000%			0.0008%
		0.0056%	0.0006%	0.0006%			0.0015%
19	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
	0.0000%	0.0002%	0.0001%	0.0000%	0.0000%	0.0002%	0.0003%
20	0.0000%	0.0000%				0.0000%	0.0000%
	0.0000%	0.0000%				0.0000%	0.0000%
21	0.0000%		0.0000%	0.0000%			0.0000%
	0.0000%		0.0000%	0.0000%			0.0000%
22				0.0000%			
				0.0000%			

767 - HANGAR FWD-MID - 18B - BNM Tests 37-39							
	A	B	D	E	F	K	L
10	0.0081%				0.0103%		0.0038%
	0.0101%				0.0117%		0.0046%
16	0.0169%	0.0149%	0.0111%	0.0040%	0.0022%	0.0030%	0.0025%
	0.0186%	0.0172%	0.0203%	0.0104%	0.0029%	0.0037%	0.0034%
17	0.0176%		0.0360%	0.0015%	0.0010%		
	0.0228%		0.0761%	0.0091%	0.0016%		
18	0.0050%	100.0000%	0.0001%	0.0001%			0.0018%
	0.0073%		0.0005%	0.0003%			0.0027%
19	0.0000%	0.0001%	0.0000%	0.0000%	0.0000%	0.0000%	0.0001%
	0.0000%	0.0001%	0.0001%	0.0000%	0.0000%	0.0002%	0.0002%
20	0.0000%	0.0000%				0.0000%	0.0000%
	0.0000%	0.0000%				0.0000%	0.0000%
21	0.0000%		0.0000%	0.0000%			0.0000%
	0.0000%		0.0000%	0.0000%			0.0000%
22				0.0000%			
				0.0000%			

767 - HANGAR FWD-MID - 18D - BNM Tests 40-42							
	A	B	D	E	F	K	L
10	0.0062%				0.0062%		0.0031%
	0.0071%				0.0094%		0.0042%
16	0.0102%	0.0091%	0.0108%	0.0052%	0.0024%	0.0025%	0.0022%
	0.0114%	0.0110%	0.0124%	0.0070%	0.0027%	0.0032%	0.0026%
17	0.0122%		0.0100%	0.0022%	0.0018%		
	0.0142%		0.0140%	0.0058%	0.0021%		
18	0.0194%	0.0094%	100.0000%	0.0006%			0.0023%
	0.0223%	0.0150%		0.0016%			0.0028%
19	0.0010%	0.0007%	0.0004%	0.0000%	0.0000%	0.0001%	0.0003%
	0.0049%	0.0043%	0.0022%	0.0005%	0.0001%	0.0004%	0.0005%
20	0.0000%	0.0000%				0.0000%	0.0000%
	0.0009%	0.0000%				0.0001%	0.0000%
21	0.0000%	0.0000%	0.0000%	0.0000%			0.0000%
	0.0004%	0.0009%	0.0002%	0.0003%			0.0000%
22				0.0000%			
				0.0000%			

767 - HANGAR FWD-MID - 18E - BNM Tests 43-45							
	A	B	D	E	F	K	L
10	0.0032%				0.0033%		0.0049%
	0.0036%				0.0045%		0.0050%
16	0.0048%	0.0047%	0.0053%	0.0042%	0.0074%	0.0055%	0.0046%
	0.0058%	0.0051%	0.0059%	0.0065%	0.0074%	0.0069%	0.0059%
17	0.0053%		0.0053%	0.0033%	0.0070%		
	0.0058%		0.0059%	0.0055%	0.0107%		
18	0.0055%	0.0049%	0.0031%	100.0000%			0.0097%
	0.0071%	0.0050%	0.0053%				0.0130%
19	0.0032%	0.0032%	0.0014%	0.0003%	0.0001%	0.0008%	0.0016%
	0.0070%	0.0049%	0.0028%	0.0006%	0.0002%	0.0012%	0.0019%
20	0.0006%	0.0000%				0.0001%	0.0001%
	0.0017%	0.0000%				0.0002%	0.0003%
21	0.0003%	0.0006%	0.0001%	0.0003%			0.0000%
	0.0009%	0.0025%	0.0004%	0.0005%			0.0000%
22				0.0000%			
				0.0000%			

767 - HANGAR FWD-MID - 18F - BNM Tests 46-48							
	A	B	D	E	F	K	L
10	0.0021%				0.0028%		0.0063%
	0.0033%				0.0042%		0.0079%
16	0.0024%	0.0024%	0.0022%	0.0034%	0.0099%	0.0091%	0.0067%
	0.0043%	0.0041%	0.0046%	0.0052%	0.0119%	0.0111%	0.0109%
17	0.0021%		0.0013%	0.0017%	0.0079%		
	0.0046%		0.0041%	0.0033%	0.0132%		
18	0.0022%	0.0011%	0.0006%	0.0022%	100.0000%		0.0157%
	0.0066%	0.0037%	0.0016%	0.0030%			0.0192%
19	0.0003%	0.0004%	0.0003%	0.0001%	0.0001%	0.0009%	0.0010%
	0.0024%	0.0018%	0.0006%	0.0002%	0.0002%	0.0017%	0.0030%
20	0.0001%	0.0000%				0.0001%	0.0001%
	0.0003%	0.0000%				0.0002%	0.0003%
21	0.0000%	0.0020%	0.0000%	0.0000%			0.0000%
	0.0002%	0.0024%	0.0001%	0.0001%			0.0000%
22				0.0000%			
				0.0000%			

767 - HANGAR FWD-MID - 18K - BNM Tests 49-51							
	A	B	D	E	F	K	L
10	0.0021%				0.0028%		0.0063%
	0.0033%				0.0042%		0.0079%
16	0.0024%	0.0024%	0.0022%	0.0034%	0.0099%	0.0091%	0.0067%
	0.0043%	0.0041%	0.0046%	0.0052%	0.0119%	0.0111%	0.0109%
17	0.0021%		0.0013%	0.0017%	0.0079%		
	0.0046%		0.0041%	0.0033%	0.0132%		
18	0.0022%	0.0011%	0.0006%	0.0022%		100.0000%	0.0157%
	0.0066%	0.0037%	0.0016%	0.0030%			0.0192%
19	0.0003%	0.0004%	0.0003%	0.0001%	0.0001%	0.0009%	0.0010%
	0.0024%	0.0018%	0.0006%	0.0002%	0.0002%	0.0017%	0.0030%
20	0.0001%	0.0000%				0.0001%	0.0001%
	0.0003%	0.0000%				0.0002%	0.0003%
21	0.0000%	0.0020%	0.0000%	0.0000%			0.0000%
	0.0002%	0.0024%	0.0001%	0.0001%			0.0000%
22				0.0000%			
				0.0000%			

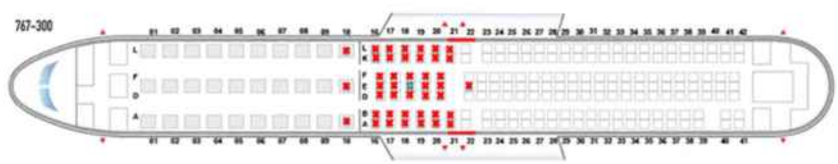
767 - HANGAR FWD-MID - 18L - BNM Tests 52-54							
	A	B	D	E	F	K	L
10	0.0021%				0.0033%		0.0067%
	0.0034%				0.0042%		0.0116%
16	0.0021%	0.0021%	0.0027%	0.0049%	0.0126%	0.0102%	0.0084%
	0.0051%	0.0046%	0.0043%	0.0105%	0.0206%	0.0228%	0.0187%
17	0.0016%		0.0007%	0.0021%	0.0231%		
	0.0039%		0.0013%	0.0139%	0.0846%		
18	0.0011%	0.0000%	0.0003%	0.0000%			100.0000%
	0.0024%	0.0015%	0.0004%	0.0113%			
19	0.0000%	0.0001%	0.0001%	0.0000%	0.0000%	0.0001%	0.0003%
	0.0004%	0.0004%	0.0002%	0.0000%	0.0001%	0.0007%	0.0011%
20	0.0000%	0.0000%				0.0000%	0.0000%
	0.0001%	0.0000%				0.0001%	0.0000%
21	0.0000%	0.0022%	0.0000%	0.0000%			0.0000%
	0.0000%	0.0024%	0.0000%	0.0000%			0.0000%
22				0.0000%			
				0.0000%			

18A, 18B, 18D, 18F,
18K, 18L Releases

% Cumulative
Tracer Particles

- 0-0.01%
- 0.01-1%
- >1%

BNM: Breathing/No Mask
BM: Breathing/Mask On
CNM: Cough/No Mask
CM: Cough/Mask On



767 Hangar "Inflight" FWD Section

95% CI based on standard error (n=3)

767 - HANGAR - FWD - BNM 5A Tests 23-25							
	A	B	D	E	F	K	L
1	0.0067%				0.0067%		0.0095%
	0.0080%				0.0086%		0.0113%
2	0.0089%		0.0133%				0.0090%
	0.0125%		0.0181%				0.0112%
3	0.0165%				0.0094%		0.0135%
	0.0198%				0.0127%		0.0172%
4	0.0201%		0.0604%				0.0146%
	0.0252%		0.0680%				0.0173%
5	100.0000%						0.0068%
							0.0095%
6	0.0013%						0.0023%
	0.0017%						0.0028%
7	0.0023%				0.0002%		0.0005%
	0.0028%				0.0005%		0.0008%
8	0.0010%		0.0003%				
	0.0014%		0.0006%				
9	0.0002%				0.0000%		0.0000%
	0.0004%				0.0000%		0.0000%
10	0.0000%		0.0000%				
	0.0000%		0.0000%				
16	0.0000%		0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
	0.0000%		0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
17		0.0000%				0.0000%	
		0.0000%				0.0000%	
18	0.0000%						
	0.0000%						

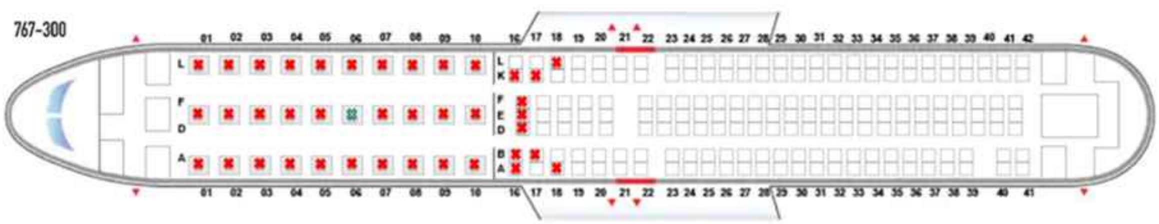
767 - HANGAR - FWD - BNM 6D Tests 28-30							
	A	B	D	E	F	K	L
1	0.0023%				0.0025%		0.0036%
	0.0029%				0.0028%		0.0040%
2	0.0034%		0.0048%				0.0034%
	0.0042%		0.0060%				0.0040%
3	0.0060%				0.0049%		0.0050%
	0.0064%				0.0060%		0.0062%
4	0.0078%		0.0098%				0.0053%
	0.0080%		0.0105%				0.0061%
5	0.0105%						0.0059%
	0.0127%						0.0071%
6	0.0201%		100.0000%				0.0070%
	0.0225%						0.0083%
7	0.0070%				0.0003%		0.0009%
	0.0083%				0.0008%		0.0029%
8	0.0014%		0.0003%				
	0.0024%		0.0005%				
9	0.0001%				0.0000%		0.0000%
	0.0002%				0.0000%		0.0000%
10	0.0000%		0.0000%				
	0.0000%		0.0000%				
16	0.0000%		0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
	0.0000%		0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
17		0.0000%				0.0000%	
		0.0000%				0.0000%	
18	0.0000%						
	0.0000%						

767 - HANGAR - FWD - BNM 5L Tests 31-33							
	A	B	D	E	F	K	L
1	0.0008%				0.0068%		0.0100%
	0.0098%				0.0085%		0.0107%
2	0.0078%		0.0077%				0.0093%
	0.0087%		0.0096%				0.0094%
3	0.0075%				0.0224%		0.0082%
	0.0088%				0.0342%		0.0150%
4	0.0029%		0.0036%				0.0083%
	0.0037%		0.0046%				0.0132%
5	0.0010%						100.0000%
	0.0020%						
6	0.0007%						0.0010%
	0.0011%						0.0022%
7	0.0010%				0.0000%		0.0002%
	0.0022%				0.0002%		0.0005%
8	0.0003%		0.0001%				
	0.0008%		0.0004%				
9	0.0001%				0.0000%		0.0000%
	0.0001%				0.0000%		0.0000%
10	0.0000%		0.0000%				
	0.0000%		0.0000%				
16	0.0000%		0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
	0.0000%		0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
17		0.0000%				0.0000%	
		0.0000%				0.0000%	
18	0.0000%						
	0.0000%						

5A, 5D, 5L Releases

% Cumulative Tracer Particles
- 0-0.01%
- 0.01-1%
- >1%

BNM: Breathing/No Mask
BM: Breathing/Mask On
CNM: Cough/No Mask
CM: Cough/Mask On



767 Terminal – AFT Section

95% CI based on standard error (n=3)

767 - Terminal AFT - 37E - BNM Tests 28-30

	A	B	D	E	F	K	L
34			0.0074%		0.0049%		
			0.0085%		0.0060%		
35	0.0043%	0.0030%	0.0054%	0.0061%	0.0106%		0.0080%
	0.0050%	0.0037%	0.0062%	0.0075%	0.0147%		0.0085%
36	0.0080%	0.0039%	0.0039%	0.0062%	0.0067%	0.0096%	0.0102%
	0.0085%	0.0052%	0.0055%	0.0081%	0.0076%	0.0123%	0.0112%
37	0.0129%		0.0071%	100.0000%	0.0095%	0.0082%	0.0189%
	0.0209%		0.0075%		0.0107%	0.0105%	0.0298%
38	0.0120%	0.0108%	0.0077%	0.0101%	0.0106%	0.0132%	0.0140%
	0.0370%	0.0134%	0.0133%	0.0139%	0.0138%	0.0156%	0.0232%
39	0.0100%		0.0111%	0.0070%			0.0066%
	0.0153%		0.0136%	0.0104%			0.0093%
40	0.0102%	0.0106%	0.0082%		0.0066%	0.0083%	0.0064%
	0.0145%	0.0147%	0.0105%		0.0090%	0.0106%	0.0103%
41	0.0047%						0.0000%
	0.0078%						0.0000%

767 - Terminal AFT - 37E - BM Tests 31-33

	A	B	D	E	F	K	L
34			0.0055%		0.0031%		
			0.0078%		0.0055%		
35	0.0026%	0.0019%	0.0044%	0.0050%	0.0116%		0.0045%
	0.0045%	0.0034%	0.0054%	0.0062%	0.0125%		0.0072%
36	0.0046%	0.0026%	0.0028%	0.0049%	0.0052%	0.0050%	0.0086%
	0.0087%	0.0045%	0.0045%	0.0066%	0.0068%	0.0144%	0.0103%
37	0.0073%		0.0040%	100.0000%	0.0075%	0.0067%	0.0220%
	0.0073%		0.0063%		0.0103%	0.0095%	0.0251%
38	0.0231%	0.0091%	0.0058%	0.0073%	0.0102%	0.0117%	0.0183%
	0.0283%	0.0117%	0.0088%	0.0102%	0.0120%	0.0147%	0.0199%
39	0.0105%		0.0091%	0.0068%			0.0064%
	0.0122%		0.0119%	0.0088%			0.0072%
40	0.0106%	0.0116%	0.0085%		0.0065%	0.0083%	0.0071%
	0.0134%	0.0125%	0.0090%		0.0075%	0.0099%	0.0079%
41	0.0060%						0.0000%
	0.0061%						0.0000%

37E Releases

% Cumulative Tracer Particles
- 0-0.01%
- 0.01-1%
- >1%

BNM: Breathing/No Mask
BM: Breathing/Mask On
CNM: Cough/No Mask
CM: Cough/Mask On