Overview of FlyHealthy Research Study

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Features of airplane cabins

- very dry air
- half of the cabin air is recycled (after passing through a bank of HEPA filters), and the other half is taken from the outside
- periodic high occupant densities
- long periods during which occupants have extremely limited mobility
- it is difficult to avoid a mobile sick person or one sitting in close proximity.

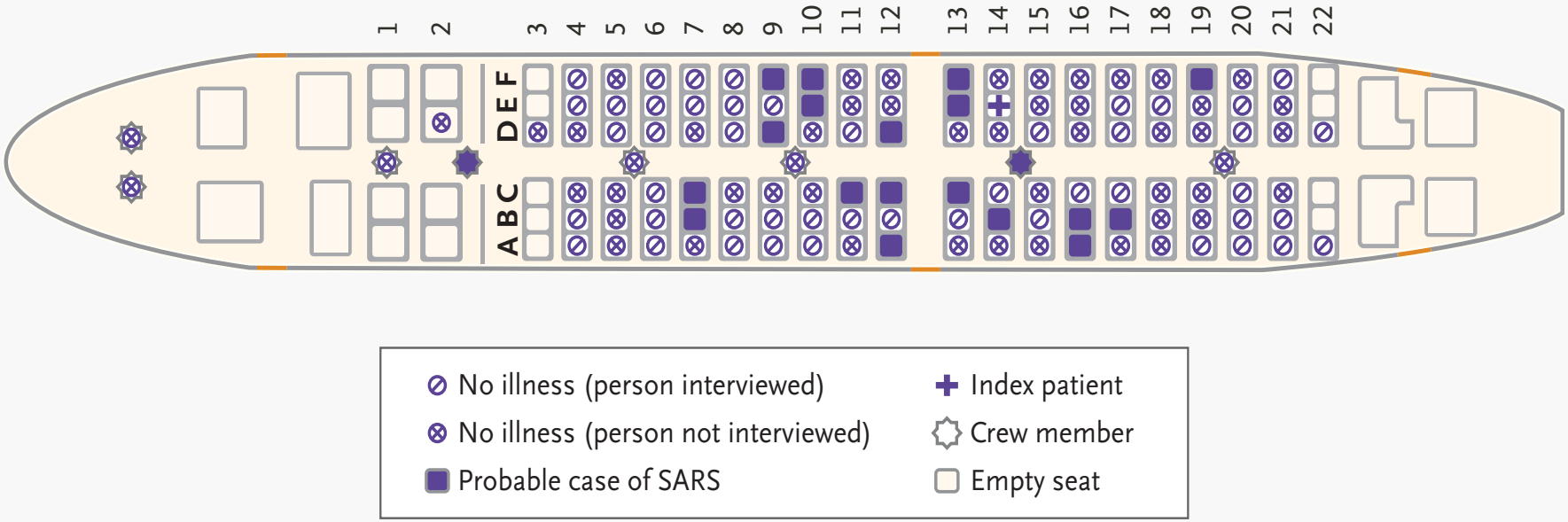
Transmission of IDs on Commercial Flights

Last year over 3e9 airline passengers and inflight transmission of infectious diseases is an important global health concern

Documented cases of in-flight transmission of IDs:

- TB (4 reports)
- Measles (2 reports)
- Influenza (5 reports, including H1N1p)
- SARS (2 reports)
- Meningococcal infection
- Norovirus (3 reports)
- Cholera
- Shigellosis

SARS transmission on CA 221 from HKG-PEK



Olsen, Sonja J., et al. "Transmission of the severe acute respiratory syndrome on aircraft." *New England Journal of Medicine* 349.25 (2003): 2416-2422.

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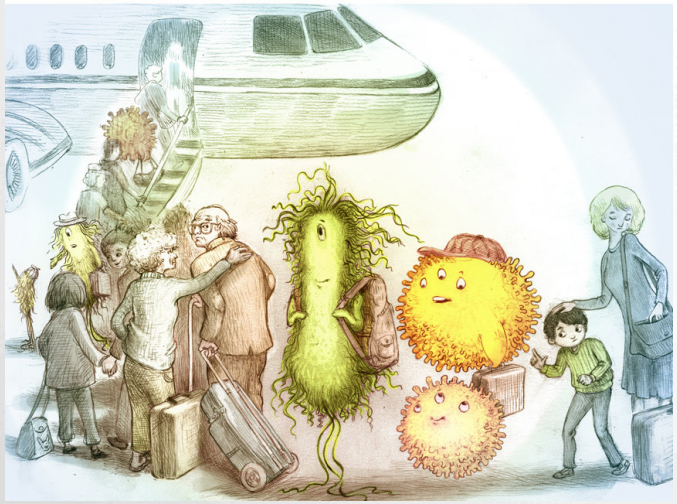

Despite many sensational media stories and personal anecdotes, the true risks of transmission are unknown

Major FlyHealthy Study Goals (Phase I)

Quantify the direct transmission of infectious diseases via respiratory droplets (which fall < 1 meter) in an airplane cabin during transcontinental US flights

1) Characterize the airplane cabin microbiome
2) Quantify transmission opportunities
3) Create seat map of risk of transmission of ID from infected individual

Study Design: In flight

1. On 10 flights on (mostly) Boeing 757's between ATL to west coast cities: November 2012 - May 2013 (8 flights during Influenza season)

2. Before, during, and after flight, take environmental samples from key touch surfaces (tray table, seat belt buckle, lavatory door handles) and in cabin air

3. Chronicle the behaviors and movements of passengers and crew while above 10k feet

Study Design: Post flight

Using samples and data from the 10 research flights:

1. Analyze environmental samples to determine microbial communities and study how they changed from pre-flight to post-flight, from location to location, etc.

2. Analyze movement data and use movement data to construct close proximity interactions.

3. Construct data driven mathematical models and produce seat map of risk of transmission of ID from infected individual.

Cabin Environmental Sampling

- 2 air sampling pumps located in rear of plane (3.5 liters/min, 2 µm PTFE filter)

- Pump 1 ran continuously from 10k feet on ascent to 10k feet on descent
- Pump 2 ran during five 30 minute periods
- Chose one random lavatory and swabbed inner and outer door handles, both pre-boarding and post-deplaning

- Chose 2 random seats and swabbed open tray table, closed tray table, and seat belt buckle, both pre-boarding and post-deplaning

Metagenomic Analysis

1. qPCR of each sample for 18 respiratory viruses
2. 16s rRNA sequencing of each sample
3. WGS (DNA and RNA) of sample aggregates

Sequencing performed at HudsonAlpha Institute for Biotechnology (Dr. Shawn Levy)

Bioinformatics performed at JCVI (Dr. Chris Dupont, Mr. Josh L. Espinoza, Dr. Karen Nelson)

Some General Findings

1. Bacterial communities were largely derived from human skin and oral commensals, as well as environmental generalists

2. Identified “core” airplane cabin microbiome

3. Very large flight-to-flight variations and no systematic pattern of change from pre- to post-flight

4. Although different primers and sequencing techniques were used, the core microbiome from Boston subway system study has significant overlap with airplane cabins

Behaviors, Movements, and Deducing Close Proximity Contacts in the Airplane Cabins

We could not use cameras, RFID tags, etc. in airplane cabin

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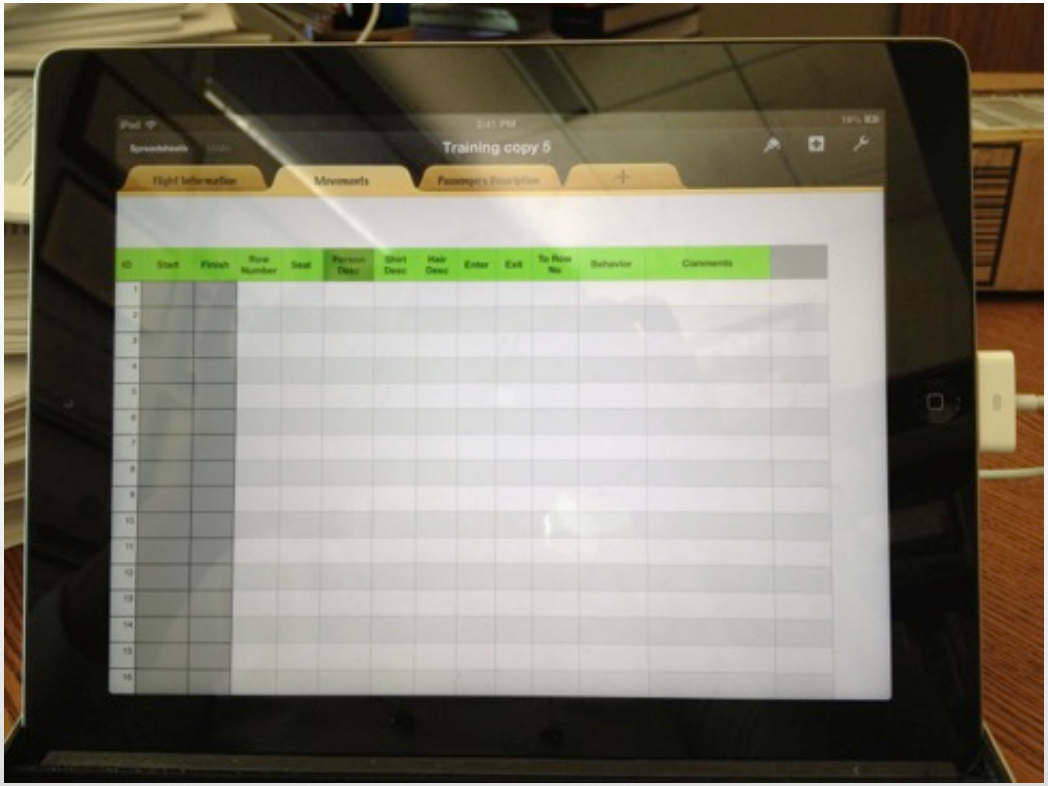
Our team developed an iPad app to record passenger and crew behaviors and movement (above 10k feet)



19 Public Health/Nursing Graduate Student Observers

10 per flight

Observer Placement

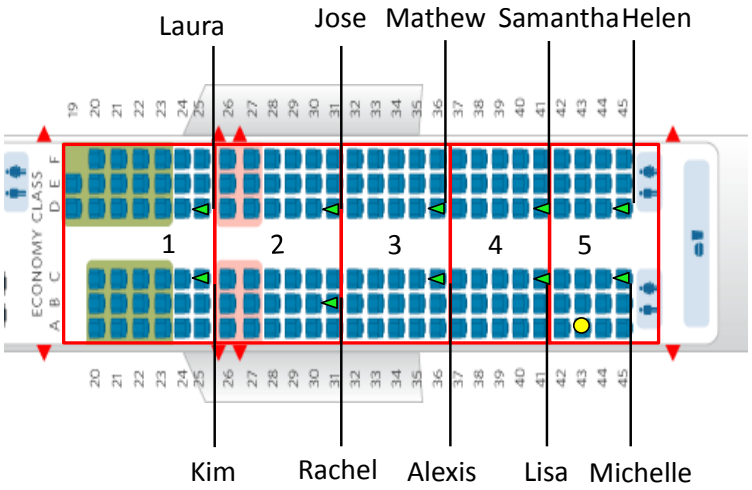
Trip 2: (outbound)

DL 1755

ATL → LAX

▲ Observer position

● Air-sampler position



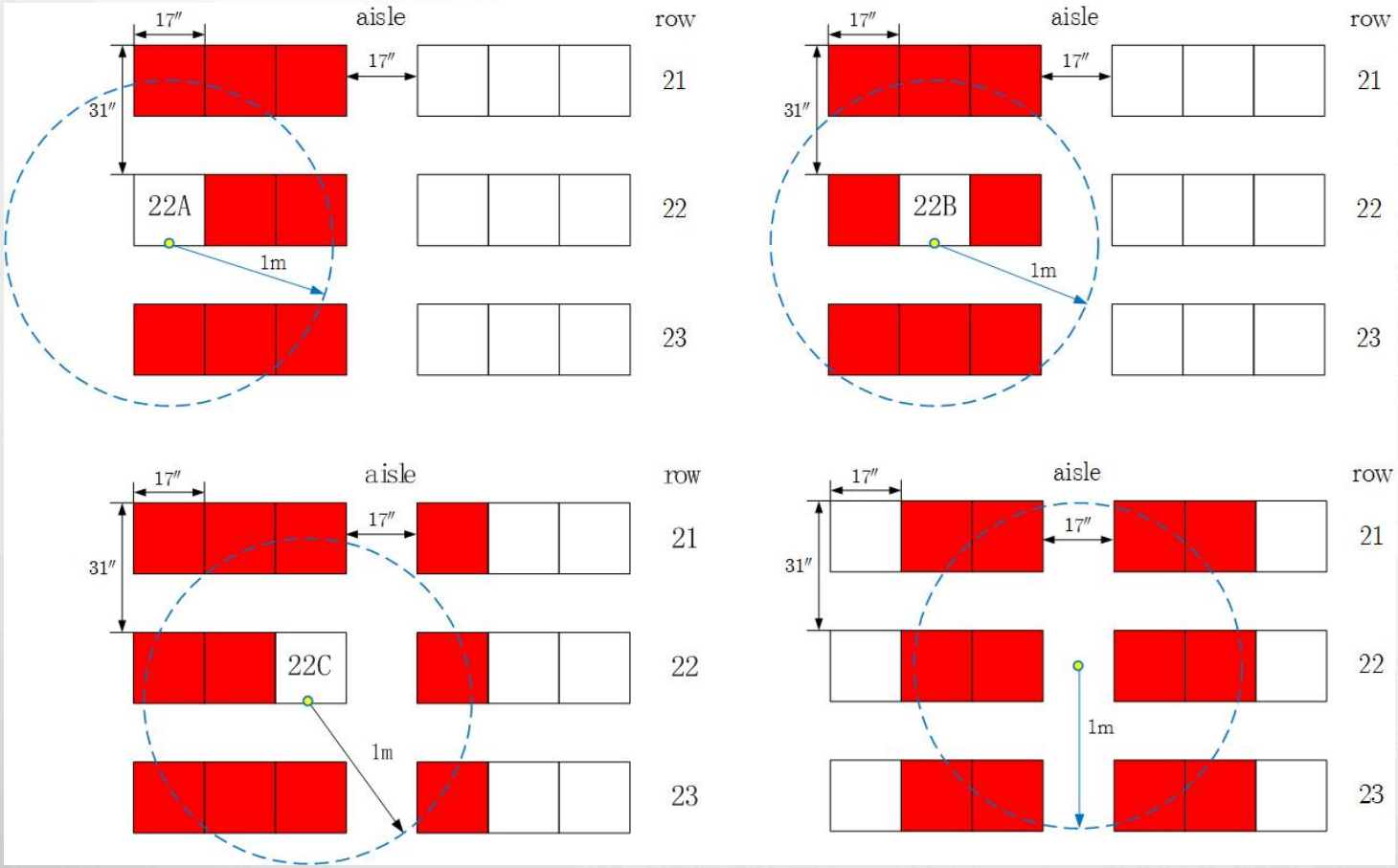
Real-time data entry by observer

Start	Finish	Row	Seat	Enter	Exit	Behavior	Person Desc	Shirt Desc	Hair Color	Hair Style	Body Type	Comment
14:36:55				Back		Passing back to front	Crew B					
14:36:58	14:37:05	19	C			Checking overhead bin			Bl			
14:45:55	14:47:24	19	C		Back	Pacing						
14:50:31	14:52:20	21	D			Front Lav						
14:51:07	14:57:15	22	E			Checking overhead bin		Paisley				Went to front lav too
14:51:23	14:57:12	22	D			Checking overhead bin						Stood in aisle , front lav too, stood in aisle after lav and waited for 22 E
14:54:04	14:56:47	20	B			Checking overhead bin						Checked bin in first class

Entries are initially reconciled immediately after flight

- Within observation zones
- Between observation zones

Close proximity contacts with contact zone: 1 meter radius



Avg # Contacts <u>while seated</u>
Aisle: 11
Middle: 8
Window: 8

Contacts while <u>moving in aisle</u>
4 per row

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From the movement data, we were able to (very reliably) recover close proximity contacts and encode them using 10 temporal networks

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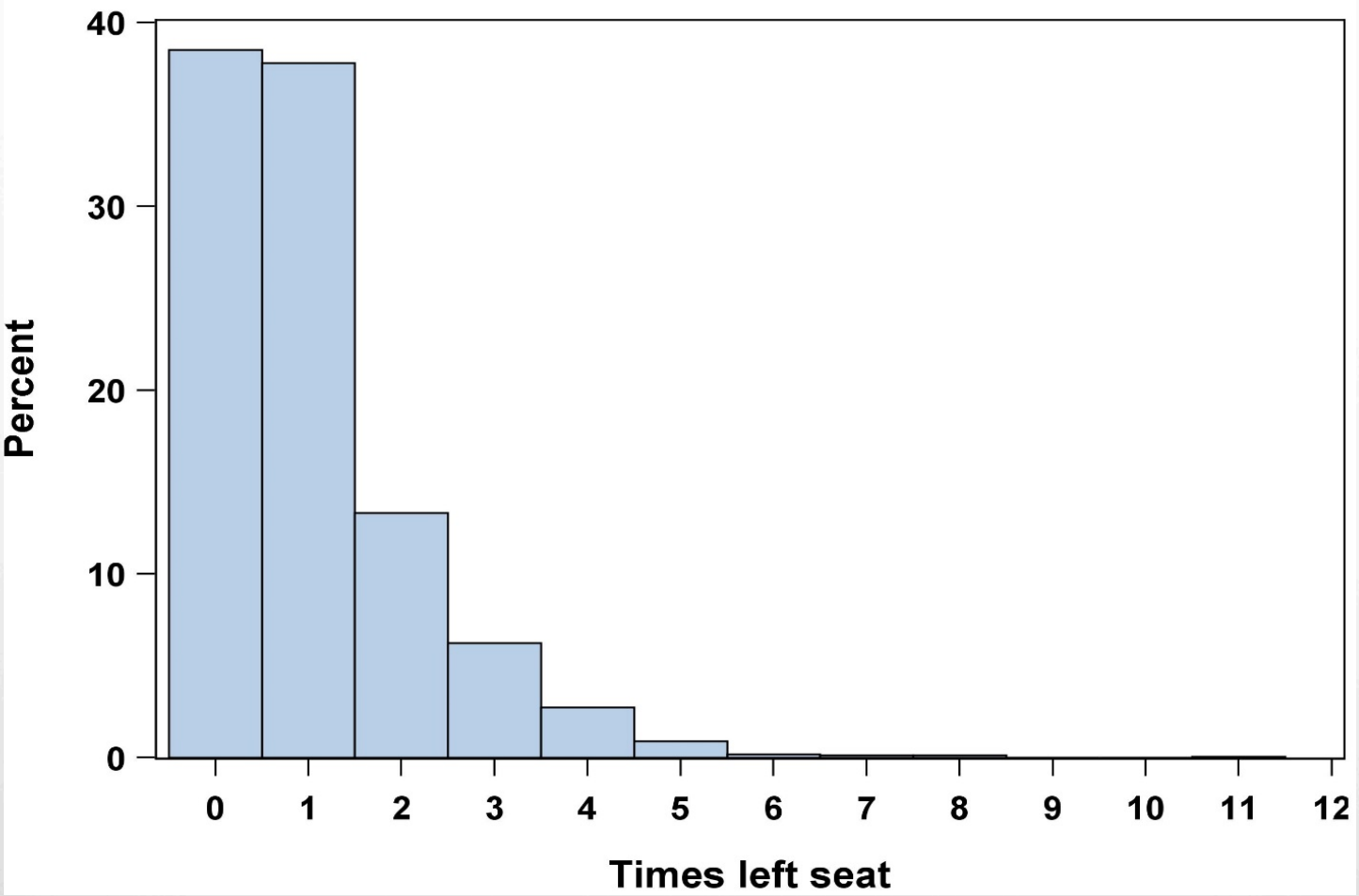
Behaviors and Movement Statistics

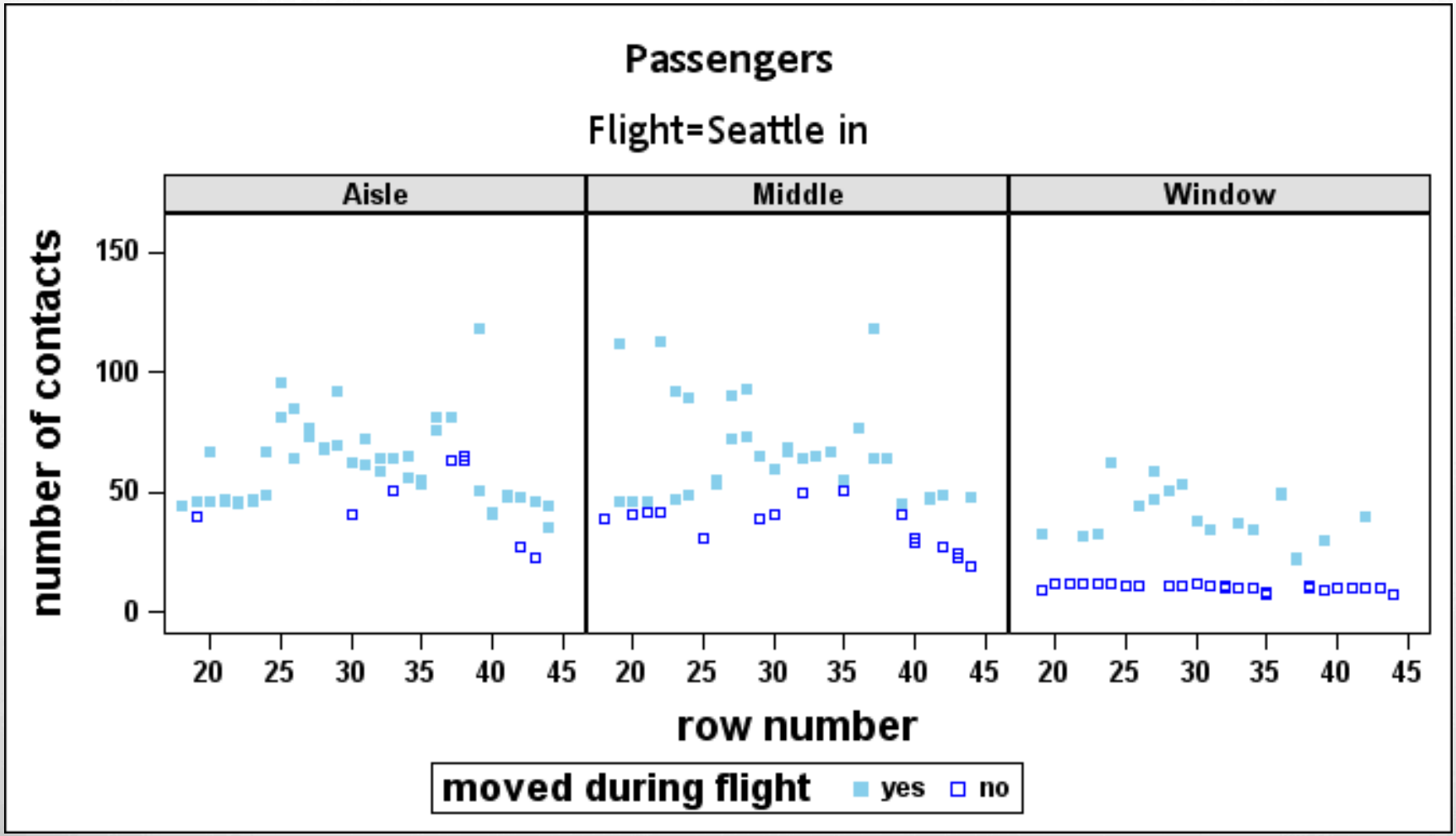
Commonly, passengers leave their seat once or twice.



Factors Influencing Quantity and Duration of Close Contacts Between Passengers

1. Behaviors
2. Seating (Aisle, Middle, Window)
3. Seat's Row
4. Length of flight
5. Time point in flight

Interplay of Row, Seating, Movement



Modeling Direct Transmission by Droplet-mediated Respiratory Virus in a Cabin

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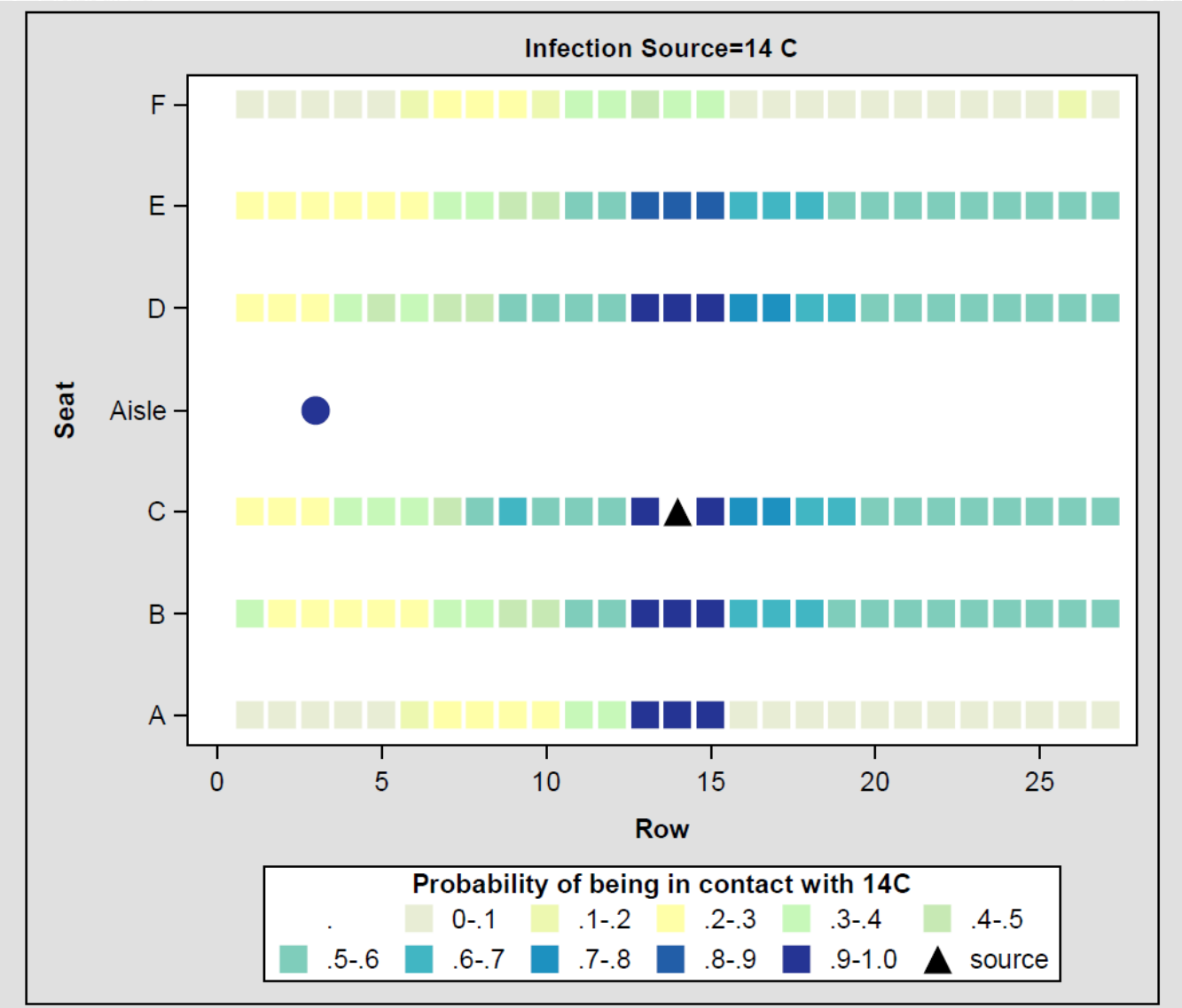
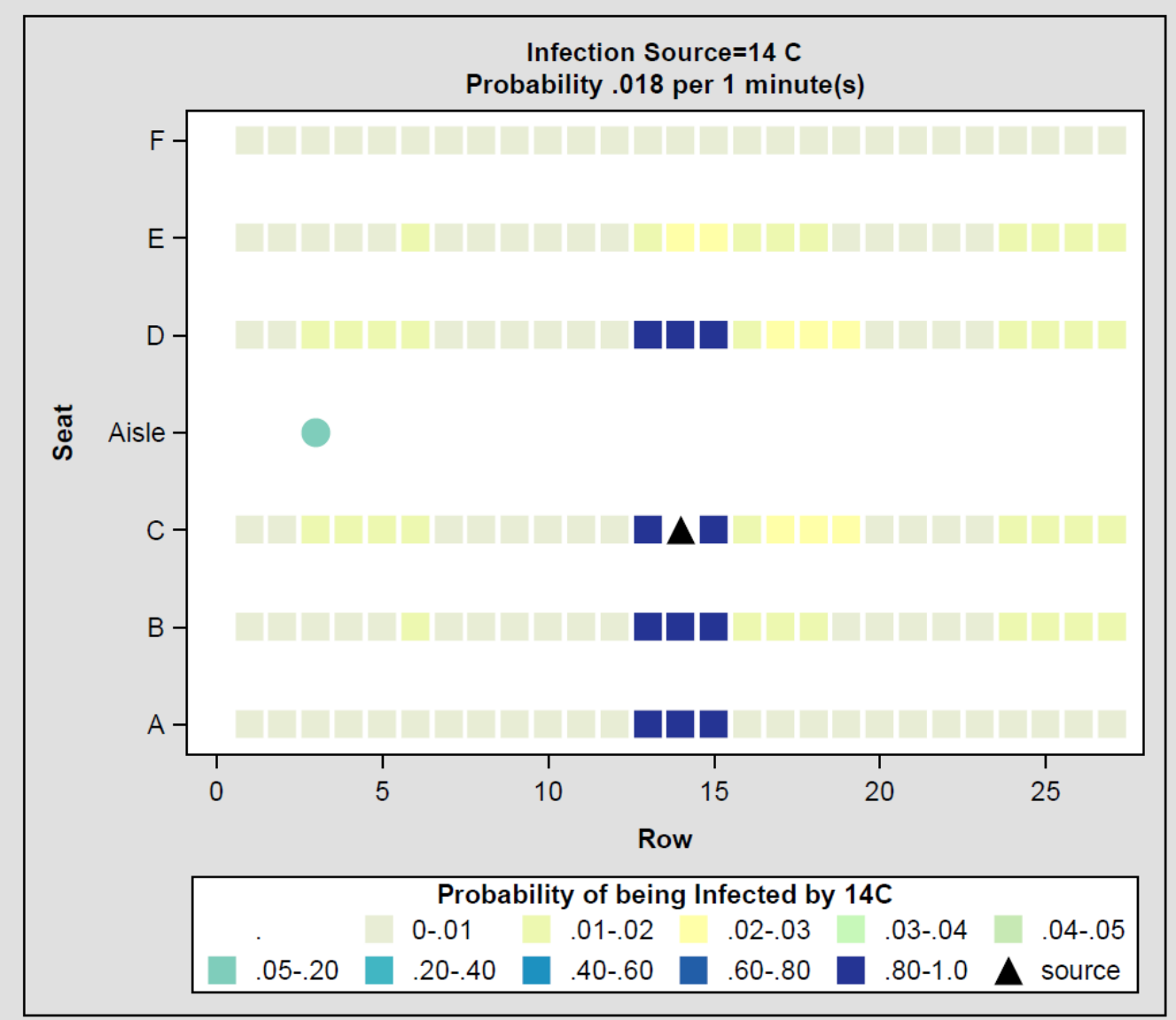
Using networks of close proximity contacts from 10 flights, generate many hundreds of thousands of 4 hour "fantasy flights"

Probability of transmission: 0.018 (2x0.009) for one minute of close contact

Moser MR*, et al.* (1979) Outbreak of influenza aboard a commercial airliner. *American Journal of Epidemiology* 110(1):1-6.


Infection Source=14 C
F
E
D
Aisle
C
B
A
Seat
0
5
10
15
20
25
Row
Probability of being in contact with 14C
.
0-.1
.1-.2
.2-.3
.3-.4
.4-.5
.5-.6
.6-.7
.7-.8
.8-.9
.9-1.0
source


Infection Source=14 C
Probability .018 per 1 minute(s)
F
E
D
Aisle
C
B
A
Seat
0
5
10
15
20
25
Row
Probability of being Infected by 14C
.
0-.01
.01-.02
.02-.03
.03-.04
.04-.05
.05-.20
.20-.40
.40-.60
.60-.80
.80-1.0
source

Models predict little transmission beyond close neighbors and crew

Possible Next Steps (with existing data)

- Where to seat an infectious passenger?
- Where to seat an immuno-compromised passenger?
- Inverse problem: given ill passengers, where was the source likely to have been seated?
- Vary
  - Radius of contact
  - Direction of contact
  - Infection process

Possible Next Steps (requiring new data)

- Aerosols
- Quantifying contacts in the gatehouse
- Quantifying contacts on long-haul flights
- Determining the role of indirect transmission via fomites

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Funding

Co-PI

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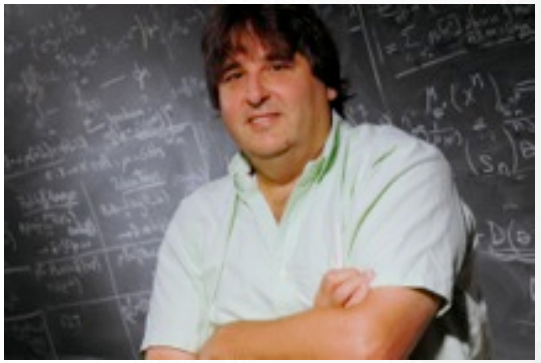

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19 Public Health/Nursing Graduate Student Observers

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Thanks also to Delta Airlines, CDC, NIOSH, TSA

Cut to video of contacts on outbound segment of LAX round-trip