WORKSHOP INTRODUCTION

Ashok Srinivasan, University of West Florida

In collaboration with

Sirish Namilae, Anuj Mubayi, Matthew Scotch, Robert Pahle, Brian Eddy, and John Coffey

VIRAL INFECTION PROPAGATION THROUGH AIR-TRAVEL

www.cs.fsu.edu/vipra

OUTLINE

- VIPRA project
- NSF CSSI grant goals
- Workshop goals

VIPRA PROJECT

MOTIVATION

- Air travel is an important factor in infection spread
- There had been calls to ban flights from Ebola infected areas
  - This can have large human and economic impact
  - Fine-tuned policy prescriptions can be as effective
    - Reassures the public that action is being taken
    - Avoids negative human and economic impacts

PROJECT GOALS

- Analyze the relative impact of different policies on spread of diseases through air-travel
  - Example: Different boarding procedures
- Why it matters
  - Provides insight to decision makers on policy or procedural choices that can reduce risk of infection spread without disrupting air travel

CHALLENGES IN MODELING

- Models yielding scientific understanding may be hard to apply to public policy analysis
  - Predictions are difficulty due to inherent uncertainties
- Aggregate-level models may be inadequate
  - Lead to coarse-scale prescriptions
- Analysis of empirical data has limitations
  - Impact of new policies difficult to evaluate
  - May not capture extreme events

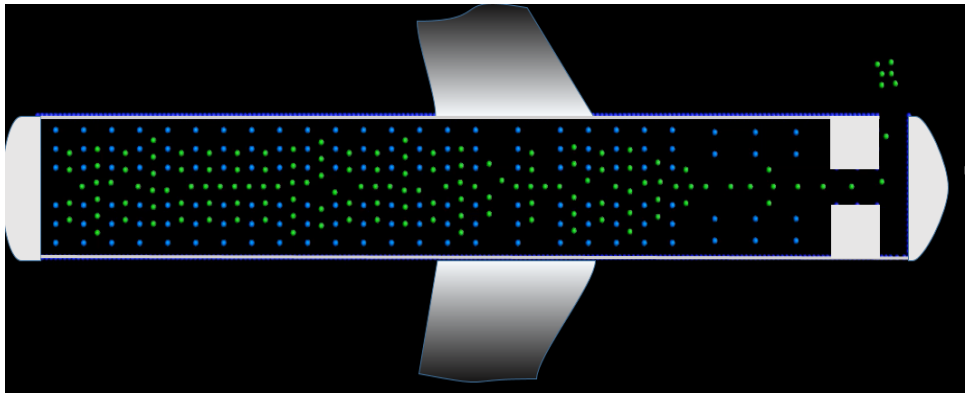
OUR MODELING APPROACH

- Use fine-scale model of human movement in planes to determine response to policies
- Parameterize sources of uncertainty
  - Parameter sweep over this space to identify vulnerability
- Link with phylogeography model to examine global consequences of local decisions

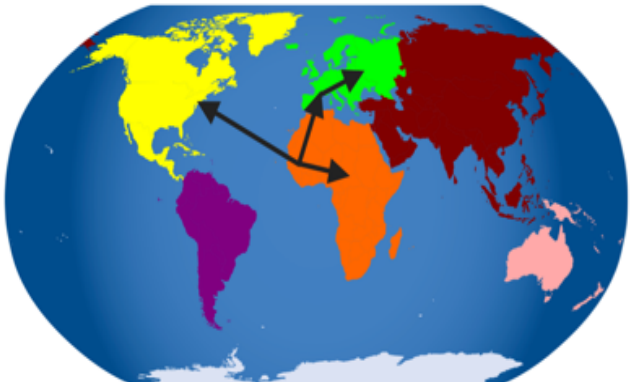
Air-travel policies to reduce infection spread

- Airport layout
- On-ground procedures
- Boarding and deplaning
- In-flight procedures

Human movement in flights and airports

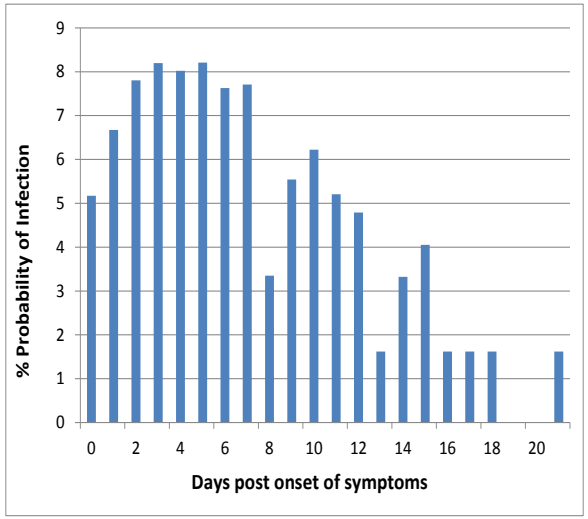


Validation and model refinement

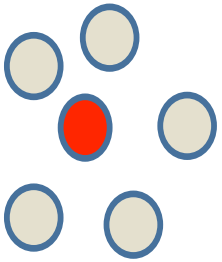


Phylogeography global model

infected per airport



Susceptible – infective stochastic model



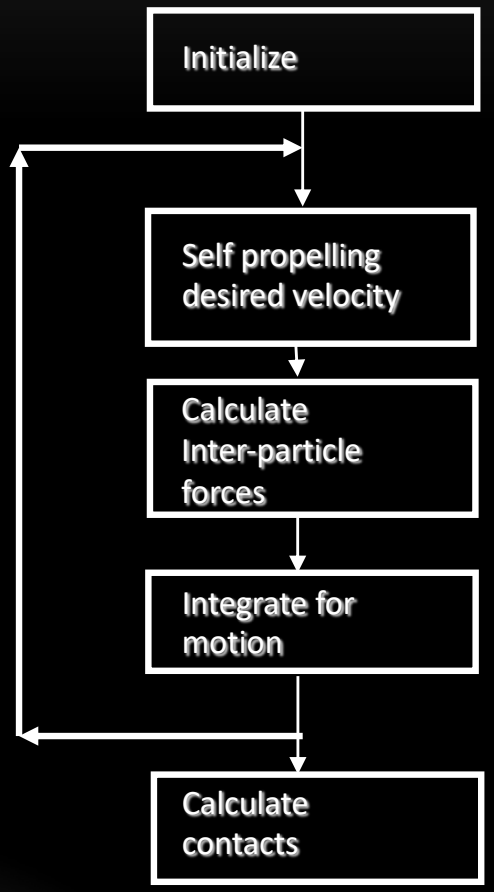
Number of contacts

QUESTIONS TO BE ANSWERED

- Can simple policies reduce infection risk without causing major disruptions?
  - Change plane type
  - Change boarding and disembarkation procedures
  - Change seating arrangements
  - Change airport layout and procedures

SELF PROPELLED ENTITY DYNAMICS MODEL

- Social dynamics is motivated by Molecular Dynamics, and treats entities as particles
  - Individuals experience self propulsion that induces them to move toward their desired goal
  - They experience repulsive forces from other persons and surfaces
- We add human behavioral characteristics to social dynamics
- Parameterize the **sources of uncertainty** and carry out a parameter sweep to identify their robustness under a variety of possible scenarios



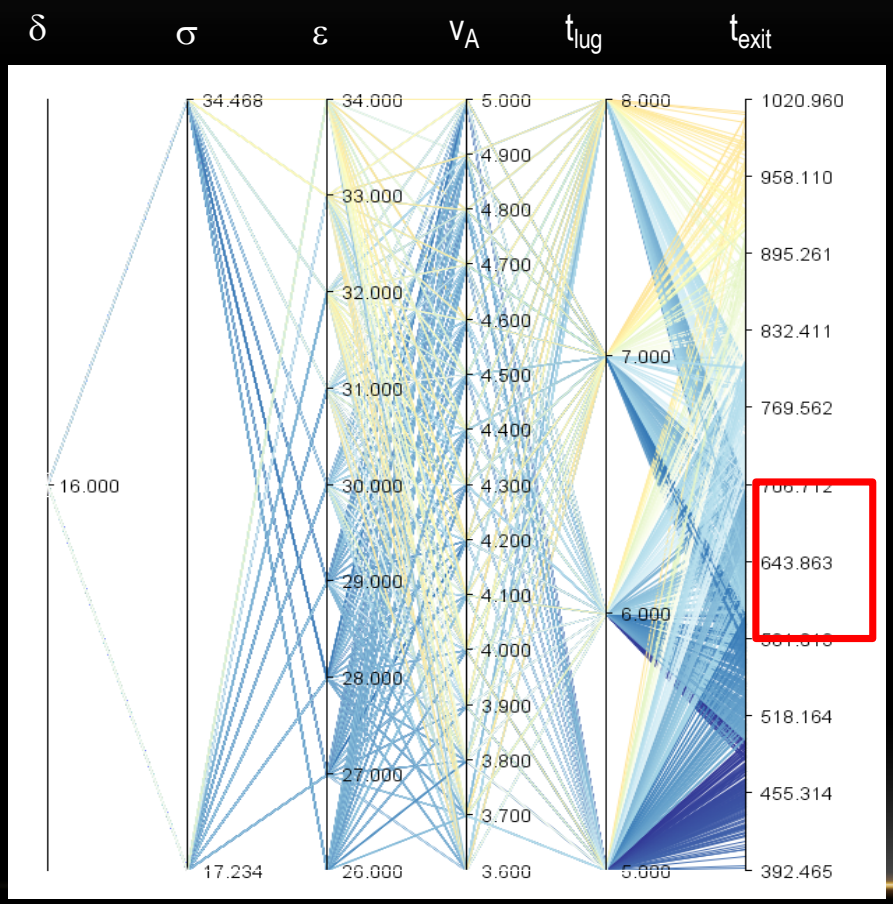
EXAMPLE OF UNCERTAINTY: PEDESTRIAN SPEED

		Manner of movement (pace)				
	Age	Slow	Ordinary	Fast	Running	Sprinting
Female	21–30	0.7–1.4	1.1–1.6	1.5–2.0	2.0–3.6	3.6–5.2
	31–40	0.8–1.3	1.1–1.5	1.5–2.1	2.0–3.7	3.9–4.5
	41–50	0.7–1.3	1.1–1.6	1.5–2.0	2.4–3.0	3.0–4.2
	51–60	0.7–1.1	1.1–1.6	1.6–2.1	2.0–3.6	2.9–4.3
Male	21–30	0.8–1.4	1.3–1.6	1.8–2.2	2.6–4.6	4.3–6.6
	31–40	1.0–1.4	1.2–1.8	1.8–2.5	2.8–4.6	4.8–6.9
	41–50	0.8–1.3	1.2–1.6	1.8–2.3	3.0–4.2	4.3–6.9
	51–60	1.0–1.3	1.3–1.6	1.8–2.1	2.6–4.2	5.0–5.7

All speeds are in m/s

From: Pedestrian speeds and accelerations, Jakub Zębala, Piotr Ciępka, Adam Reza, Problems of Forensic Science 91, (2012)

PARAMETER COMBINATIONS



Choose parameter combinations that reflect real behavior

Select a variety of distinct scenarios

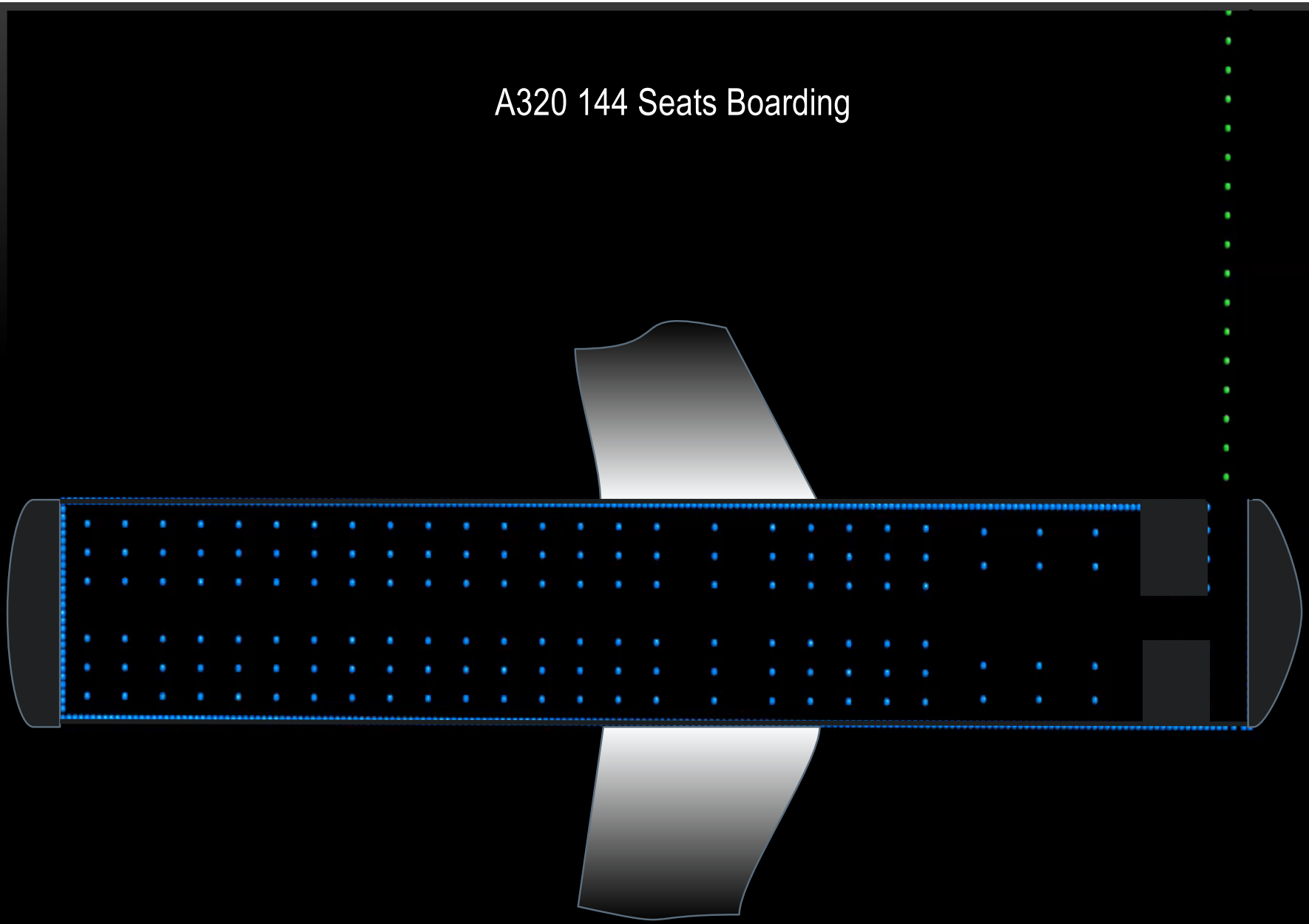
δ, σ, ε are MD parameters

V_A is avg. passenger speed in the absence of anyone in front

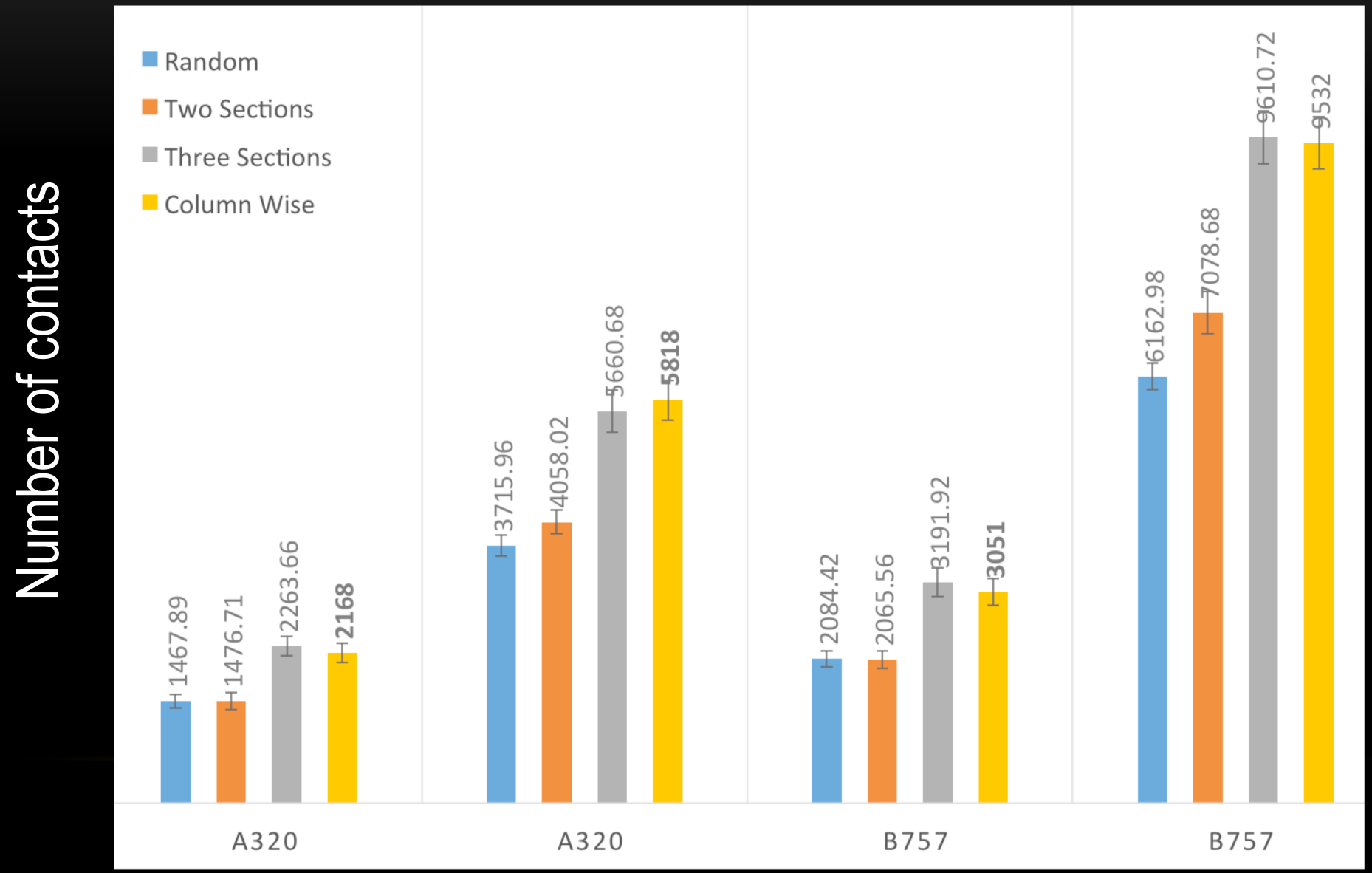
t_{lug} is the avg. time a passenger spends taking luggage out or putting luggage in the overhead bin

t_{exit} is the time for exiting the plane, obtained as simulation output

A320 144 Seats Boarding

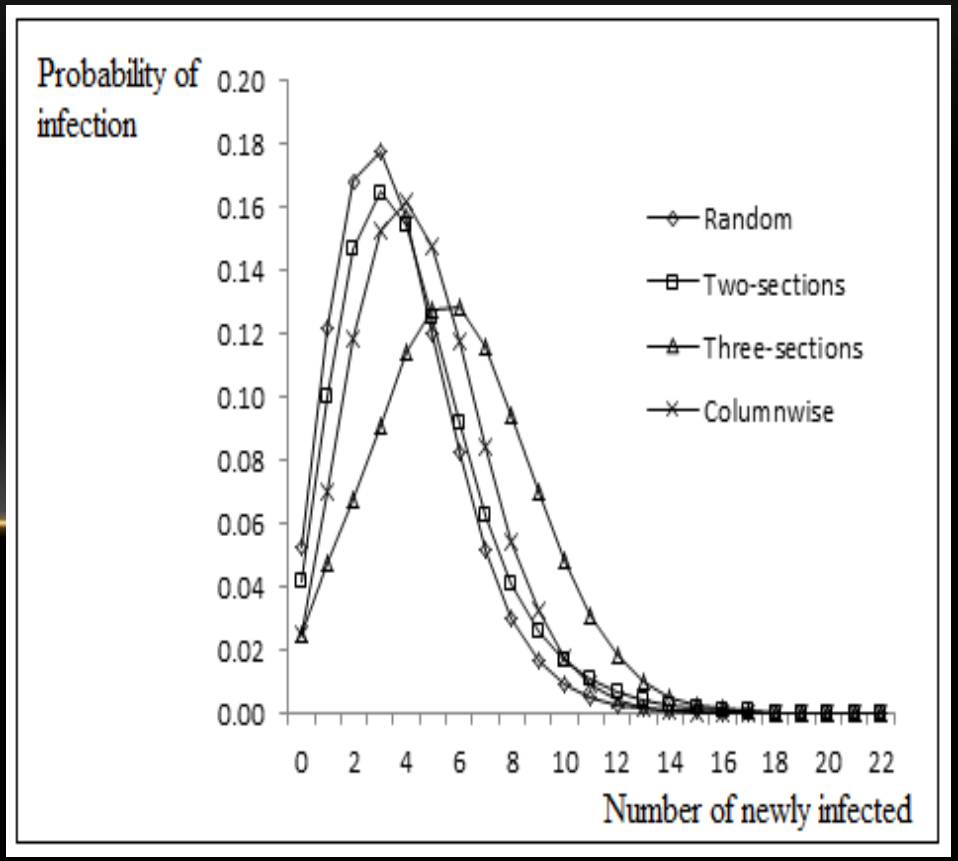


BOARDING STRATEGIES



IMPACT OF BOARDING STRATEGIES

- Boarding Boeing 757-200
  - One passenger at the first day of infection
  - Infection probability = 0.06
  - Contact radius = 1.2 m
- Strategies that prevent clustering in the cabin reduce infection likelihood



Probabilities are meant to compare different alternatives, not predict infection likelihood precisely

SUMMARY OF APPLICATION RESULTS

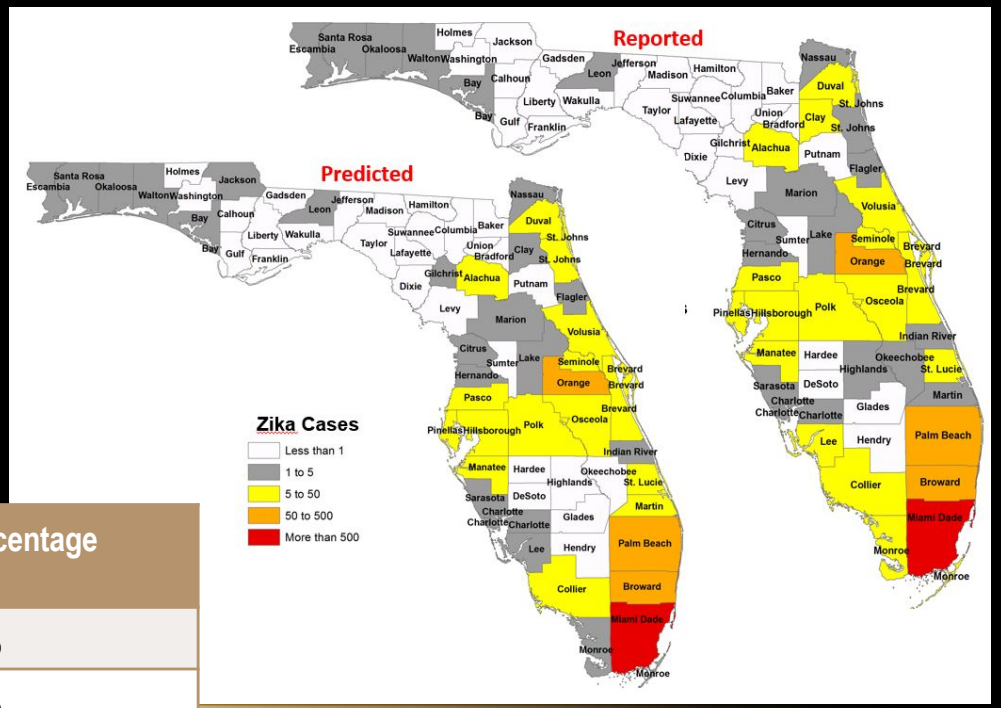
- Identified procedures that can lead to decrease in contacts
  - Random boarding leads to lower risk of infection spread
  - Boarding has a higher impact than deplaning
  - Smaller planes are better than larger ones
- Use of better procedures and smaller planes could have reduced Ebola risk by 87% without travel restrictions

FUTURE DIRECTIONS

- Assimilate data into simulation model
- Consider the consequences of air travel

Zika importation risk prediction

- Identify human mobility from social media data and link with metapopulation epidemic model
- Fine-grained results predict locations within Miami with granularity of the order of a square mile



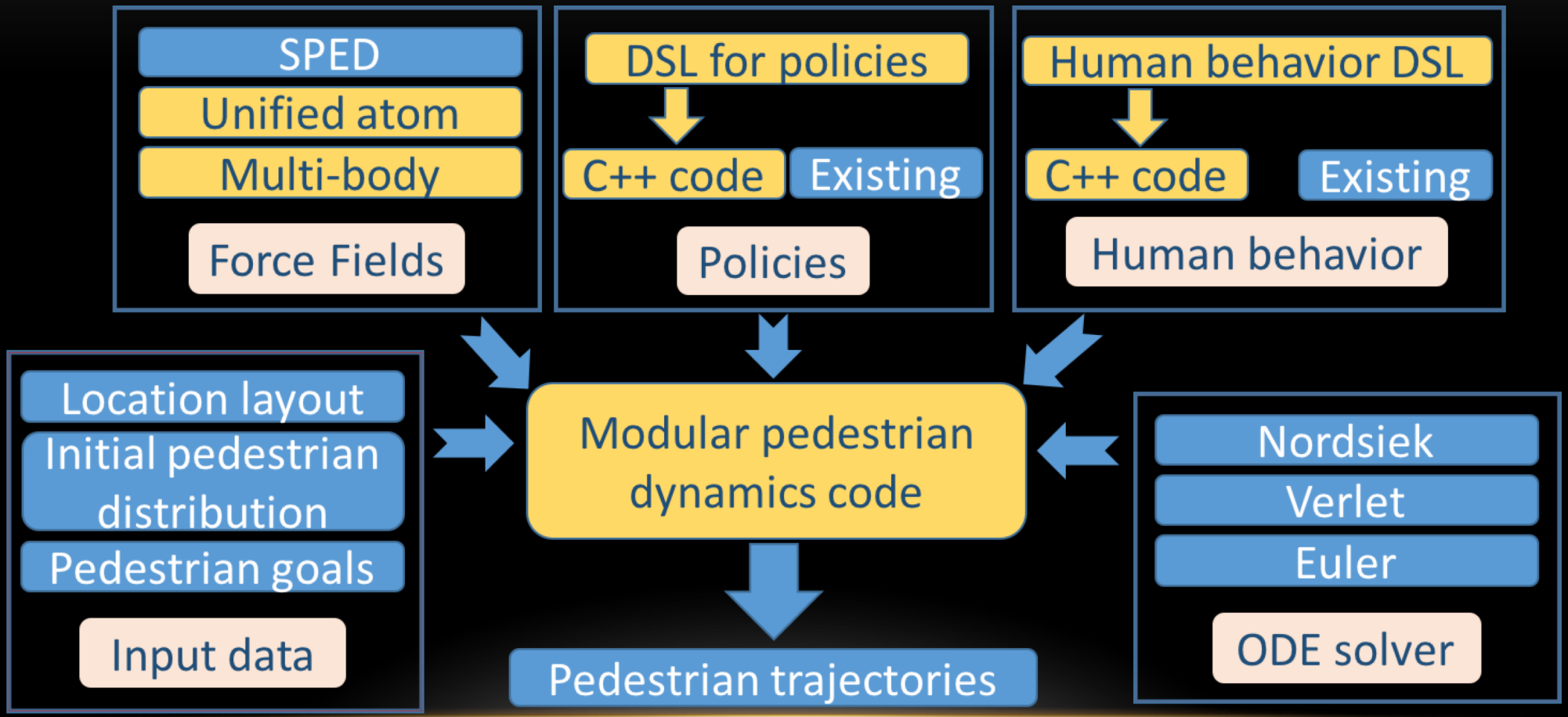
Top neighborhoods for Puerto Rico residents	Percentage	Top neighborhoods for Miami residents	Percentage
Miami Airport	16.9%	Downtown	25%
Marlin Parks	14.2%	Miami Beach	20%
Wynwood	14.0%	Wynwood	10%
InterContinental	13.5%	Miami Airport	10%
Miami Beach	10.0%	Allapattah	10%

NSF CSSI GRANT GOALS

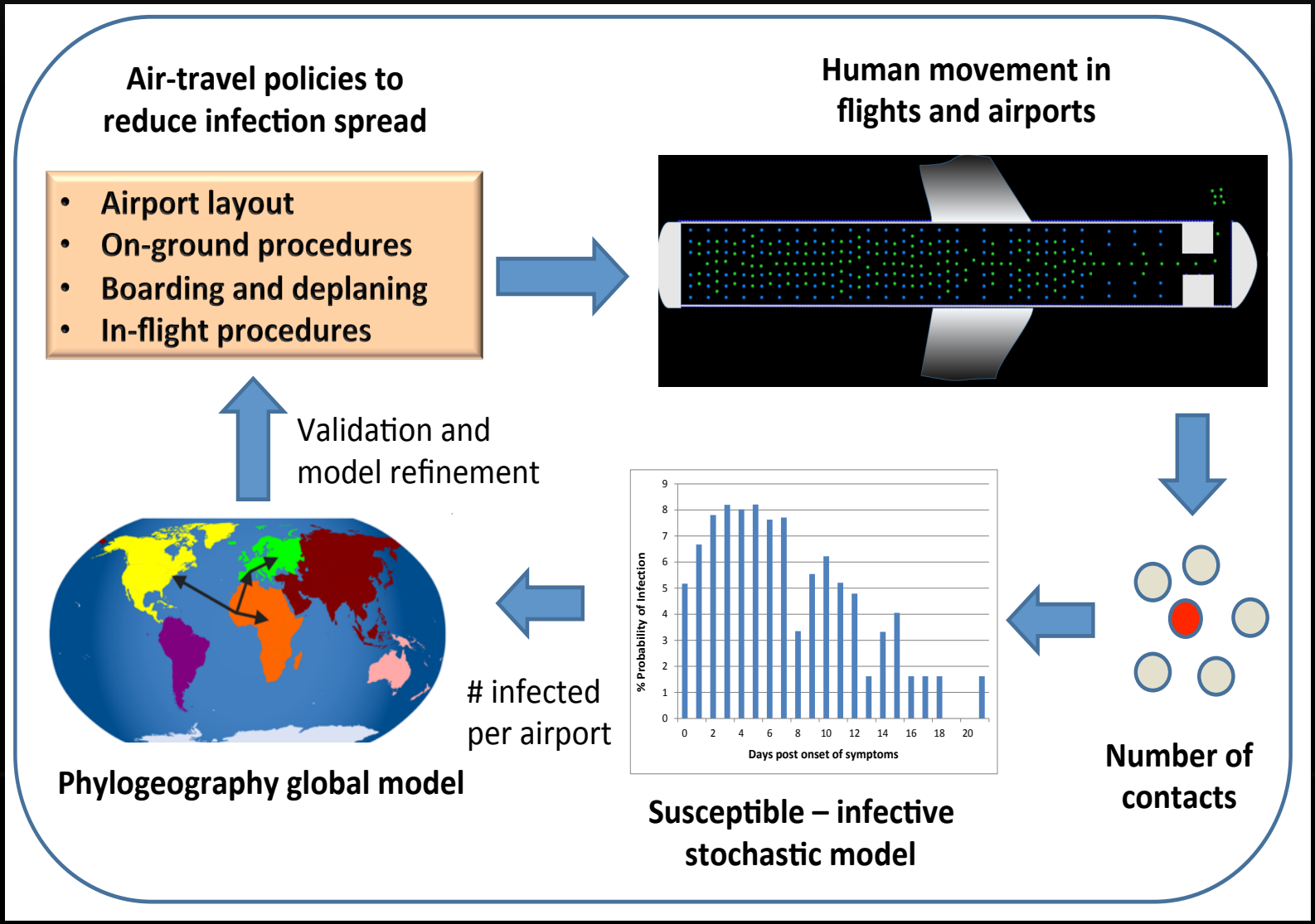
BROAD GOALS

- A modular software for pedestrian dynamics
  - Enable code contributions from the research community
- A workflow to link pedestrian dynamics with epidemic and phylogeography models
- Tools and data to permit rigorous analysis and validation
- Interfaces for researchers and decision makers to visualize their results

PEDESTRIAN DYNAMICS SOFTWARE



WORKFLOW


Air-travel policies to reduce infection spread
Airport layout
On-ground procedures
Boarding and deplaning
In-flight procedures
Human movement in flights and airports
Validation and model refinement
Phylogeography global model
infected per airport
% Probability of Infection
Days post onset of symptoms
Susceptible – infective stochastic model
Number of contacts

TOOLS AND DATA

- Tools
  - Uncertainty analysis
  - Parameter sweep
  - Others?
- Data for validation and analysis
  - Summary of LBS data from Florida
  - Others?

WORKSHOP GOALS

BROAD GOALS

- Identify desirable features for the pedestrian dynamics software
- Identify desirable features of the workflow to link pedestrian dynamics and epidemic models
- Identify the types of questions that decision-makers would want scientists to answer
- Develop plans for a research community that leverages pedestrian dynamics for modeling disease spread
  - Plan a “perspectives”-type paper, perhaps
  - Think about a frameworks proposal for the future

WORKSHOP FORMAT

- Short talks that provide a high-level view of research trends in different sub-fields
  - Discussion at lunch for a research agenda linking these fields
- Discussion with decision makers to identify their needs
  - What questions should we answer and what type of science should we perform?
- Identify software features that will lead to a sustainable community code and develop a user base
- Finalize plans for the above on the second day