Homeland Defense & Security
Information Analysis Center

Predicting the Immediate Civilian Reaction to a Nuclear WMD Event

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Center for Social Complexity
Department of Computational & Data Sciences

August 19, 2019

Introduction

HDIAC & Today's Topic

HDIAC Overview

What is the Homeland Defense & Security Information Analysis Center (HDIAC)?

- One of three Department of Defense Information Analysis Centers managed by DoDIAC at Fort Belvoir
- Responsible for acquiring, analyzing, and disseminating relevant scientific and technical information, in each of our eight focus areas, in support of the DoD and U.S. government R&D activities

HDIAC's Mission

Our mission is to be the go-to R&D, S&T, and RDT&E leader within the homeland defense and security (HDS) community, by providing timely and relevant information, superior technical solutions, and quality products to the DoD and HDS Communities of Interest/Communities of Practice.

HDIAC Subject Matter Expert Network

Our Subject Matter Expert (SME) Network is comprised of qualified professionals whose expertise falls within HDIAC's eight focus areas.

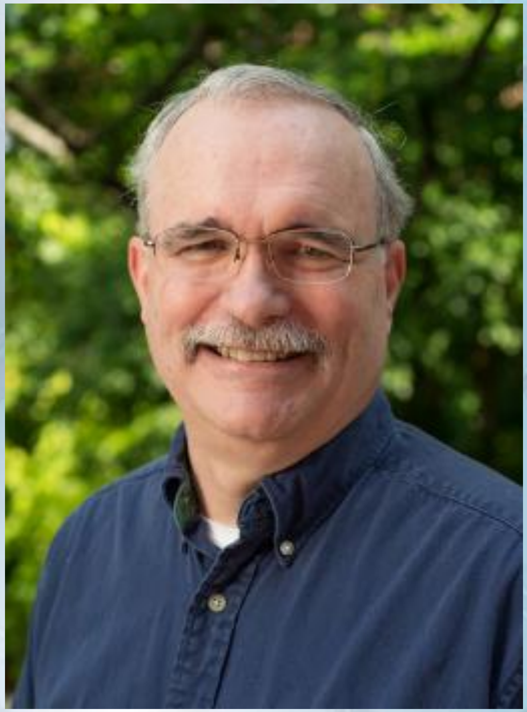
Individuals are vetted based on experience, education, professional practice, and publication.

SMEs are involved in a variety of HDIAC activities:

- Authoring HDIAC Journal/Spotlight articles
- Presenting Webinars
- Contributing to Tech Talks
- Answering Technical Inquiries
- Assisting with Core Analysis Tasks
- Engaging in discussions within the HDIAC community

If you are interested in joining the HDIAC SME Network, please visit HDIAC.org or email info@hdiac.org.

Presenter



Dr. William G. Kennedy is an associate professor at George Mason University. Before coming to Mason in 2008, he had completed full careers in the U.S. Navy (30 years in the Submarine Service and the Naval Reserves) and with the federal government (Nuclear Regulatory Commission [10 years] and then Department of Energy [15 years]). He earned a Ph.D. in Information Technology in 2003 (Artificial Intelligence) and retired from federal civil service two years later.

A three-year post-doc at the Naval Research Laboratory in cognitive robotics changed his research interests toward Cognitive Science. His research is now in modeling cognitive processes, such as learning and trust, and modeling human behavior in agent-based models of groups and societies. His research home is the Center for Social Complexity in the Krasnow Institute for Advanced Study, but he is also also affiliated with the College of Science’s Department of Computational and Data Science and teaches for both the Computational Social Science program and the Department of Psychology.

Outline

- Introduction
- Resources Extending Our Research
- Synthetic Population and Routine Behavior
- Modeling Weapons Effects and Initial Behaviors
- Characterizing the Population’s Reaction
- Publications
- Plans & Further Work

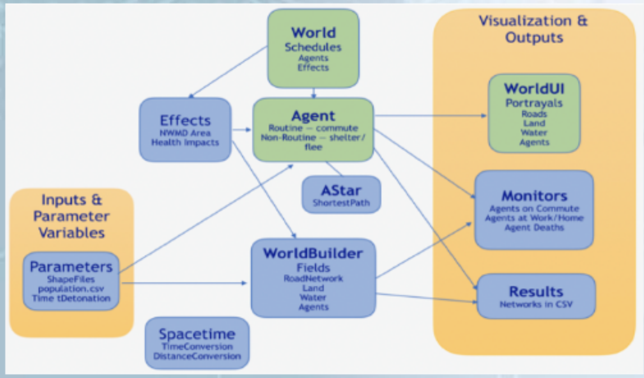
A Framework for Modeling Society Following a Nuclear WMD Event

W.G. Kennedy, George Mason University,

Grant: HDRA1-16-0043

Objective: Characterize the reaction of the population of a mega-city to a nuclear WMD event.

Method: Build a 1:1 agent-based model of the population with heterogeneous, individual agents interacting with their environment, the WMD event, and each other emerging the society-level reaction such as medical/ humanitarian assistance needs and migration.



Status of effort: Added weapons effects and reactive behaviors to the agent-based model and collected results of many runs.

Personnel Supported: 2 faculty part time, 2 graduate students (full time) and 1 graduate student (part time)

Publications & Meetings: One peer reviewed long review article published, 1 in revision, 3 symposia & workshop presentations, and 5 national and international conference presentations and posters.

1. Review literature, collect & model infrastructure data, and synthesize population & social networks
2. Implement full scale model of entire New York City region with routine (control) & disaster behaviors.
3. Validate behaviors over first minutes, hours, days after a nuclear WMD event.
4. Enhance fidelity of modeling of behaviors.
5. Conduct experiments exploring variations.

Funding Profile

$149K FY'16 $154K '17 $159K '18 $150K '19 & 20

Contact information: W.G. Kennedy, PhD, Captain, USN (Ret.) wkennedy@gmu.edu, (703 993-9291)

Objective

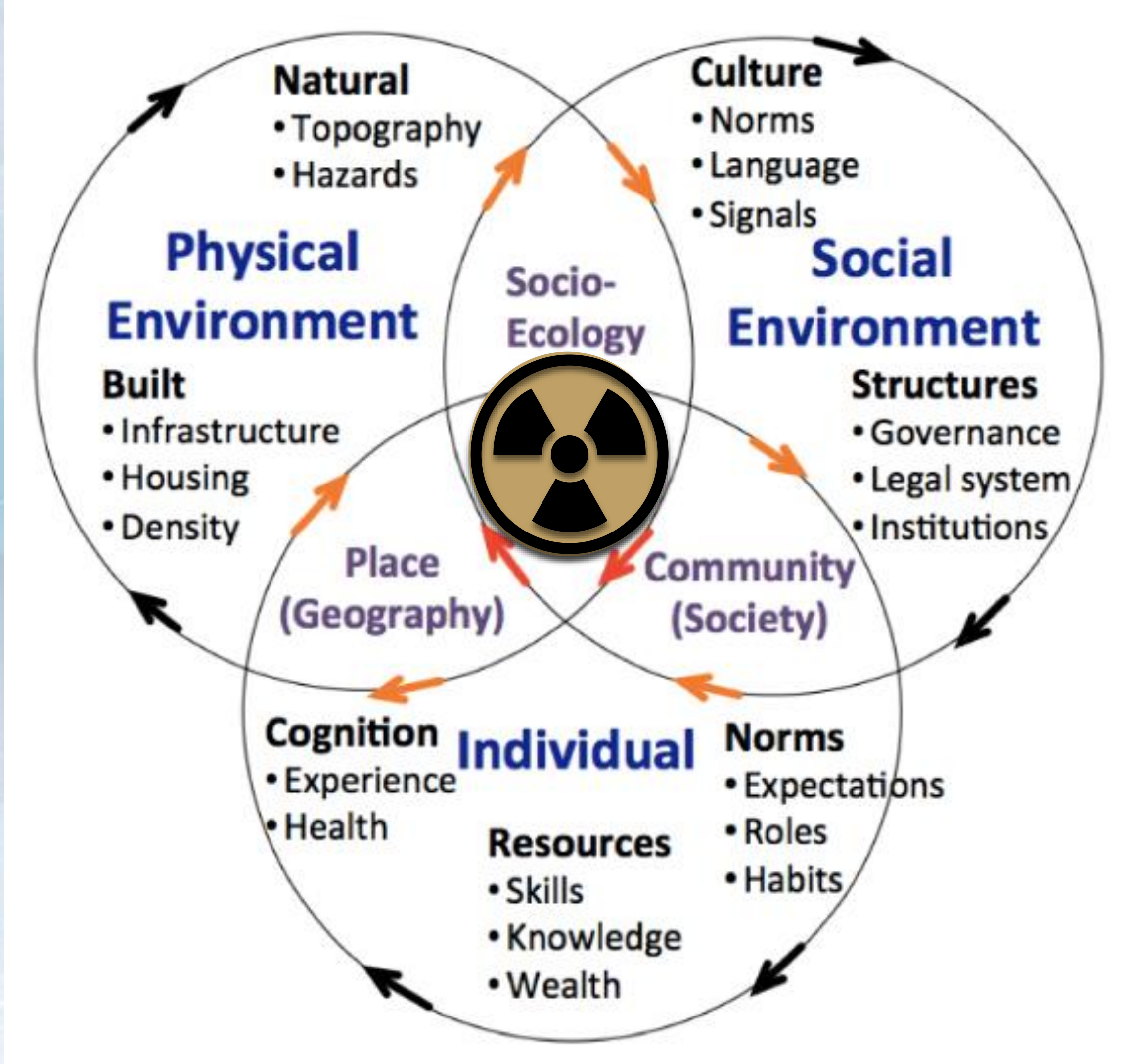
The objective of this research is to characterize the reaction of the population of a megacity and surrounding region to a nuclear WMD event.

The Nature of The Task

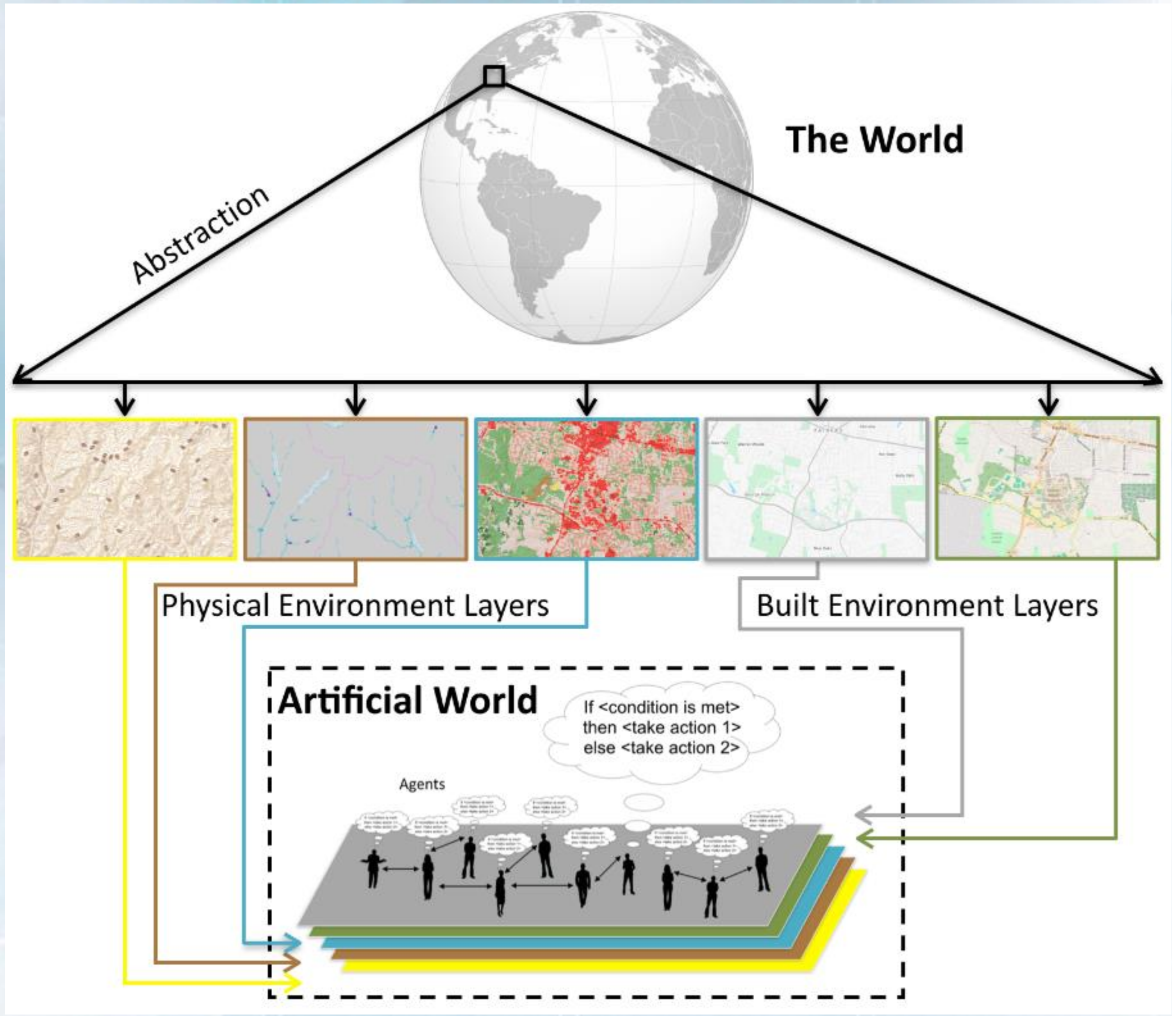
- Murray Gell-Mann: “Imagine how much harder physics would be if electrons could think.”
- Richard Feynman: “Can you imagine how hard physics would be if electrons had feelings?”

Big Picture

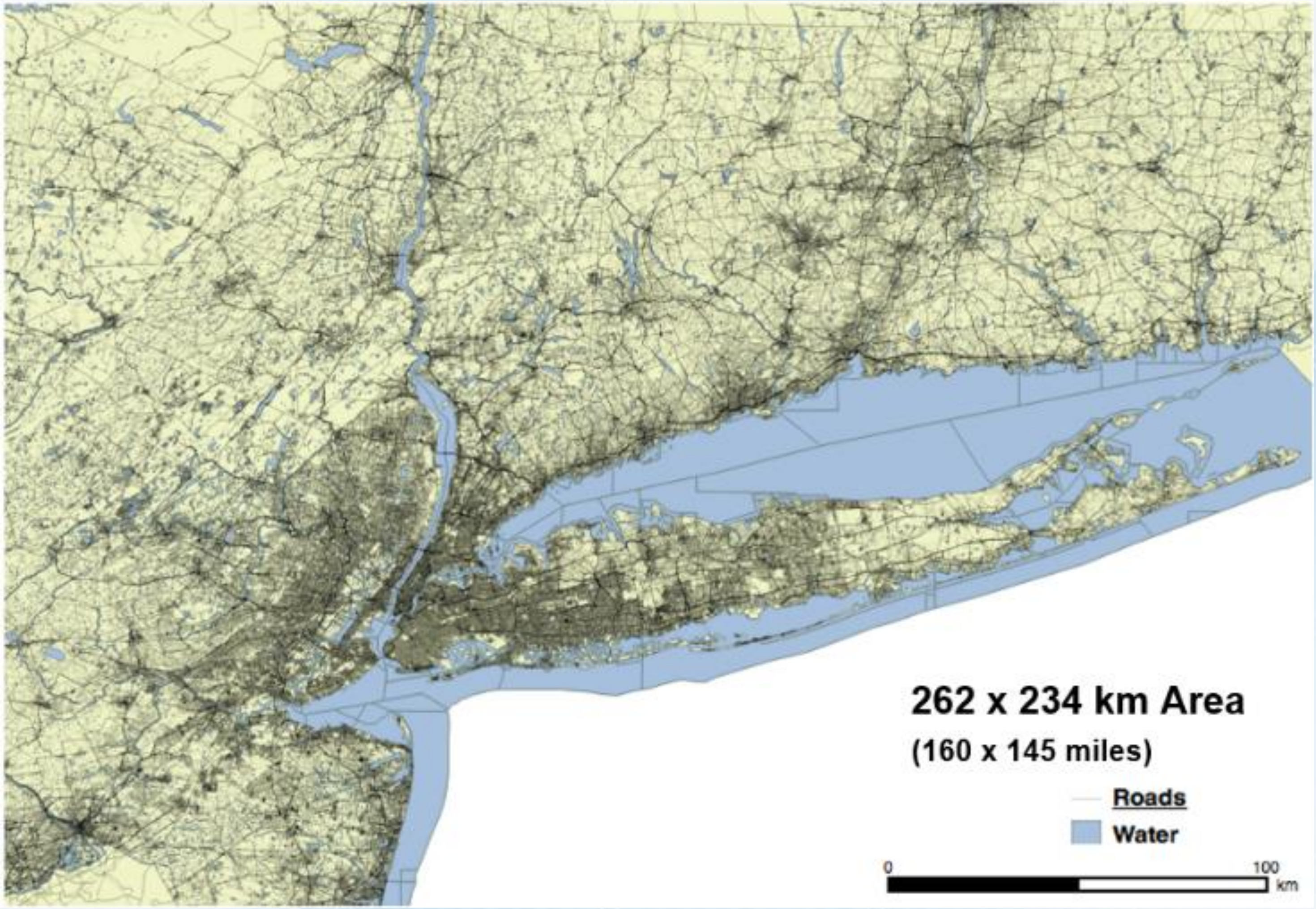
- Finished year 3, started first extension year
- **First year:** literature review and pilot models
- **Second year:** scaled modeling up and first runs
- **Third year:** explored and characterized behavior
- **Fourth year:** refine and enhance modeling fidelity
- **Fifth year:** explore characterization of reactions


Natural
• Topography
• Hazards
Culture
• Norms
• Language
• Signals
Physical Environment
Socio-Ecology
Social Environment
Built
• Infrastructure
• Housing
• Density
Structures
• Governance
• Legal system
• Institutions
Place (Geography)
Community (Society)
Cognition
• Experience
• Health
Individual
Norms
• Expectations
• Roles
• Habits
Resources
• Skills
• Knowledge
• Wealth

Capturing the Physical Environment



Study Area: NYC and its Region: CT, MA, NJ, NY, PA, RI



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- Progress, Plans, & Further Work

Resource Challenge

- **Project creates valuable students**
- **Turnover**
- **Creative resourcing: volunteers**

Resources

- 3 USAF Cadets majoring in Behavioral Sciences
- Two local high school students
- New Grad Student started in Fall
- Undergrad added in Fall, became a grad student

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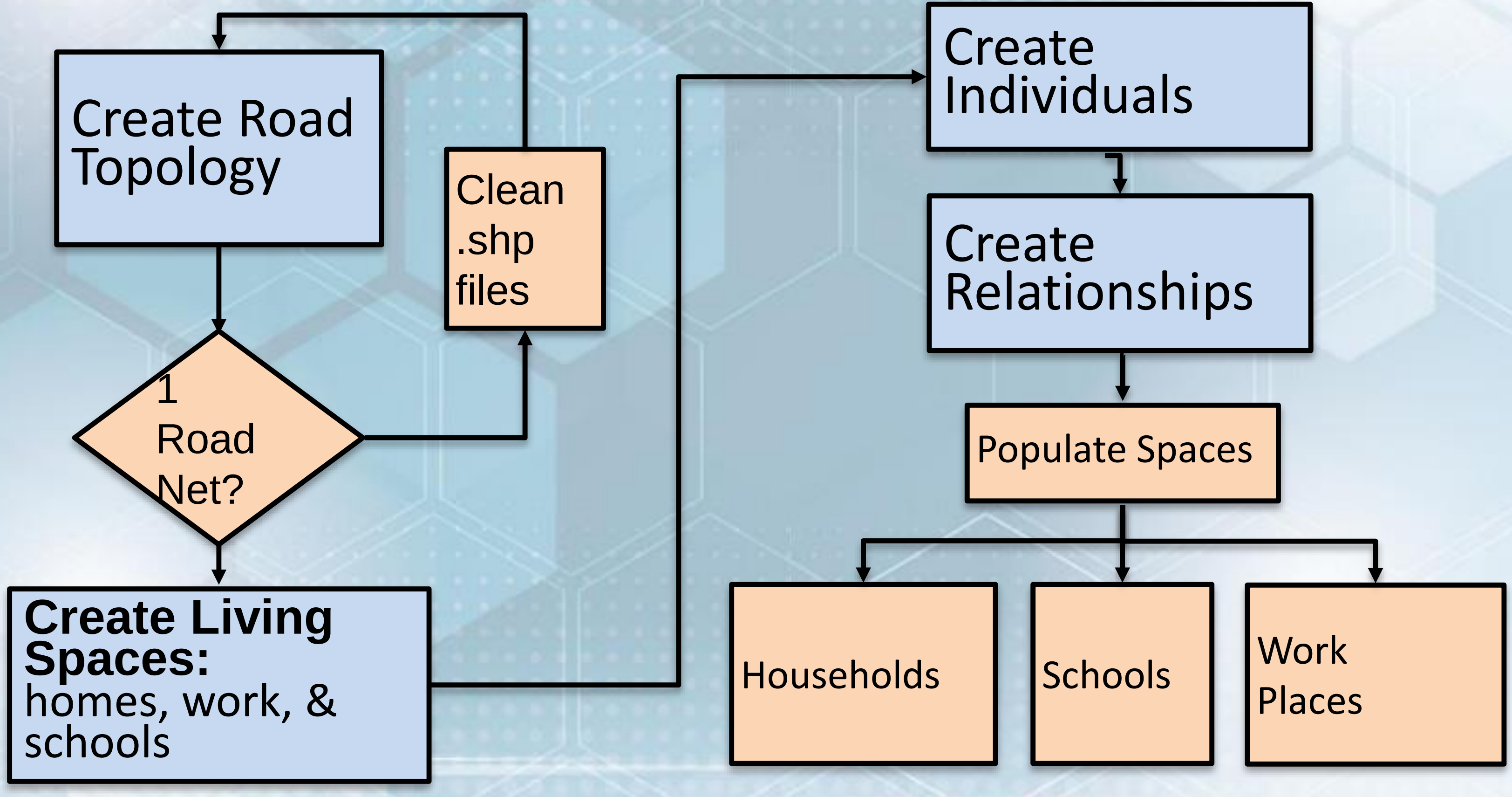
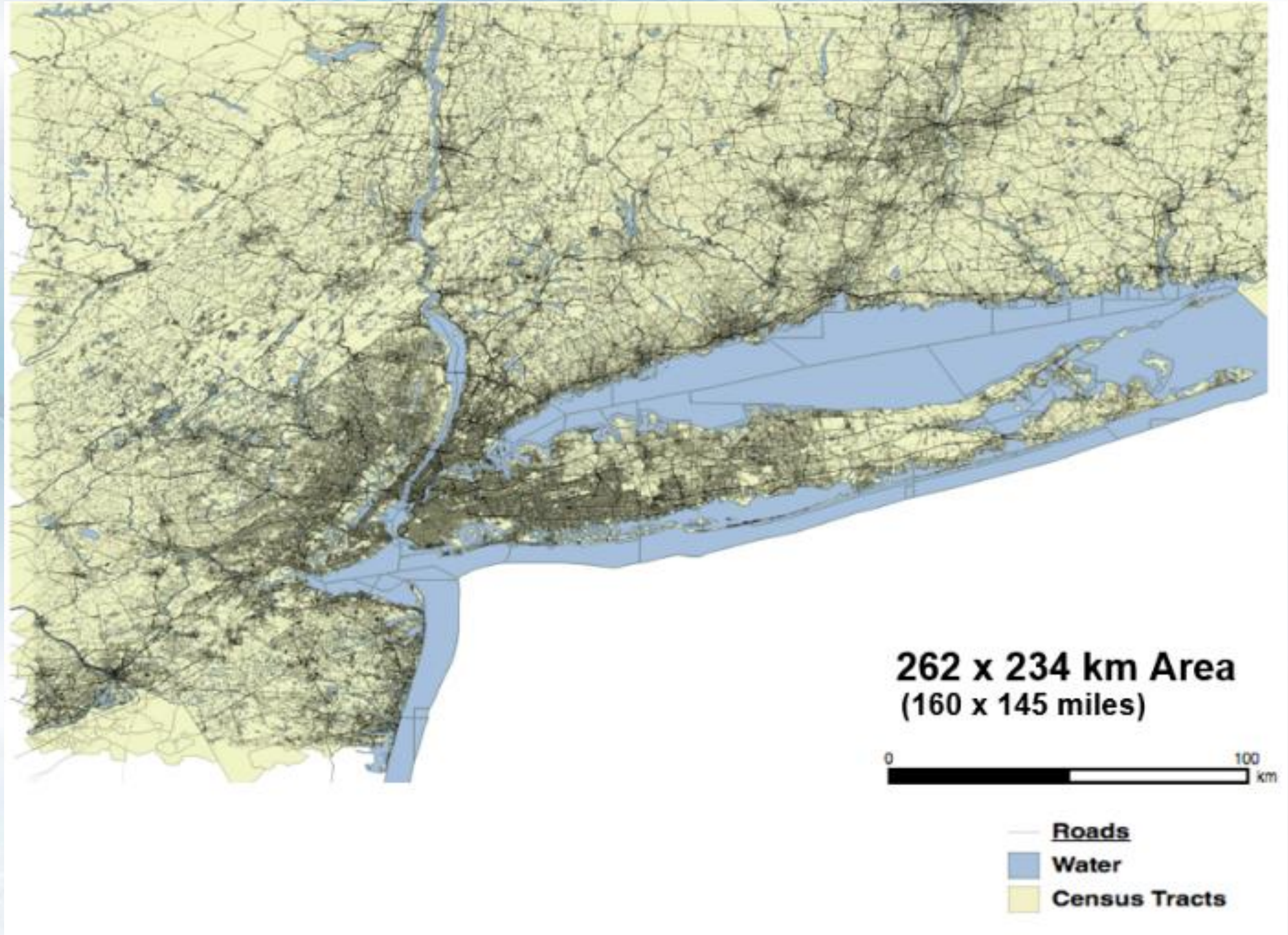
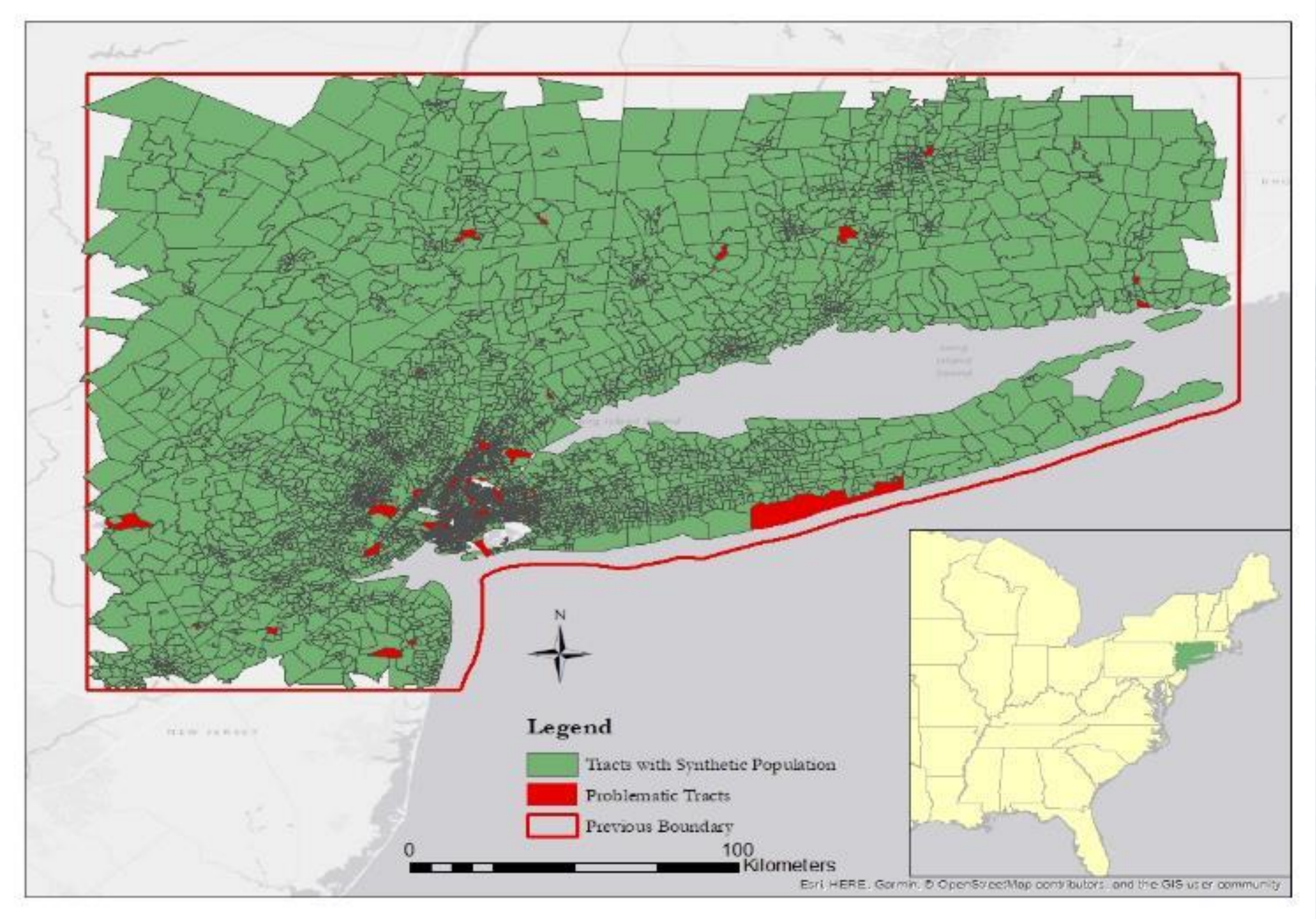
Population and Network Synthesis



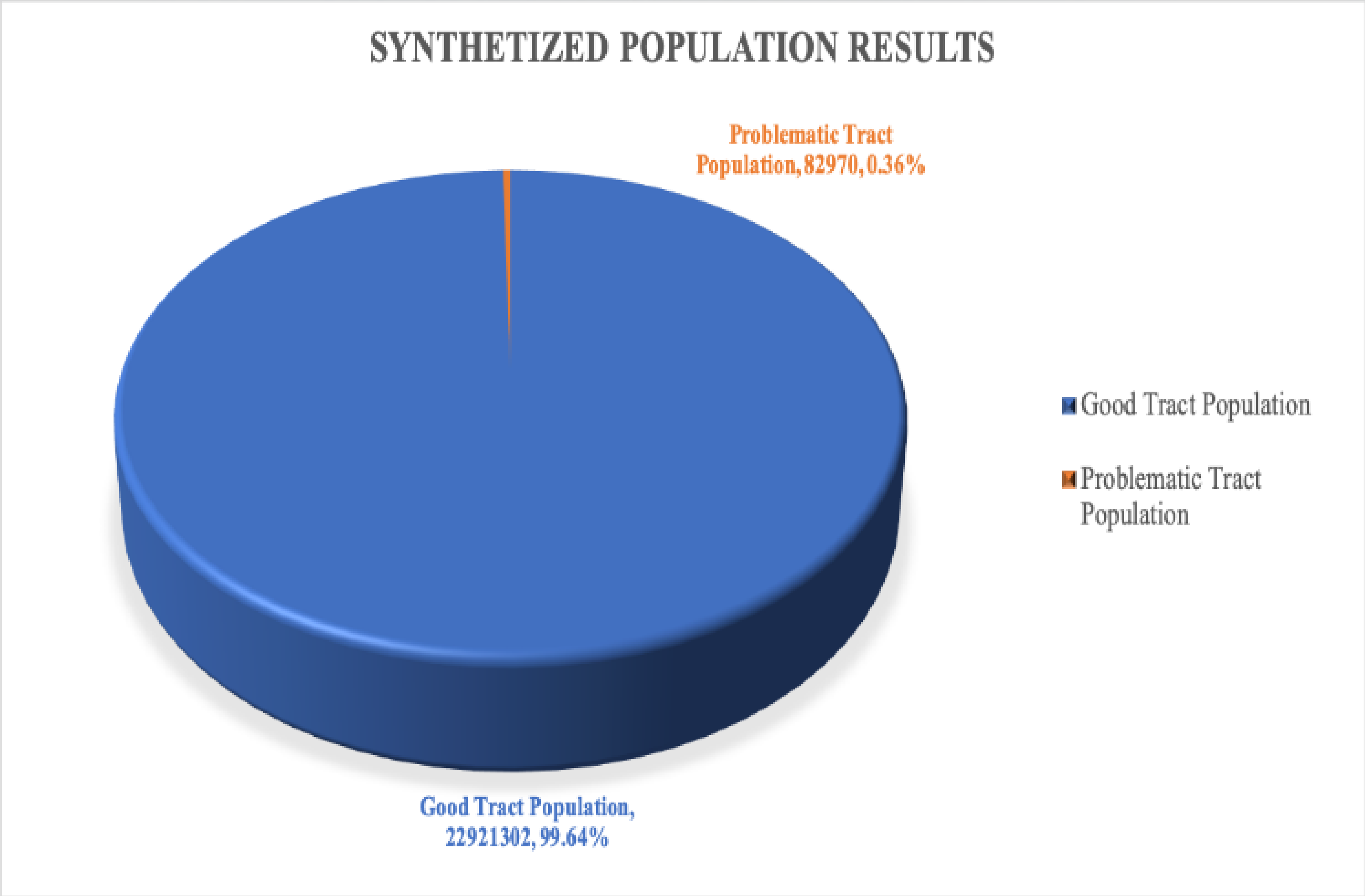
Improved Synthetic Population



Improved Synthetic Population



Improved Synthetic Population

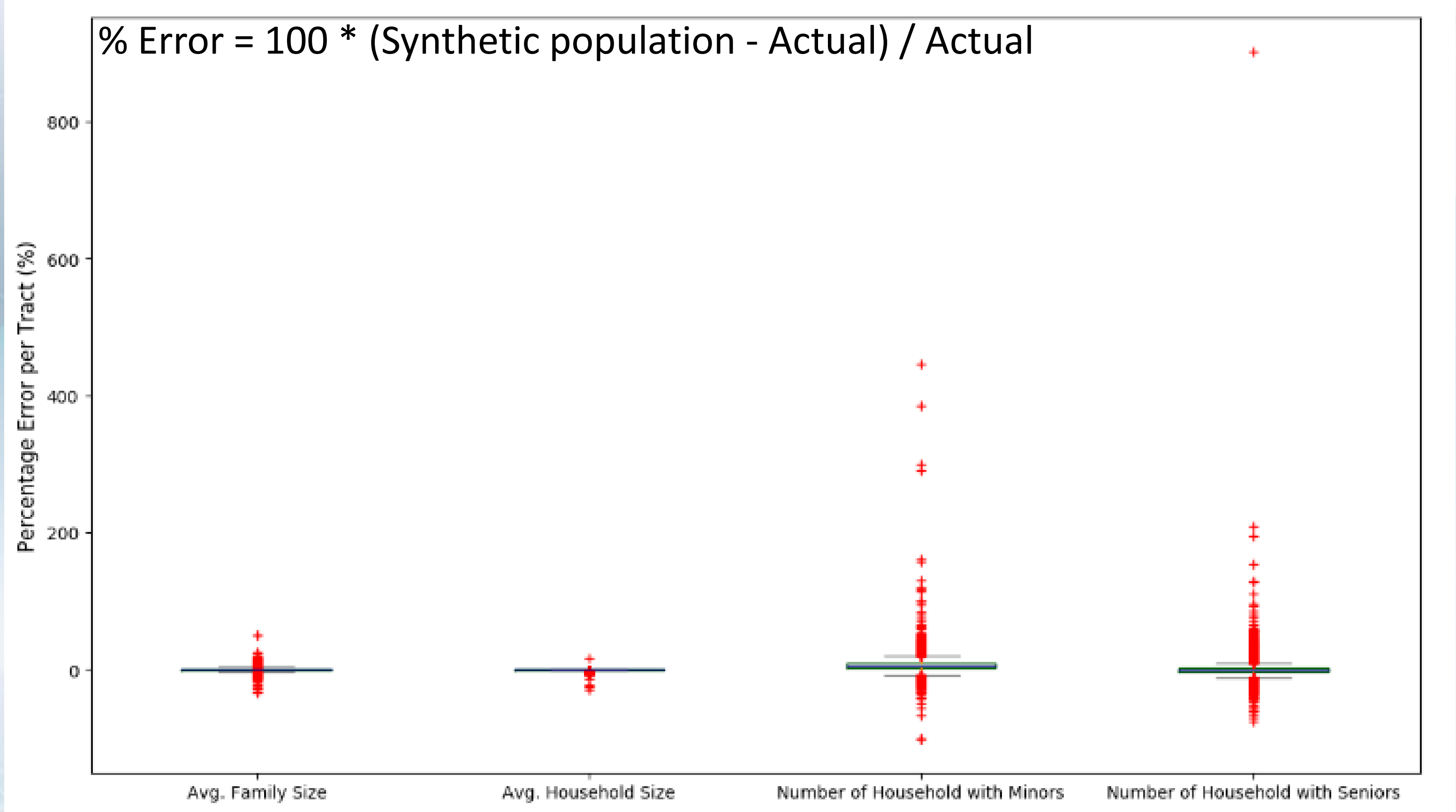


Validating the Synthetic Population

Two part process:

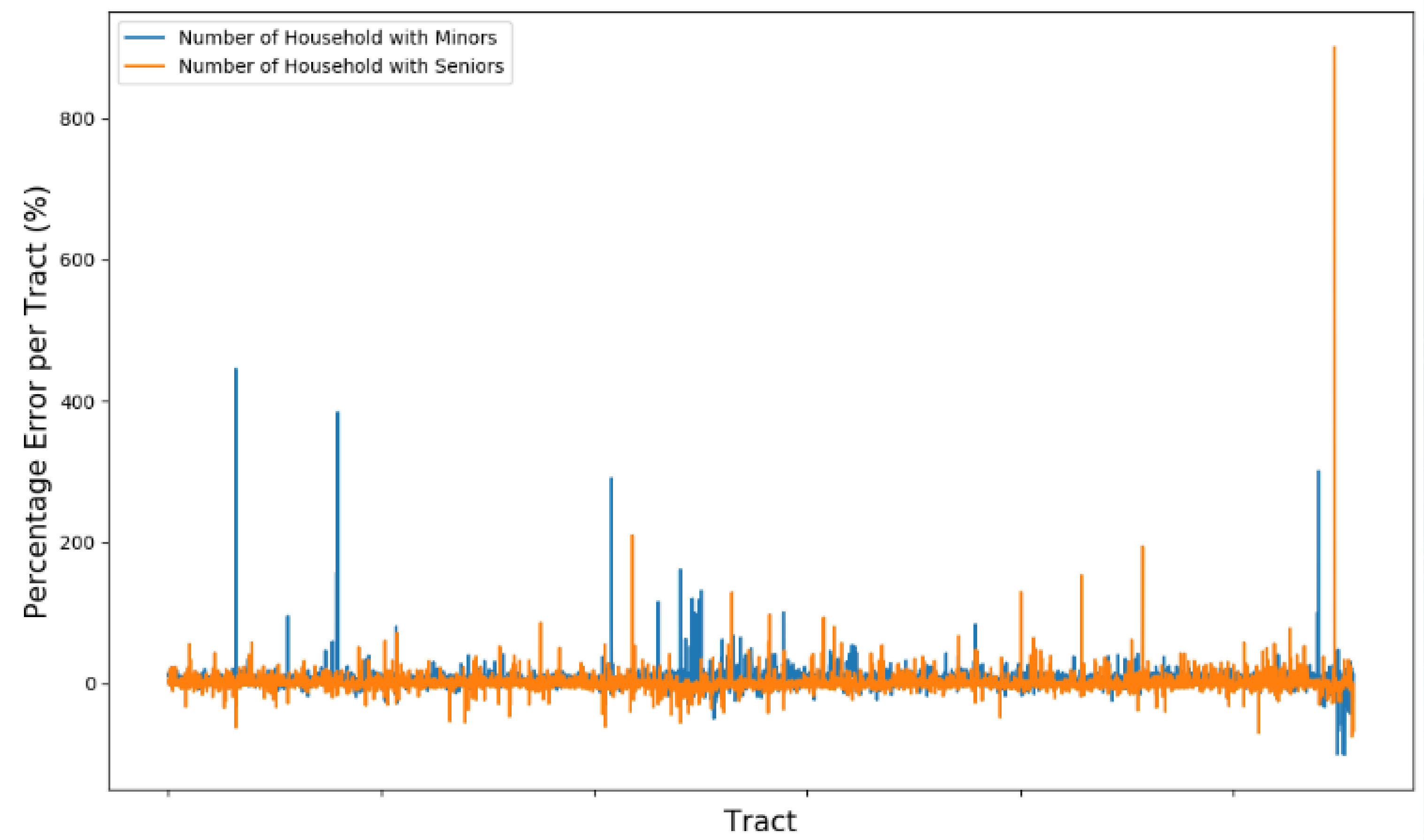
1. Compare to aggregates from the US 2010 Decennial census
2. Compare to the 2010 U.S. Synthetic Population (from RTI International)
   - Models of Infectious Disease Agent Study (MIDAS) funded by the National Institute for General Medical Sciences (NIGMS)
   - 2010 Decennial census and the Public Use Microdata Sample (PUMS) from the American Community Survey (ACS)

Previous Synthetic Population vs. the Census Bureau Data



Percentage error per tract comparing our synthetic population with the Census

Previous Synthetic Population vs. the Census Bureau Data



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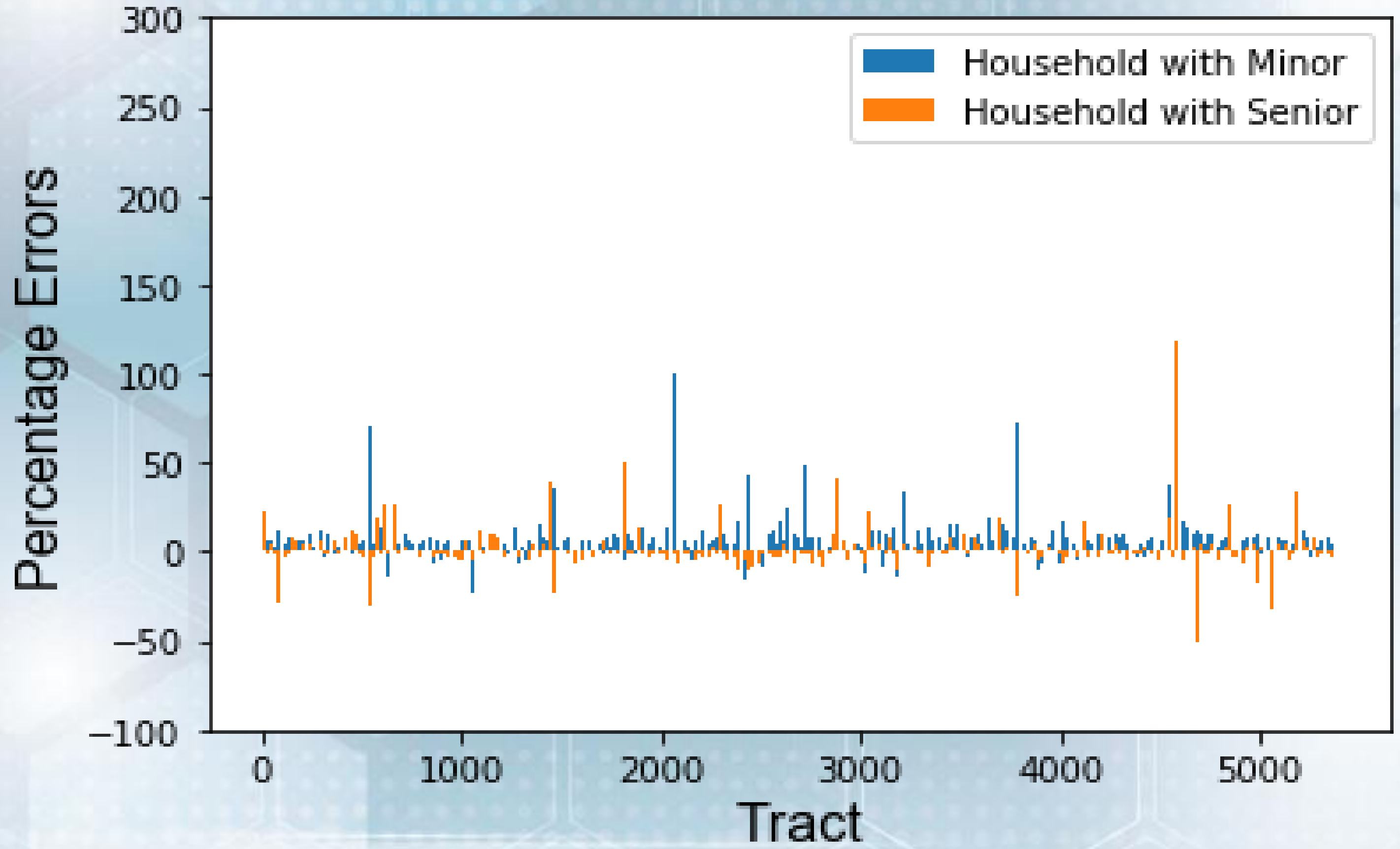
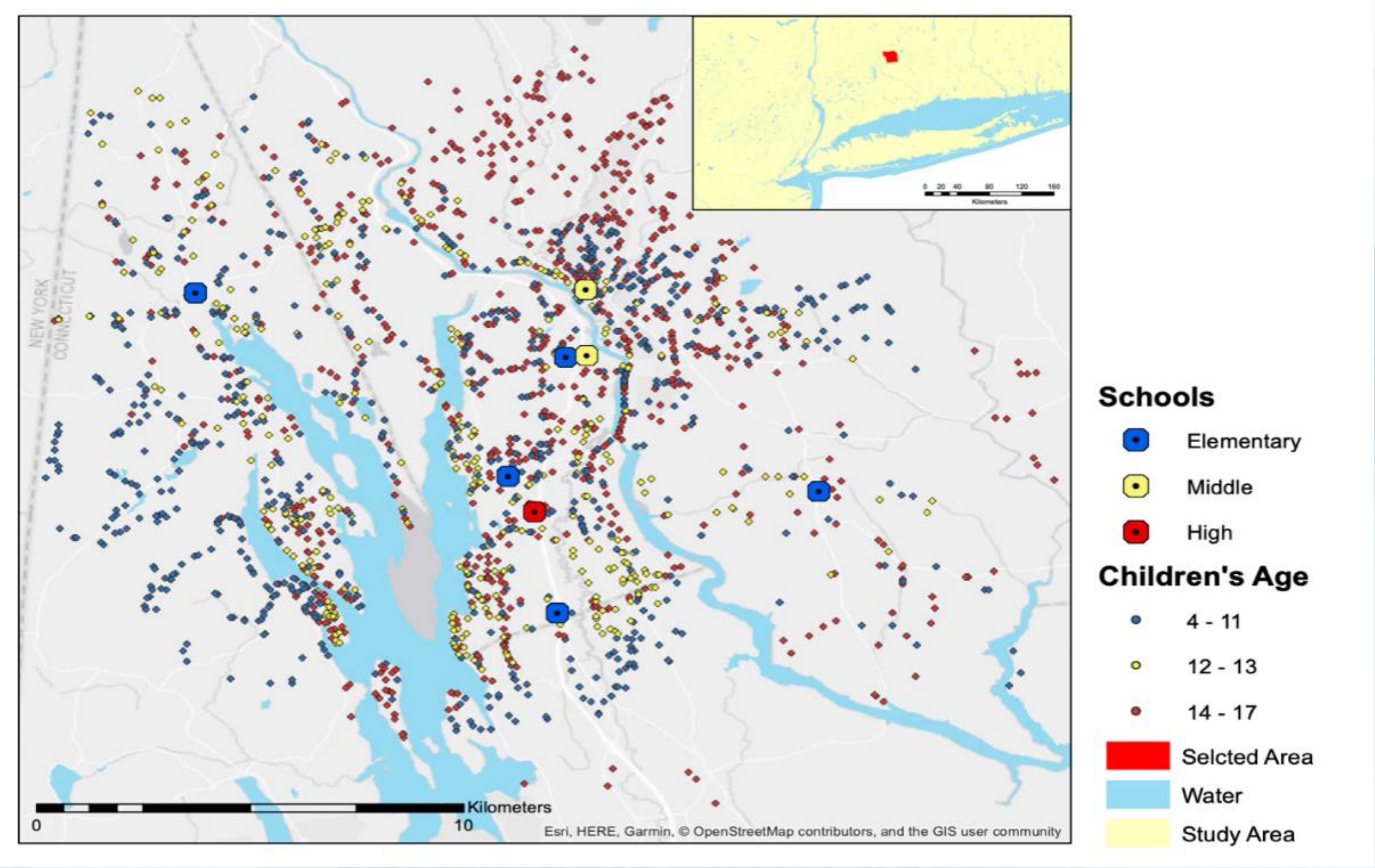


Error percentage per tract comparing our synthetic population with the Census

Students Assigned to Nearest Appropriate School



Synthetic Networks

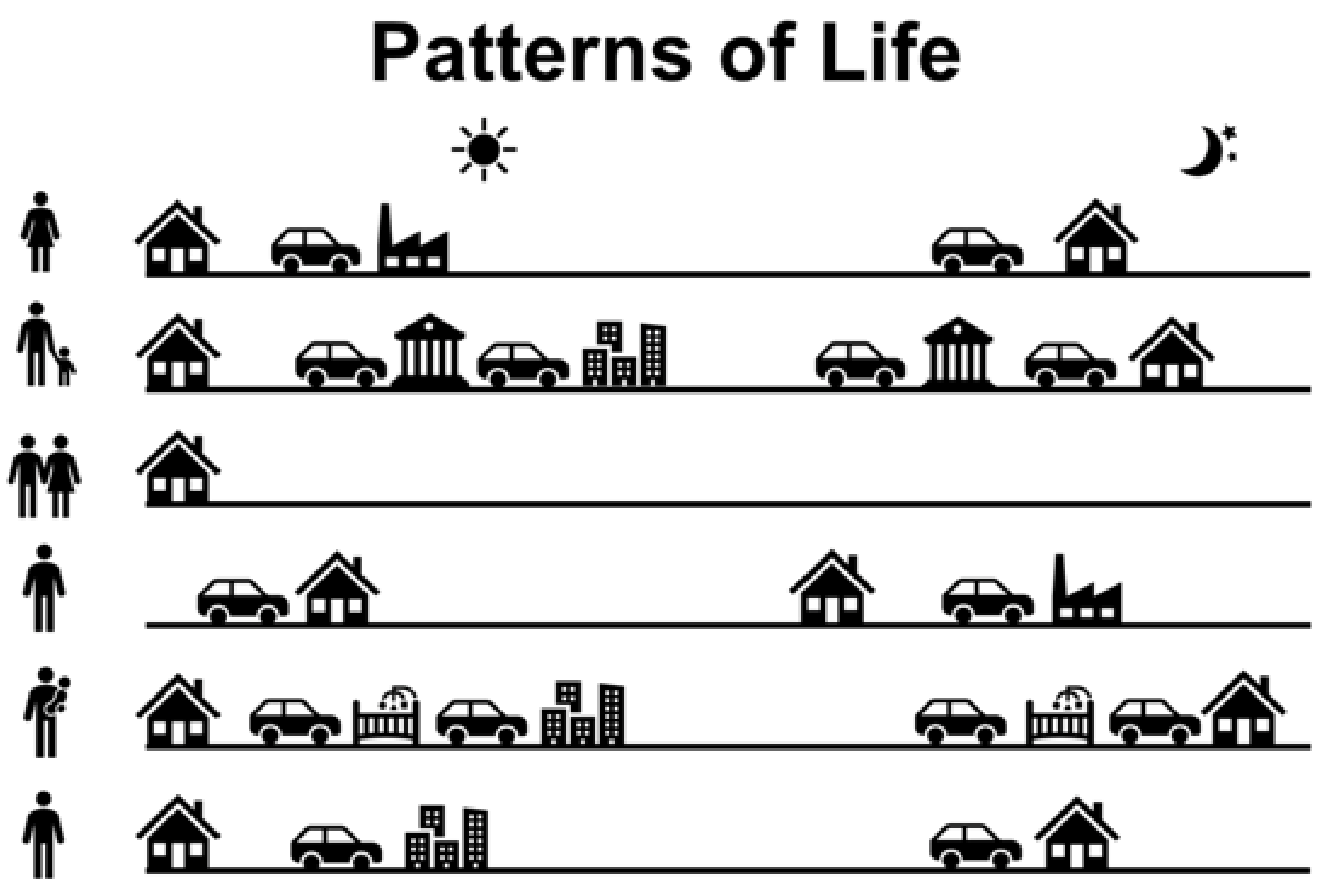
Blue: Synthetic Agents

Red: Connections Within A Household

Orange: School + Work Connections
(Work If Person Is 18+, Otherwise School)

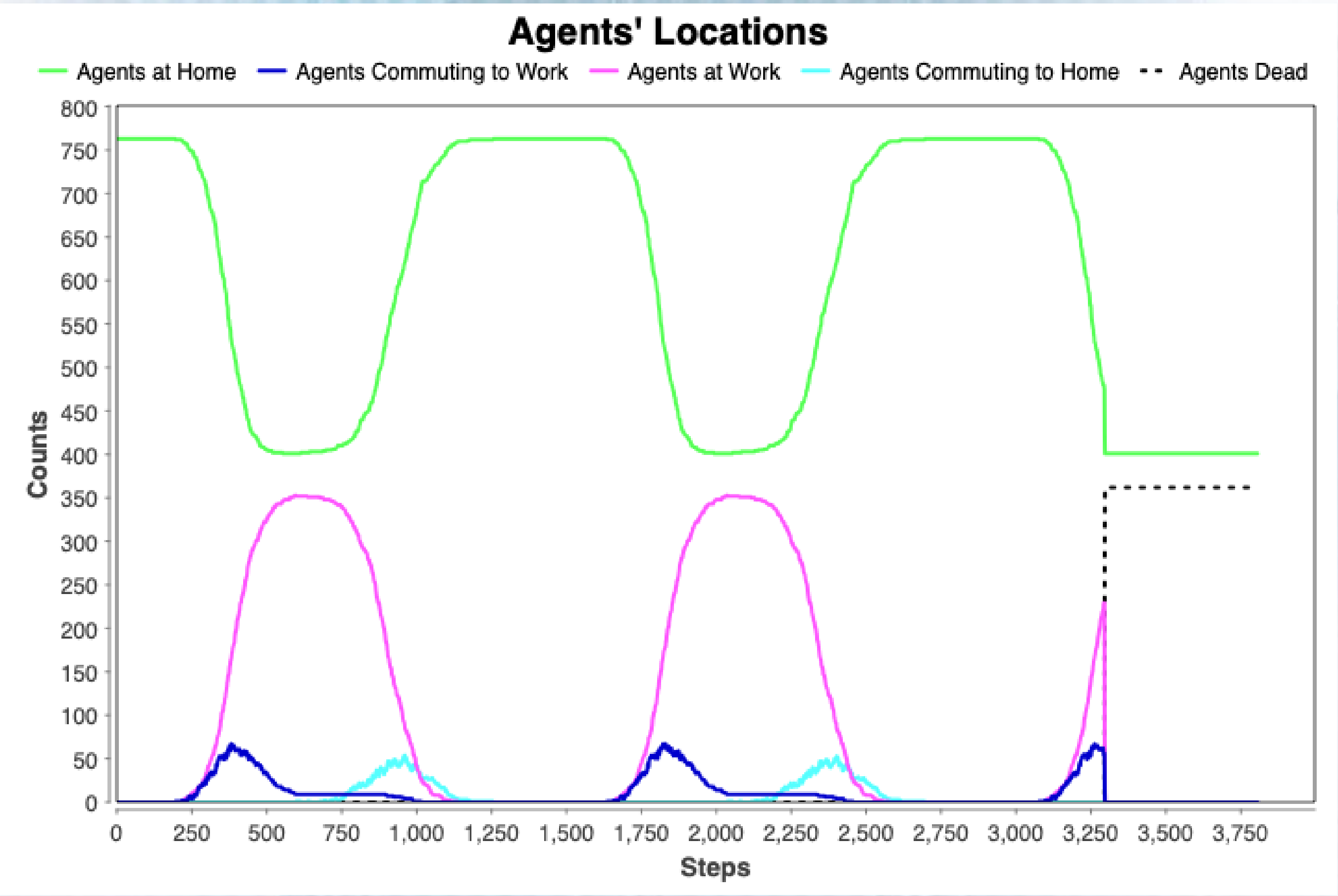
Green: Entire Census Tract Agents

Temporal Behaviors



midnight noon midnight

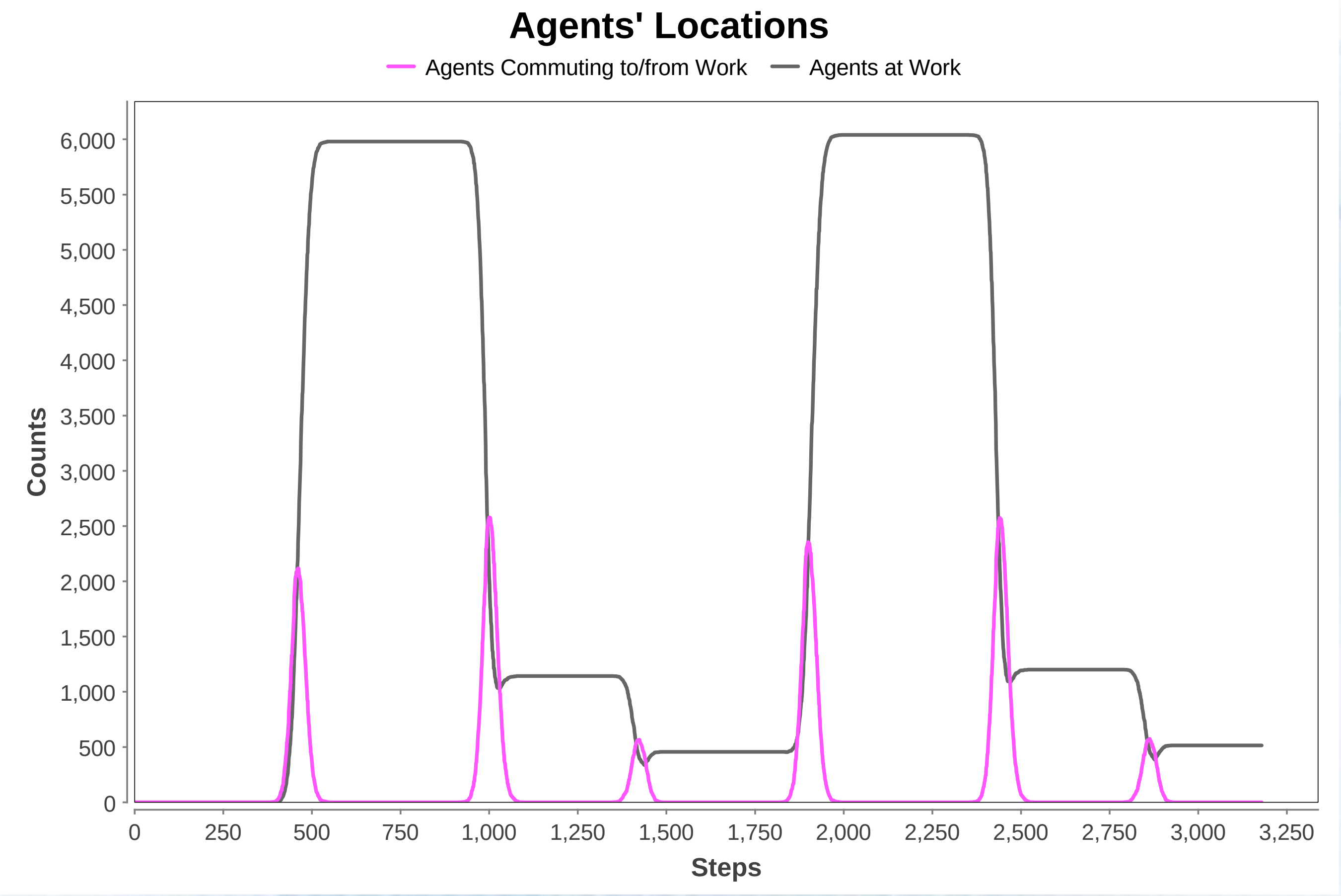
Commuting Behaviors



Routine Behaviors

- **Routine behaviors (commuting)**
  - Commuting done last year (single shift)
  - Exploring 3-shift routine behaviors

Routine Behaviors (3 Shifts)



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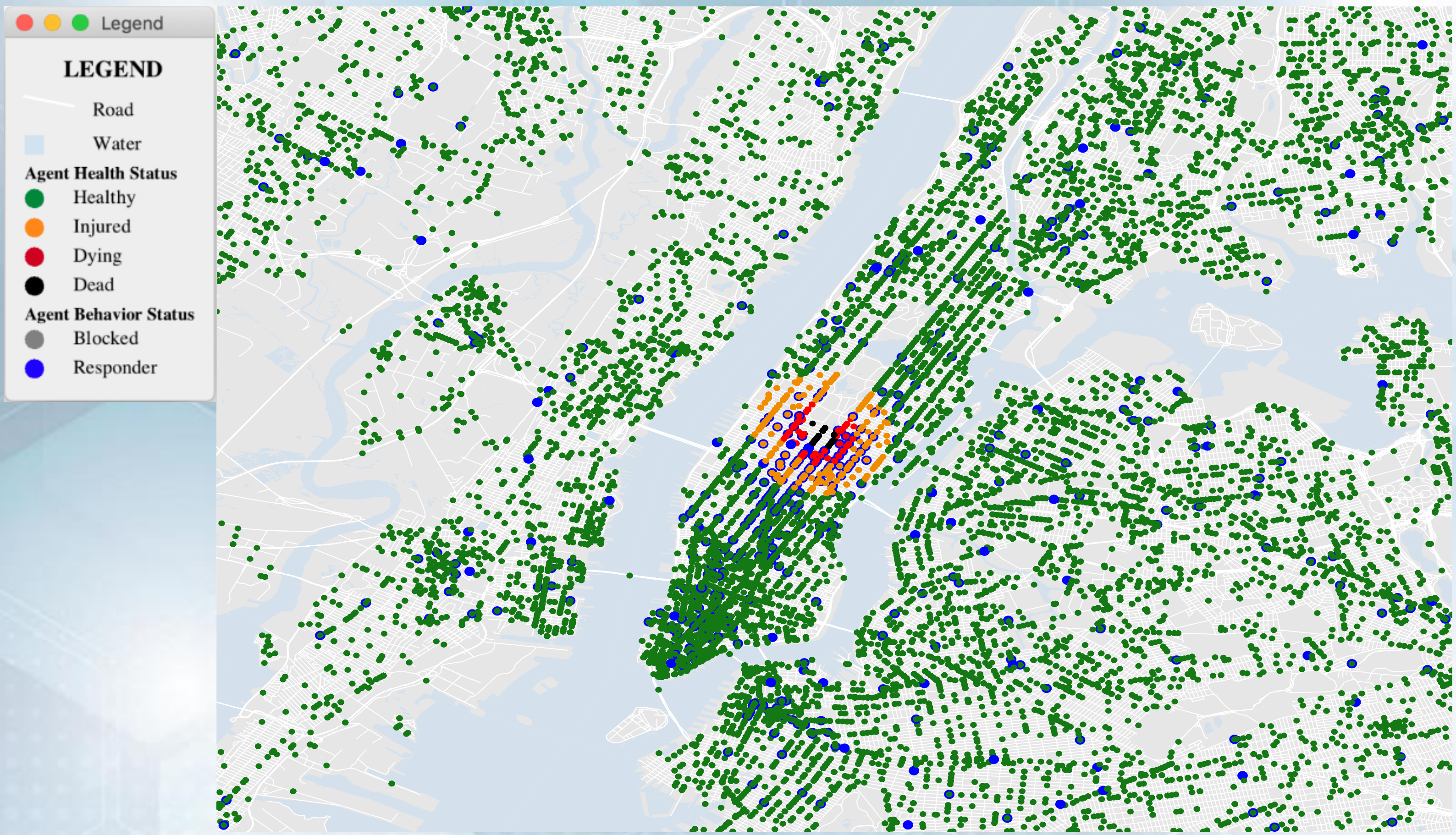
Modeling Weapon Effects

- Small nuclear WMD (no notice event)
- Parameterized location and yield of a ground burst
- Inside R1: (fireball) All killed instantly
- Inside R2: Mortally injured: most die in 48 hours, significant infrastructure damage, fires, radiation
- Inside R3: Injured but survivable, passable rubble
- Outside R3: Uninjured & free passage

Modeling Weapon Effects



Those Killed Instantly (in black), Mortally Injured (red), and Recoverably Injured (orange) Based on Distance from Ground Zero. (First responders are shown in blue.)

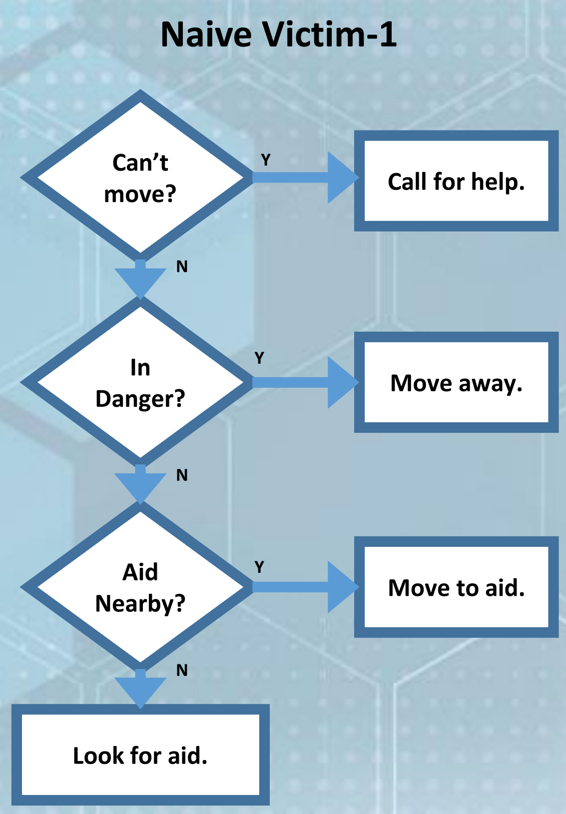
Initial Reactive Behaviors

First: ID agents in 3 zones: dead, dying, fleeing

Second:

- Victims in zone 2 flee on foot based at rate based on health
- Victims in zone 3 exit buildings and flee to transportation
- First responders
  - Travel toward ground zero
  - Driving speeds to edge of zone 3, then on foot
  - Aid first slowest victim found

Reactive Behaviors



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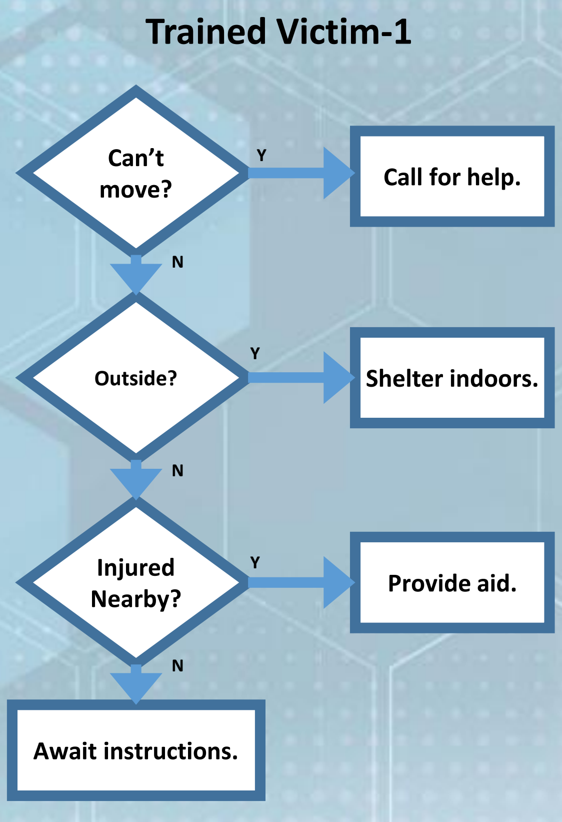
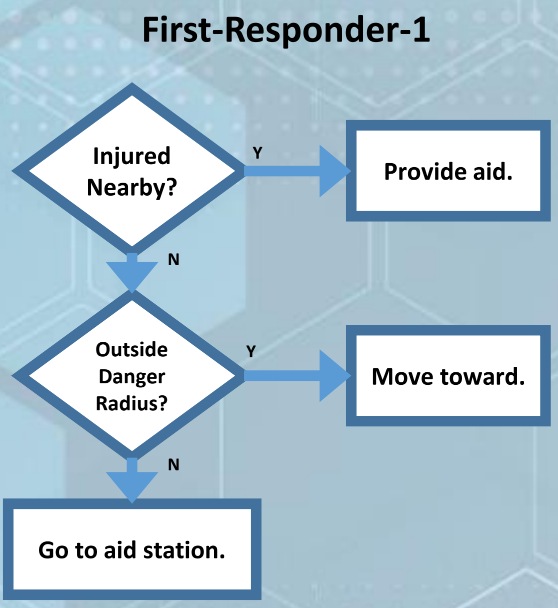
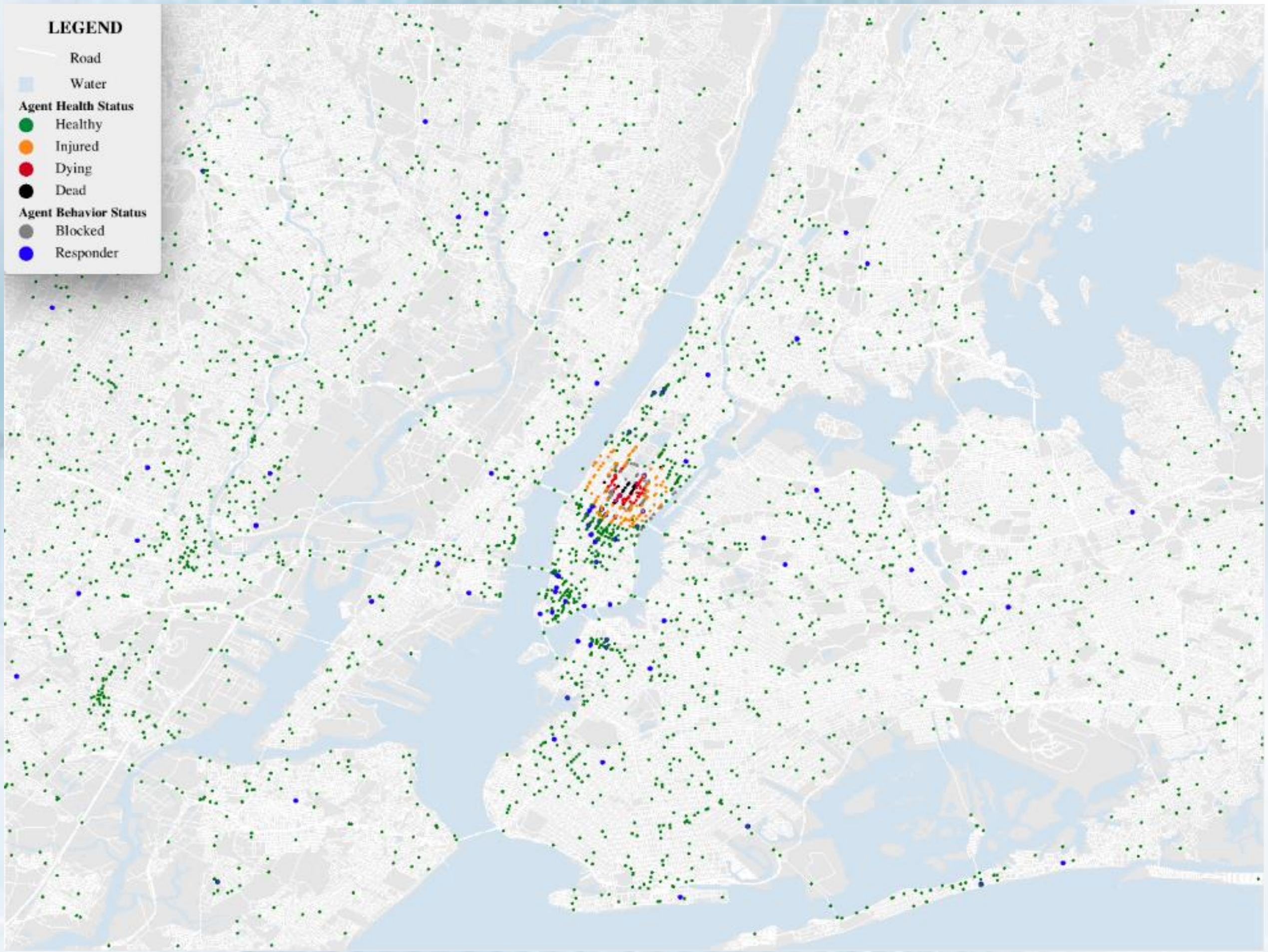


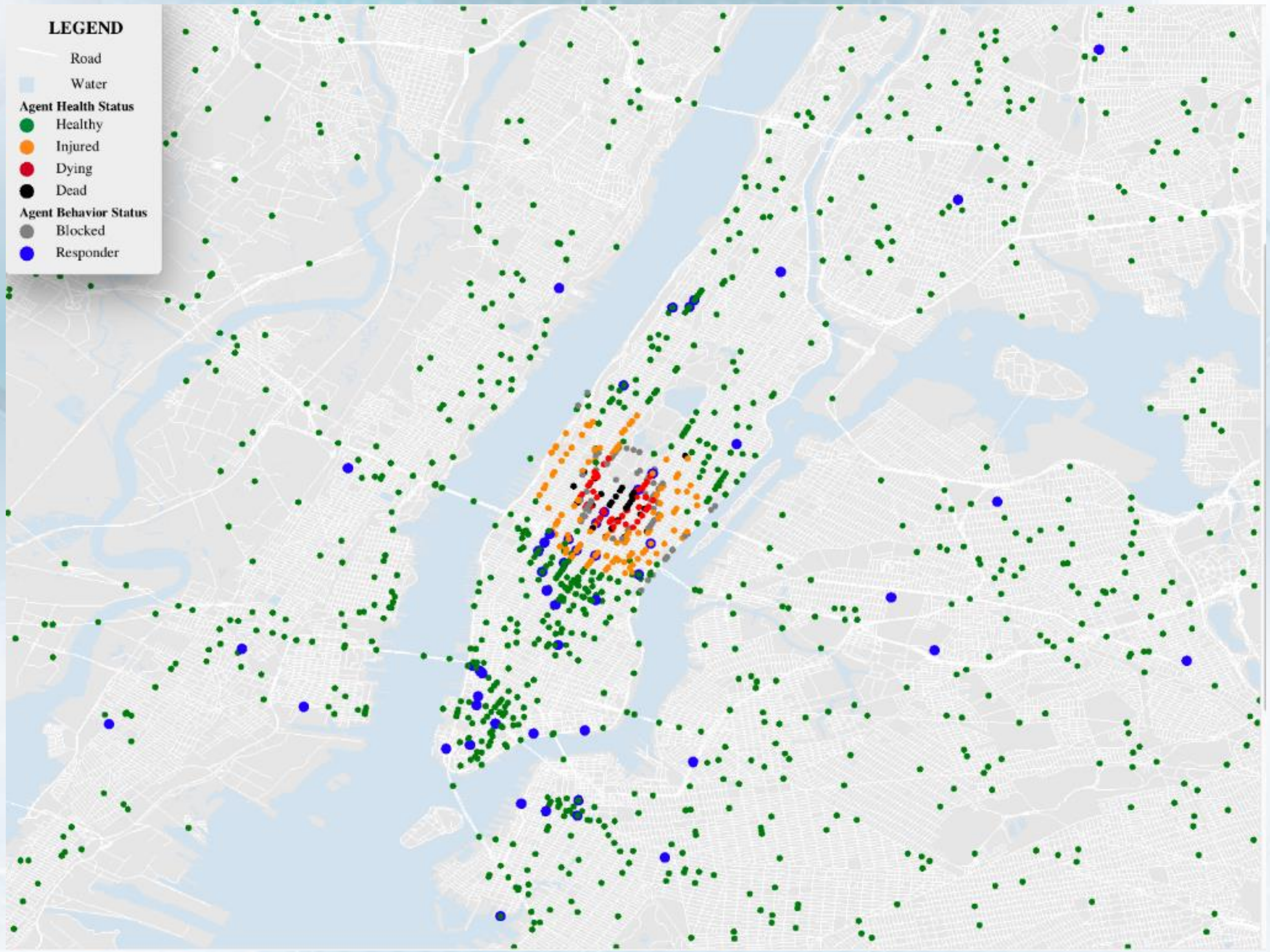
Reactive Behaviors



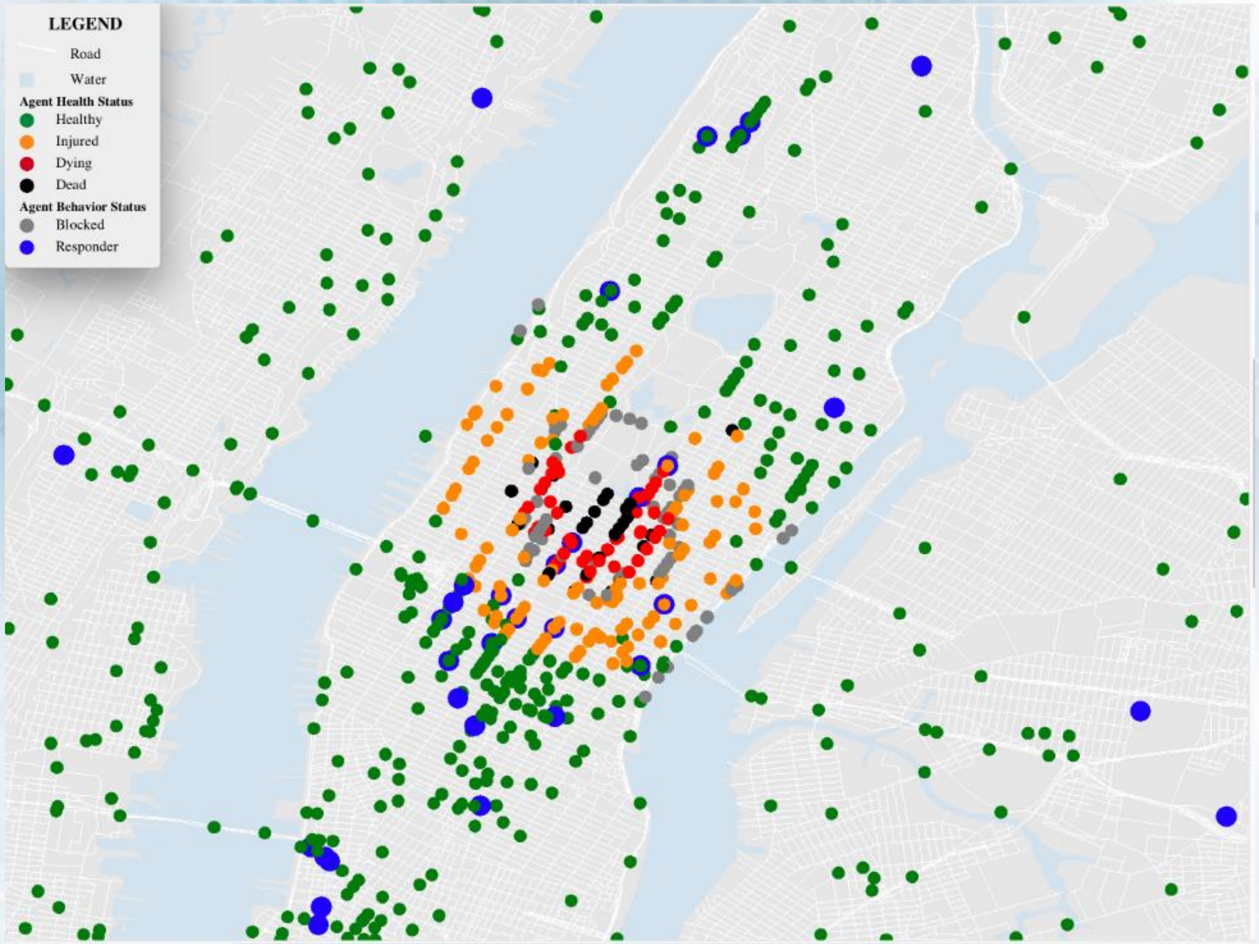
Agent Behavior



Agent Behavior



Agent Behavior



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Characterizing Reactions

- Quantifying how many people do what in reaction
- Variation in reactions

Characterizing the Population's Reaction

23K Agent Locations in One Run


Agents at Home
Agents Commuting to/from Work
Agents at Work
Agents Dead
Agents Fleeing
Counts
0
2000
4000
6000
8000
300
350
400
450
500
550
600
650
5am
Midnight
Morning Commute
10am
WMD+Reaction
23K Agents Locations in 25 Runs

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Publications and Presentations

- DTRA
- Anthropologists
- Geographers
- Computational Social Scientists
- Academic Seminars
- Undergrad & Graduate Classes

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Progress

- Demonstrated, benchmarked, and verified a population synthesis & synthetic social networks generation method and dataset of 23M
- Integrated household social networks explicitly into a spatially explicit models
- Demonstrated and benchmarked agent commuting patterns for the New York City Commuter Region with a population of 260K
- Demonstrated and benchmarked agent initial reactions post NWMD detonation with a population of 23K

Future Work

- Refine agent modeling fidelity to include additional health effects, communication, and shift schedules
- Extend infrastructure modeling to include damaged road network and communications as well as additional transportation modes
- Add parameter-driven Electromagnetic Pulse (EMP) effects
- Validate model and conduct experimentation

Summary

- Addressing resource challenges
- Characterizing population's reactions
- Enhancing model fidelity

Questions?