NPS

PRAESTANTIA PER SCIENTIAM

1909

NAVAL
POSTGRADUATE
SCHOOL

NAVAL POSTGRADUATE SCHOOL

28 Models Later

Simulating the NPS Zombie Apocalypse

Authors: David Allen & Marcus Boswell
Date: 11 June 2024

How can NPS be better prepared for the Zombie Apocalypse?

- Background
- Current Zombie Research & Models
- Study Objective & Research Questions
- Measures of Performance
- Data Collection
- Constraints, Limitations and Assumptions
- System Components
- Model Mechanics
- Experimental Framework
- Results and Recommendations

Background

- NPS Emergency Management
- Zombies are a blind spot
- Bioterrorism response does not consider the unique challenges of Zombie events
- Zombies are a blind spot
- Preparation is key

Category	Danger	Agents
Category A	Category A pathogens are those organisms/biological agents that pose the highest risk to national security and public health because they: ○ Can be easily disseminated or transmitted from person to person ○ Result in high mortality rates and have the potential for major public health impact ○ Might cause public panic and social disruption ○ Require special action for public health preparedness	Bacillus anthracis (Anthrax) Clostridium botulinum toxin (Botulism) Yersinia pestis (Plague) Variola major (Smallpox) and other related pox viruses Fracisella tularensis (Terlaremia) Viral hemorrhagic fevers ○ Arenaviruses (Junin, Machupo, Guanarito, Chapare, Lassa, Lujo Bunyaviruses ○ Hantaviruses, Rift Valley Fever, Crimean Congo Hemorrhagic Fever Flavivruses ○ Dengue Filoviruses ○ Ebola, Marburg Zombies?

Safety > Programs > Programs > Emergency Management

Hazard Specific Appendices:

1. Destructive Weather
2. Seismic / Geological Hazards
3. Fire Hazards
4. Pandemic Influenza
5. Hazardous Materials Spill / Release
6. Transportation Accidents
7. Structural Failure / Collapse
8. Infrastructure or Utility Loss or Interruption
9. Terrorism Incidents
10. Chemical Terrorism
11. Bioterrorism
12. Radiological Terrorism
13. Nuclear Terrorism
14. Explosive / Incendiary Terrorism
15. Civil Disturbance (Riots, Strikes, Protests)
16. Special Events (Presidential / Air Shows)
17. All Hazards Response

- [ ] Copy of your emergency plan (see redcross.ca/ready for
- [ ] Crank or battery-operated flashlight, with extra batteries
- [ ] Crank or battery-operated radio, with extra batteries
- [ ] Extra keys for your house and car
- [ ] First aid kit
- [ ] Extra cash in small bills and coins
- [ ] Personal hygiene items
- [ ] Extra cell phone charger or battery pack
- [ ] Supplies for your pet, including:
  - [ ] Food
  - [ ] Medication
  - [ ] Vaccination records
- [ ] Paper and pens
- [ ] Whistle
- [ ] **Shotgun, baseball bat…**

Mad Cow

COVID

SARS

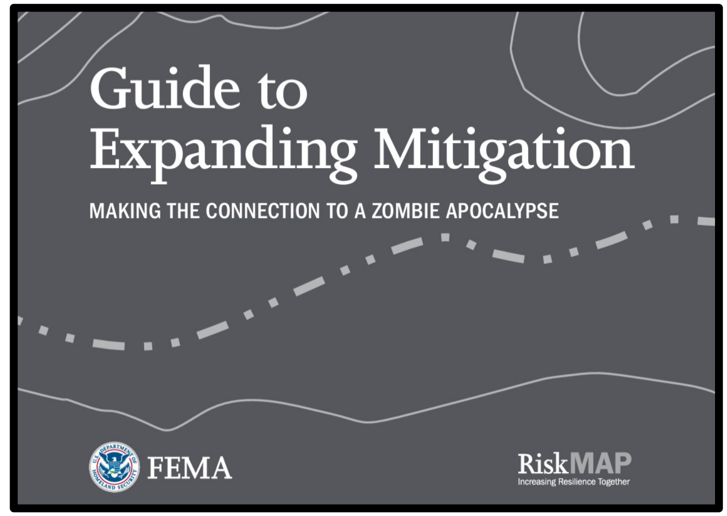
Zombie-Ant Disease

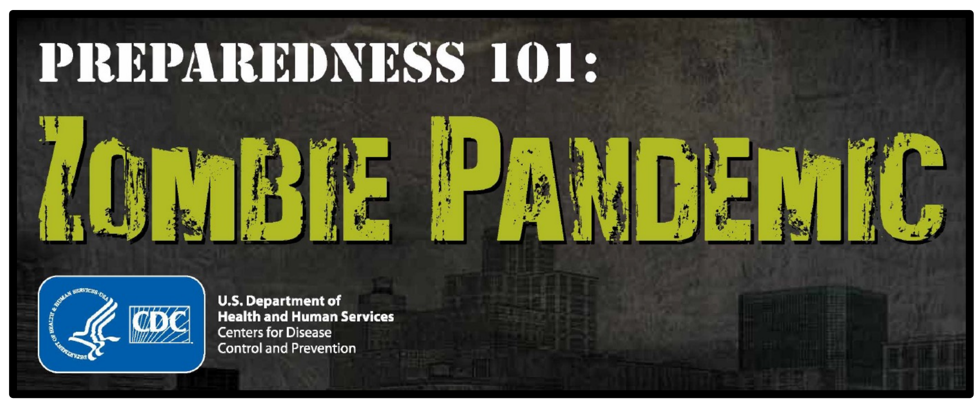
EBOLA

Current Zombie Research

- Using the Zombie Apocalypse as a proxy for extremely infectious disease simulation is a well-known practice.
  - CDC Site
  - Homeland Defense
  - FEMA

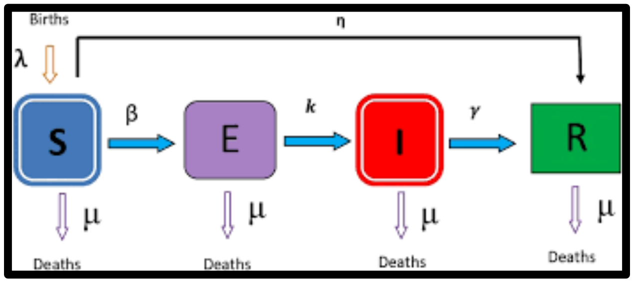
- Modeling approaches frequently used:
  - Mathematical
  - Agent Based
  - SEIR
  - Real-time

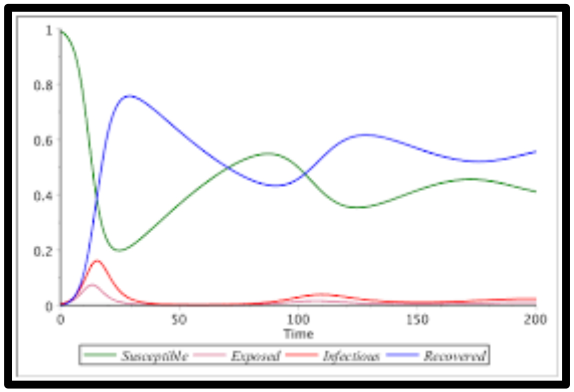




Model Examples (1)

Susceptible, Exposed, Infected, Recovered model (SEIR)





Mathematical Modeling (Fourier Series, Diffusion, and interaction kinetics)

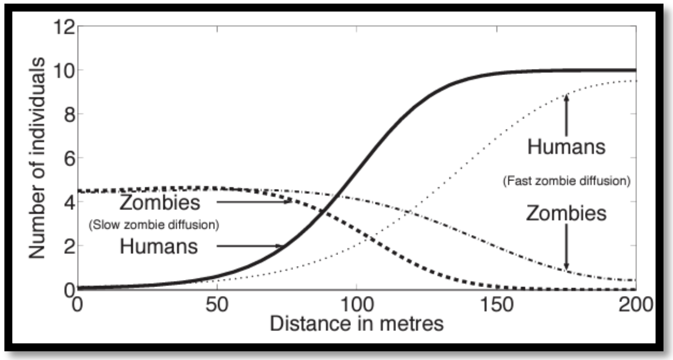
$$\frac{\partial}{\partial x} = \frac{\partial}{\partial u}\frac{\partial u}{\partial x} = \frac{\partial}{\partial u}$$
$$\frac{\partial^2}{\partial x^2} = \frac{\partial^2}{\partial u^2}$$
$$\frac{\partial}{\partial t} = \frac{\partial}{\partial u}\frac{\partial u}{\partial t} = -v\frac{\partial}{\partial u}.$$

These are then used in equations (6.12) and (6.13) to produce the form

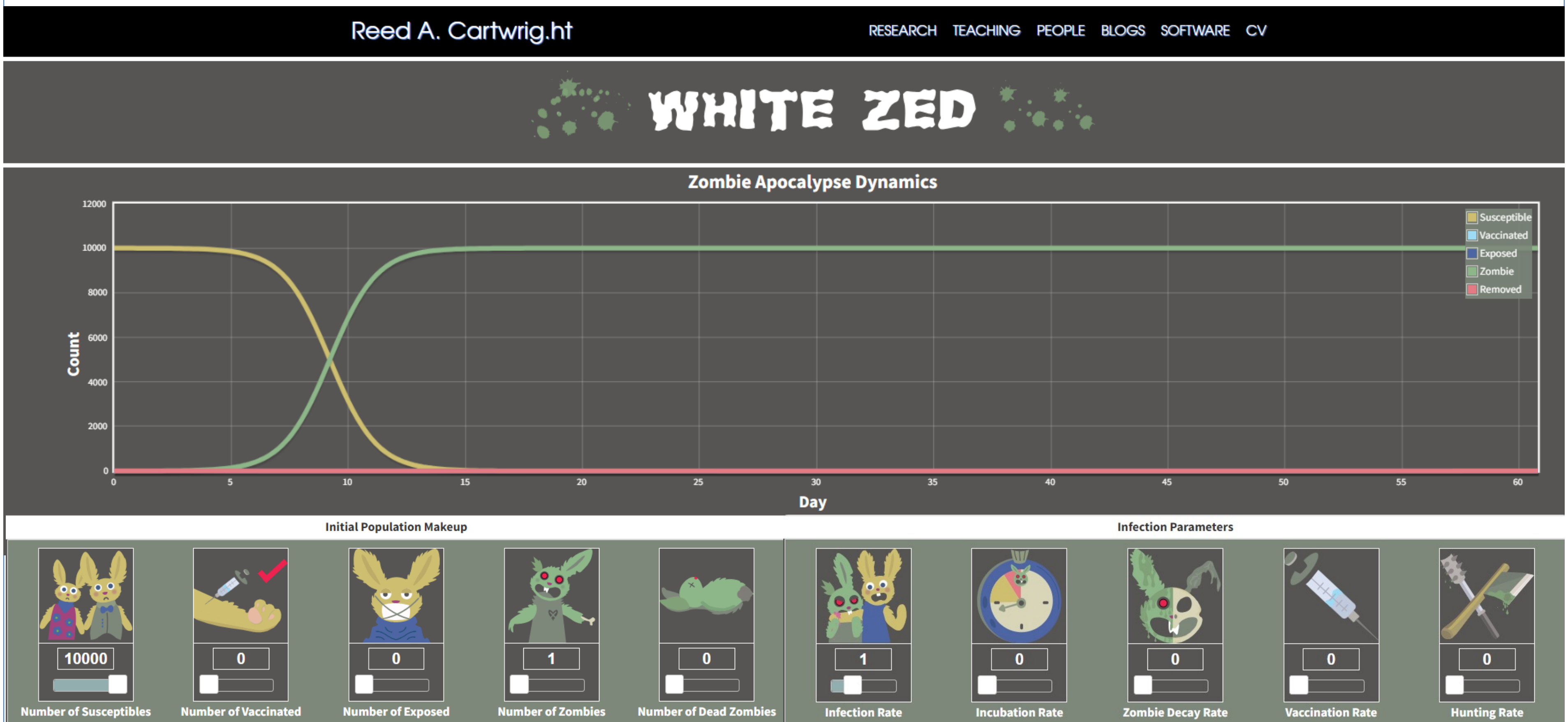
$$0 = D_H H'' + vH' - \alpha HZ \qquad (6.23)$$
$$0 = D_Z Z'' + vZ' + \beta HZ, \qquad (6.24)$$

where we have used the notation

$$' = \frac{d}{du}.$$



Model Examples (2)



https://cartwrig.ht/apps/whitezed/

Study Objective and Research Questions

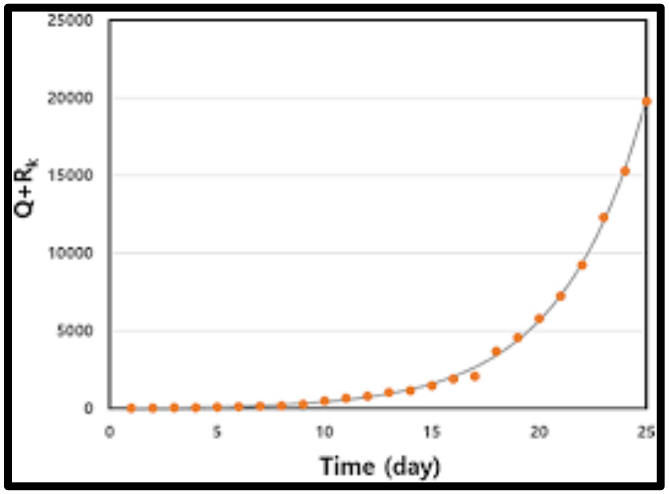
Study Objective: Improve NPS's Zombie related readiness and resilience, so it is best prepared to deal with Zombie events and similar infectious diseases.

Research Questions:

1. How long could humans survive a Zombie event at NPS? (Rescue scheduling)
2. What factors influence infection rate? (Strategy design)
3. Is Shelter-in-Place procedures an effective plan? (Consistency in planning)
4. What are the safest and most dangerous buildings? (Resource allocation)
5. Is student hand-to-hand lethality a major factor? (Training opportunities)
6. Is there a critical threshold of infection for NPS? (P.A.C.E)

Measures of Performance

- Time of key milestones
  (75%, 50%, 25%, 0% survival)
- Human / Zombie "win" rate
- Rate of infection & its major factors
- Foot traffic by building
- Most defended vs. most human deaths by building
- Number of zombies and humans alive at termination



Data Collection (Zombie Lore)

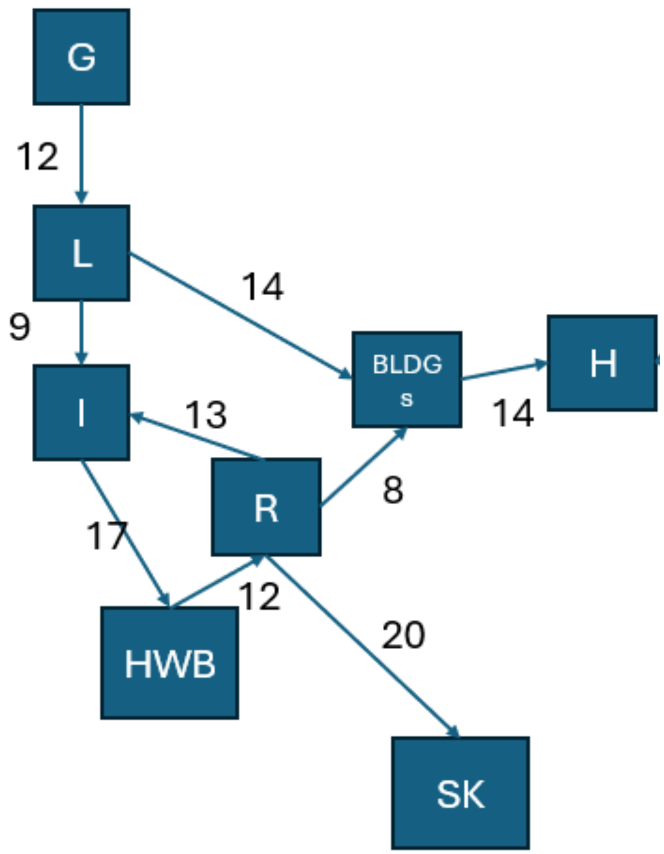
Sources

- Literary Review
- Cinematography Review
- Prior Zombie Experience
- Geospatial Data

The Facts

- 28 Days / Weeks as lore foundation
- Zombies can die of normal causes and "decay" around ~2 days
- Minimal impact of injuries to Zombies
- Transmission happens ***fast*** (~12.4 seconds)
- P(H-lose a 1:1 fight) = 56% (day), 86% (night)
- Survival rate: 1 out of 3733
- Fights can be lethal (3:1 death to injury)

Data Collection (NPS Network)



- NPS is a network, position & distance matter
- ~1,616 students, ~598 faculty
- Logical movement in a crisis
- Distances correspond to travel times
- Distances estimated between center points of buildings; increments of 0.01 km
- Travel times can vary: obstructions, sneaking vs. running, reverse breaching
- Highschool avg 40yd (~5.x) -> 12 sec / 100m
- Travel time formula: U(Run,10*Run)

Limitations, Assumptions, and Constraints

Limitations

- Simplified Behavior: minimal needs other than survival
- Day/night cycle is not fully represented
- Class IV: unlimited
- Buildings are equally defendable

Constraints

- Movement rules & set paths
- Entity types
- Interaction rules: move, defend, fight

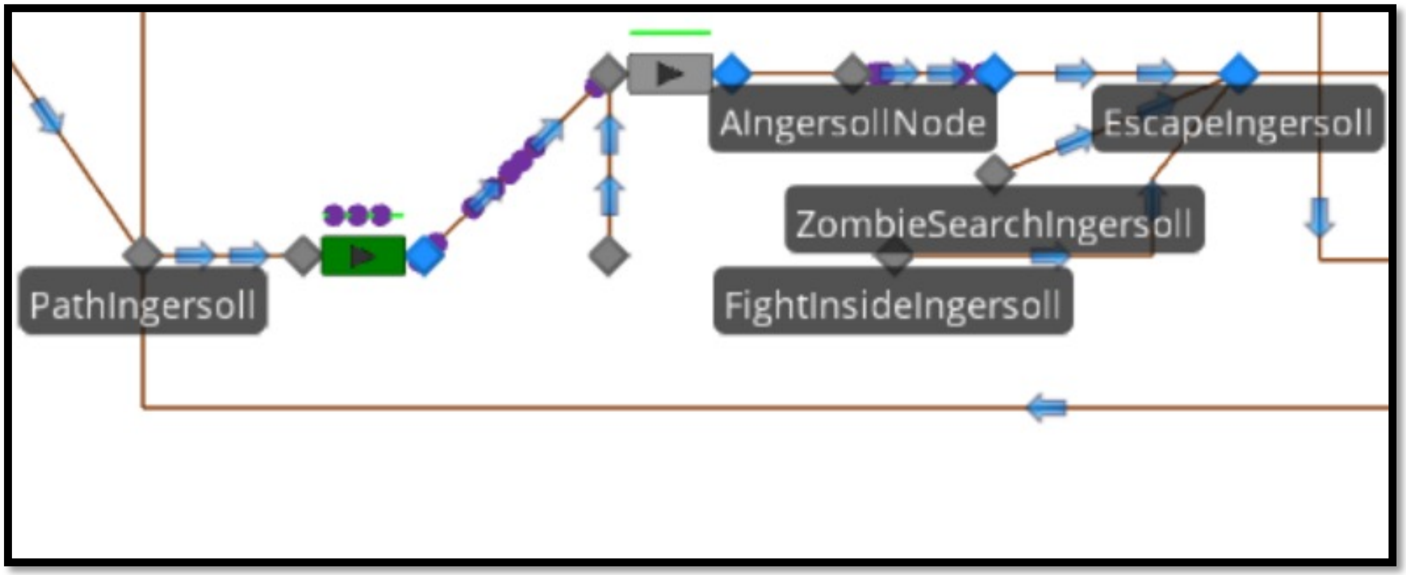
Assumptions

- Closed system
- Zombies & Humans share physical properties
- Infection is through physical contact
- Human attributes and responses can be generalized to the population
- No advanced warning of the infection
- Human to Zombie transition period is instantaneous

Scenario: A student carelessly infects their entire first class on a random school day (Mon-Thur). NPS becomes aware of the outbreak during the transition between classes. The government acts swiftly, ***almost pre-emptively***, to contain the outbreak.

Our Model

- Agent based – Two types of entities have a set of decision criteria that defines their behavior. Since we are modeling survival, the behavior is simplistic
- Queueing model – We used queues and servers to represents length of time for an interaction and the result of the interaction as well



System Components

System – The students of NPS and a subset of major buildings: Glasgow, Dudley Library, Ingersoll, Del Monte, Root, Watkins, Herrman, King

Entity – Humans and Zombies

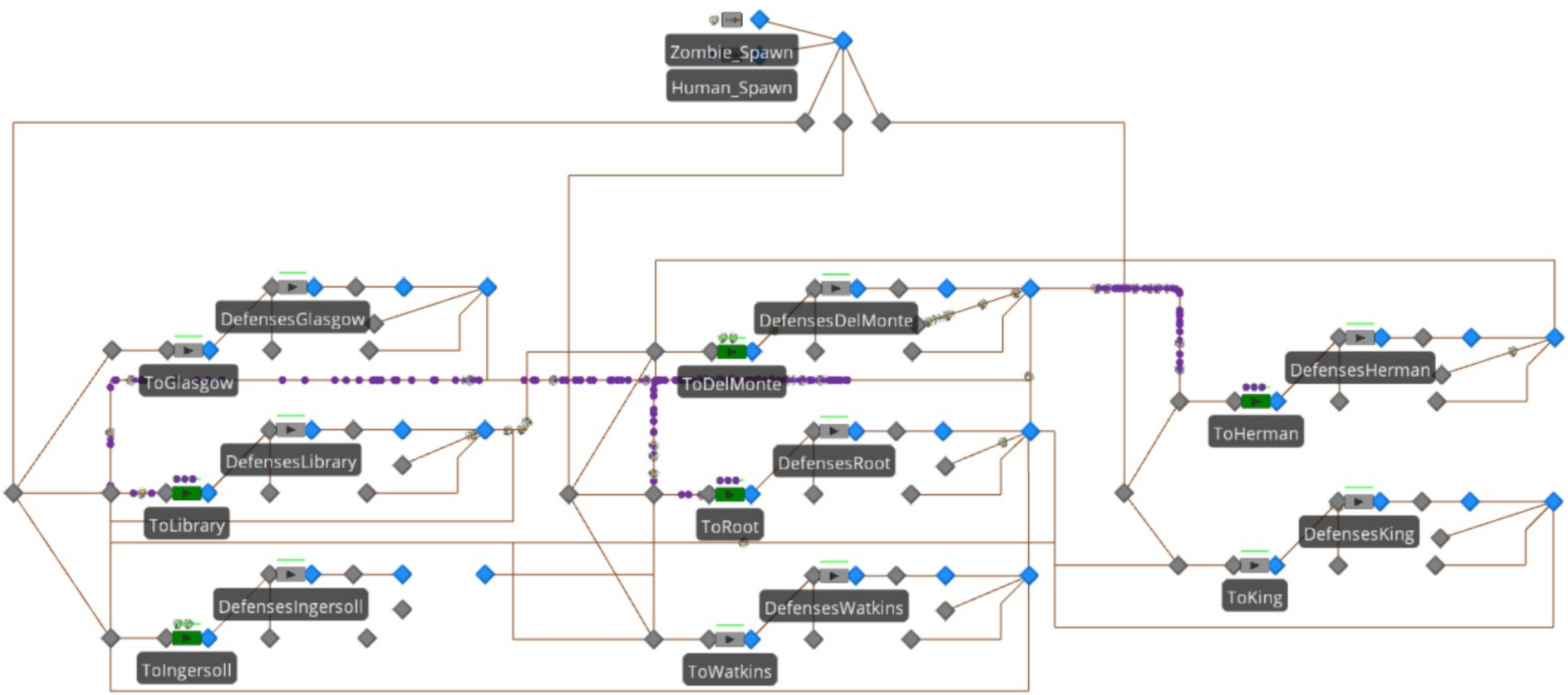
Attribute – Starting location, probability of fighting & winning

Activity – Movement times, breaching, searching

Event – Fighting outside, defense breached, fighting inside, death of entity, human infection

State Variable – # of humans / zombies: alive, at or enroute to "To_" nodes, breaching or defending a building, defense status of a building

28 MODELS LATER



Model Mechanics: Movement

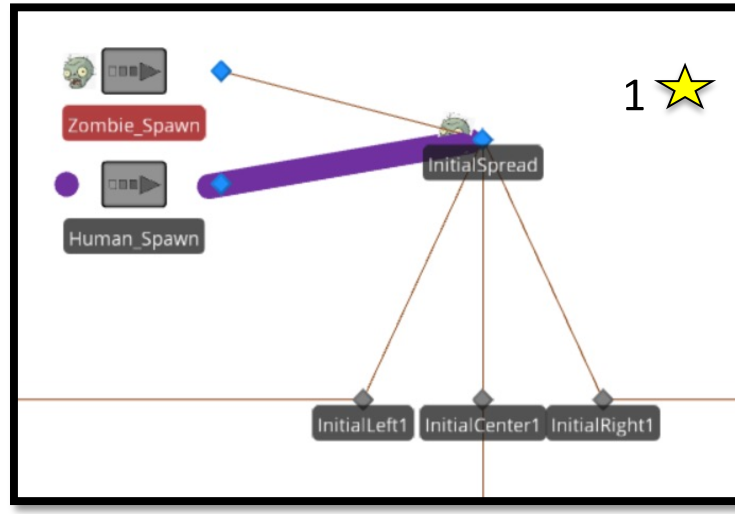
Human Movement

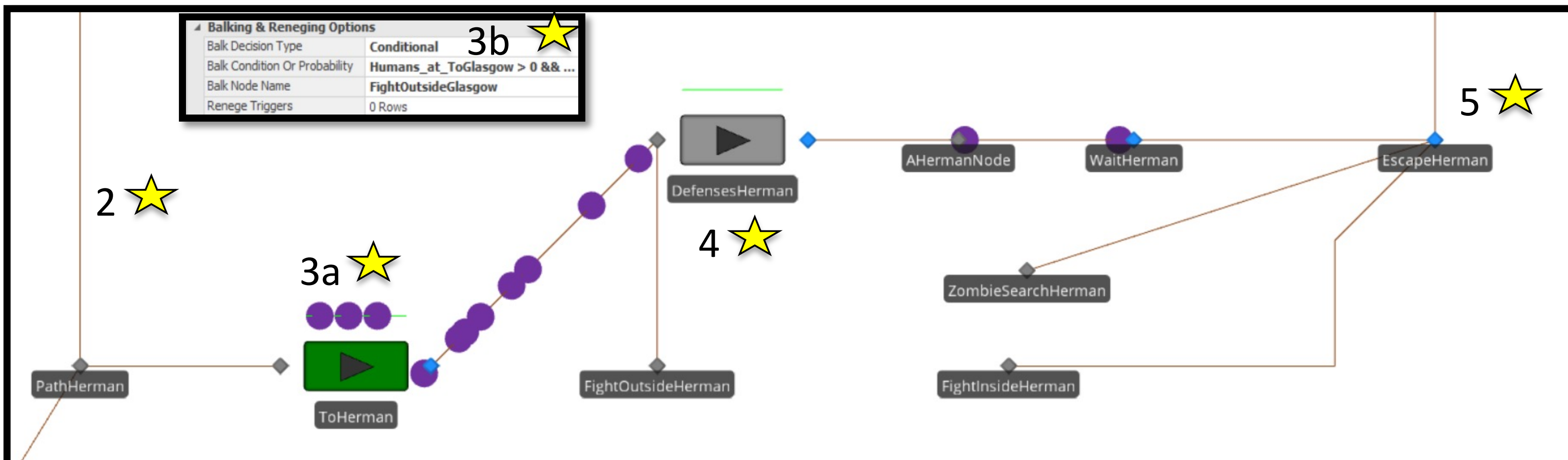
Zombie Movement

- Decisions: “Escape_” -> entities at "To_" nodes

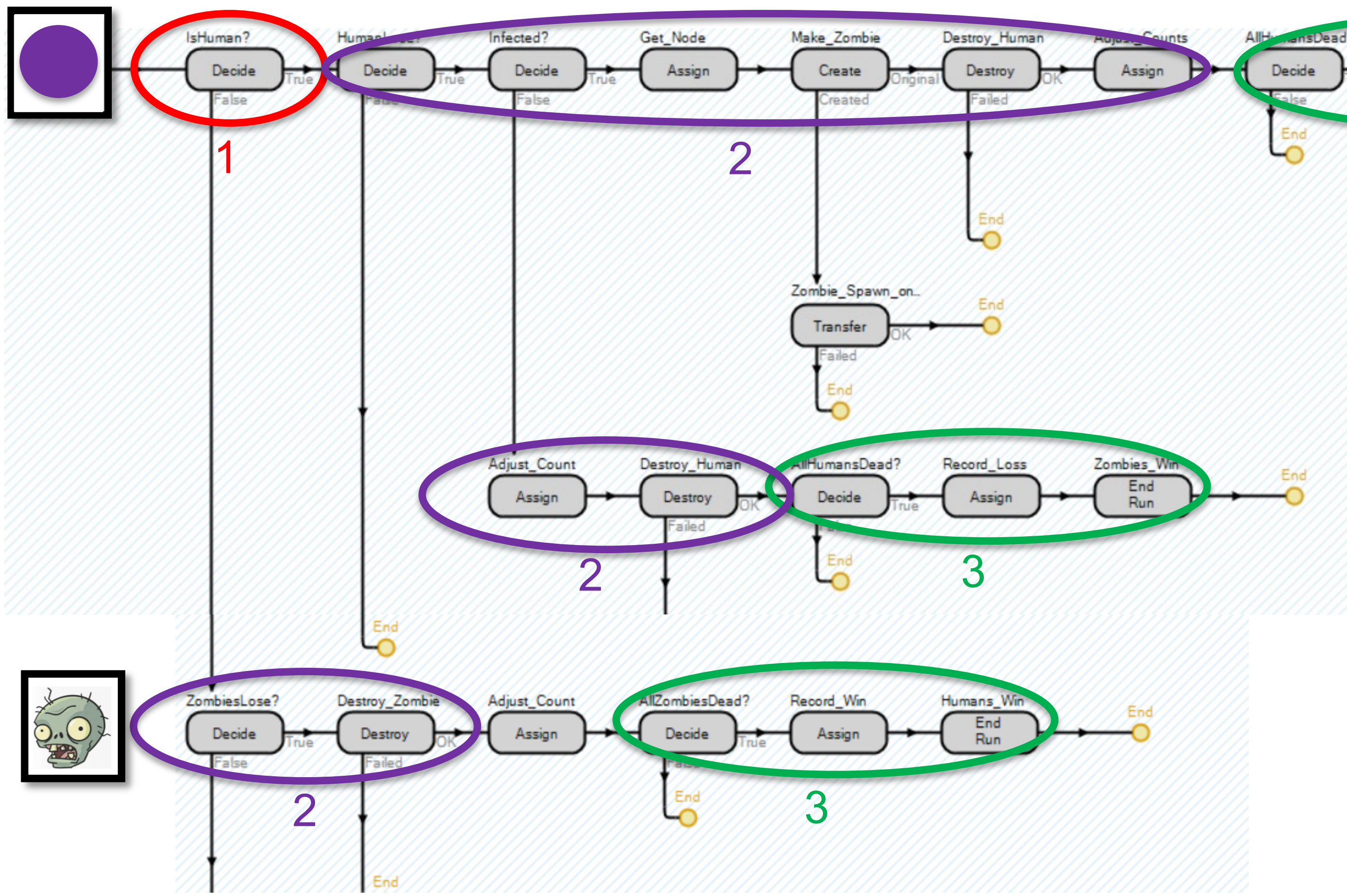
- Inter-building travel: timed ~U RV at the individual entity level

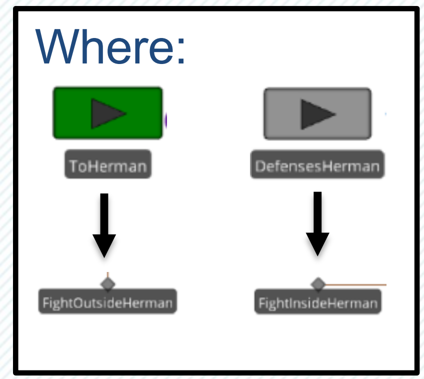
- Servers: areas of interactions





Model Mechanics: Fight





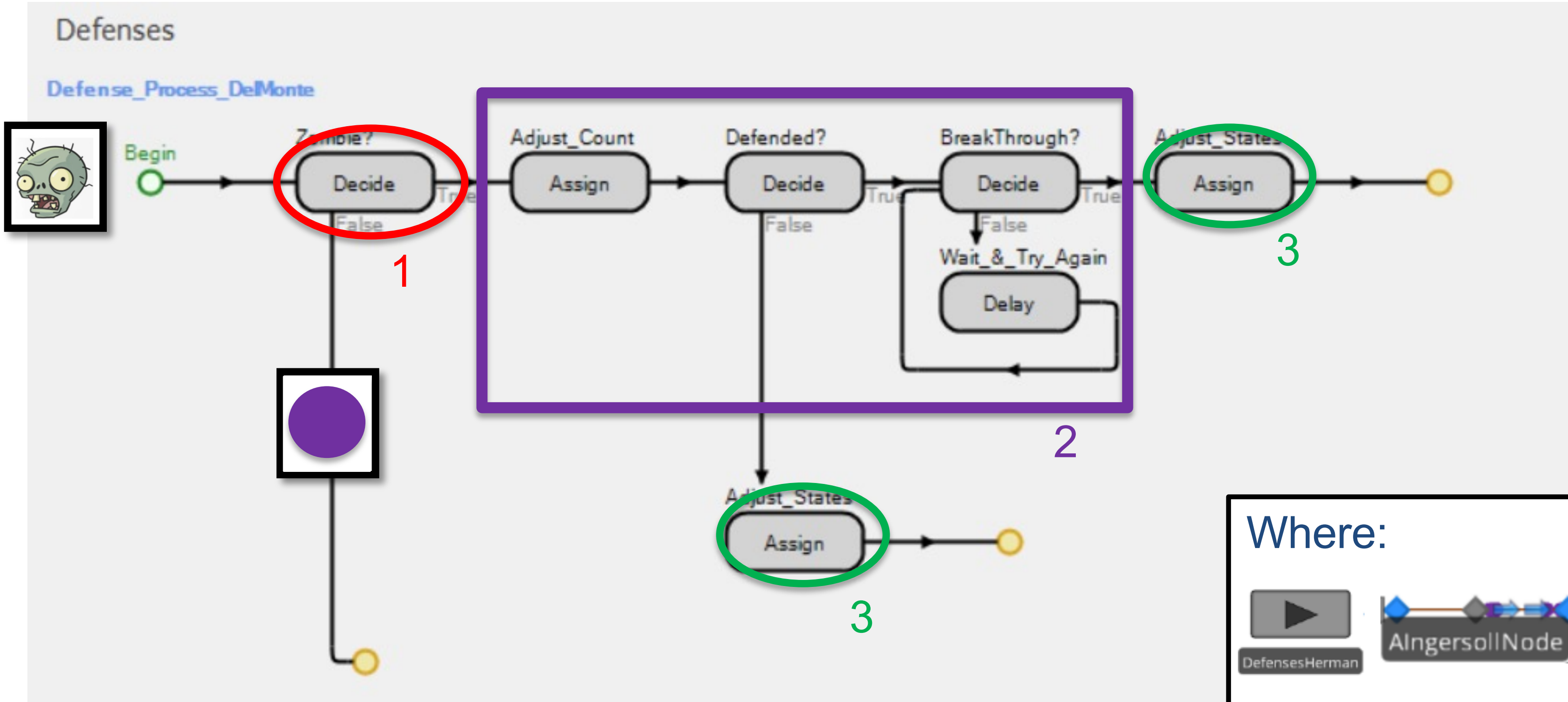
Steps

1 - Identify

2 - Result

3 - End Criteria

Model Mechanics: Defend

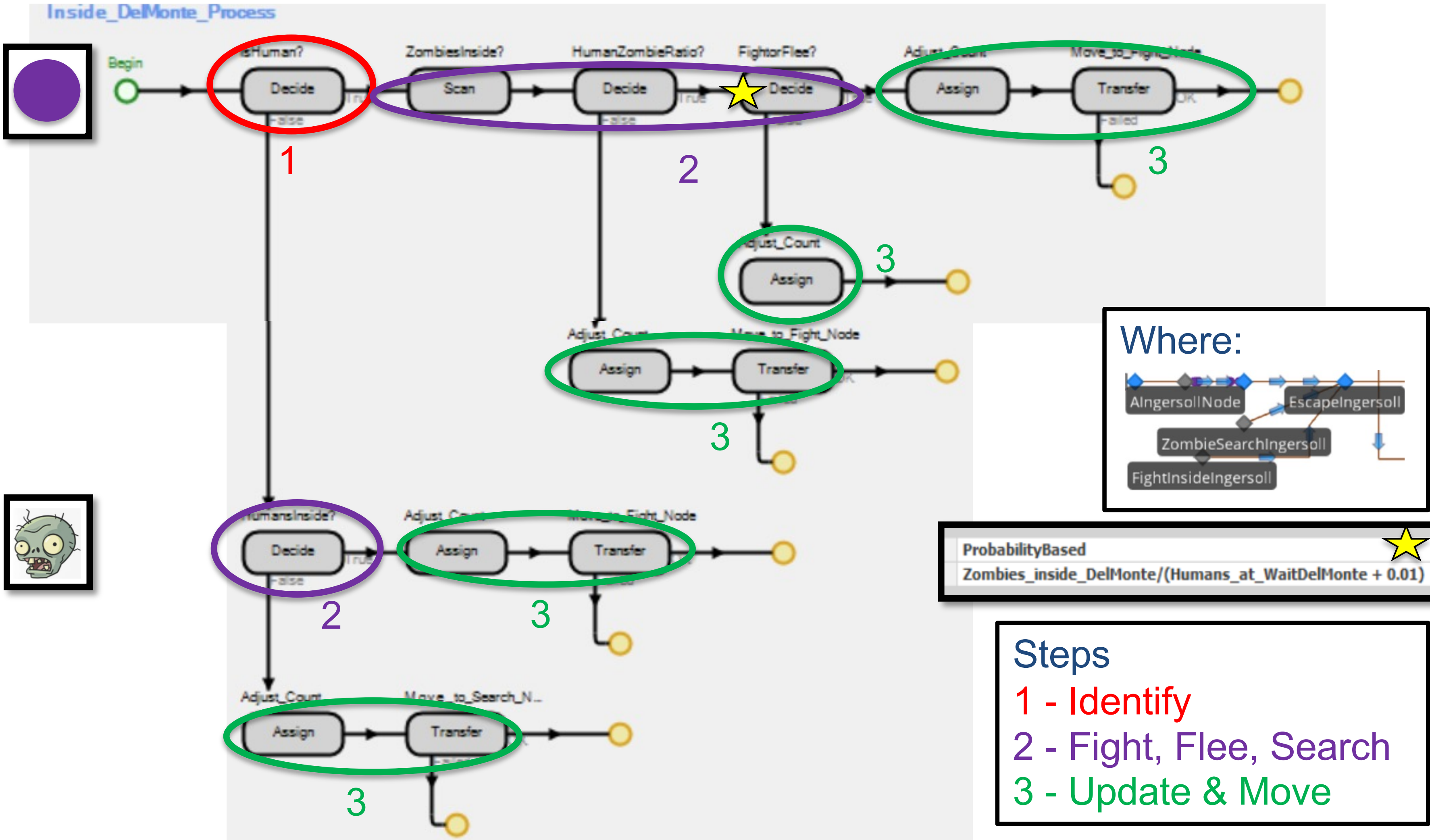


Where:

DefensesHerman
AIngersollNode

Steps
1 - Identify
2 - Breach
3 - Transition to Inside

Model Mechanics: Inside



Steps
1 - Identify
2 - Fight, Flee, Search
3 - Update & Move

Regular Zombies

Parameters

- # of Susceptible – 1616
- # of Zombies – 5
- Infection Rate – 75%
- Break-In – 1%
- Zombie Kill Rate – 55%
- Human Kill Rate – 45%

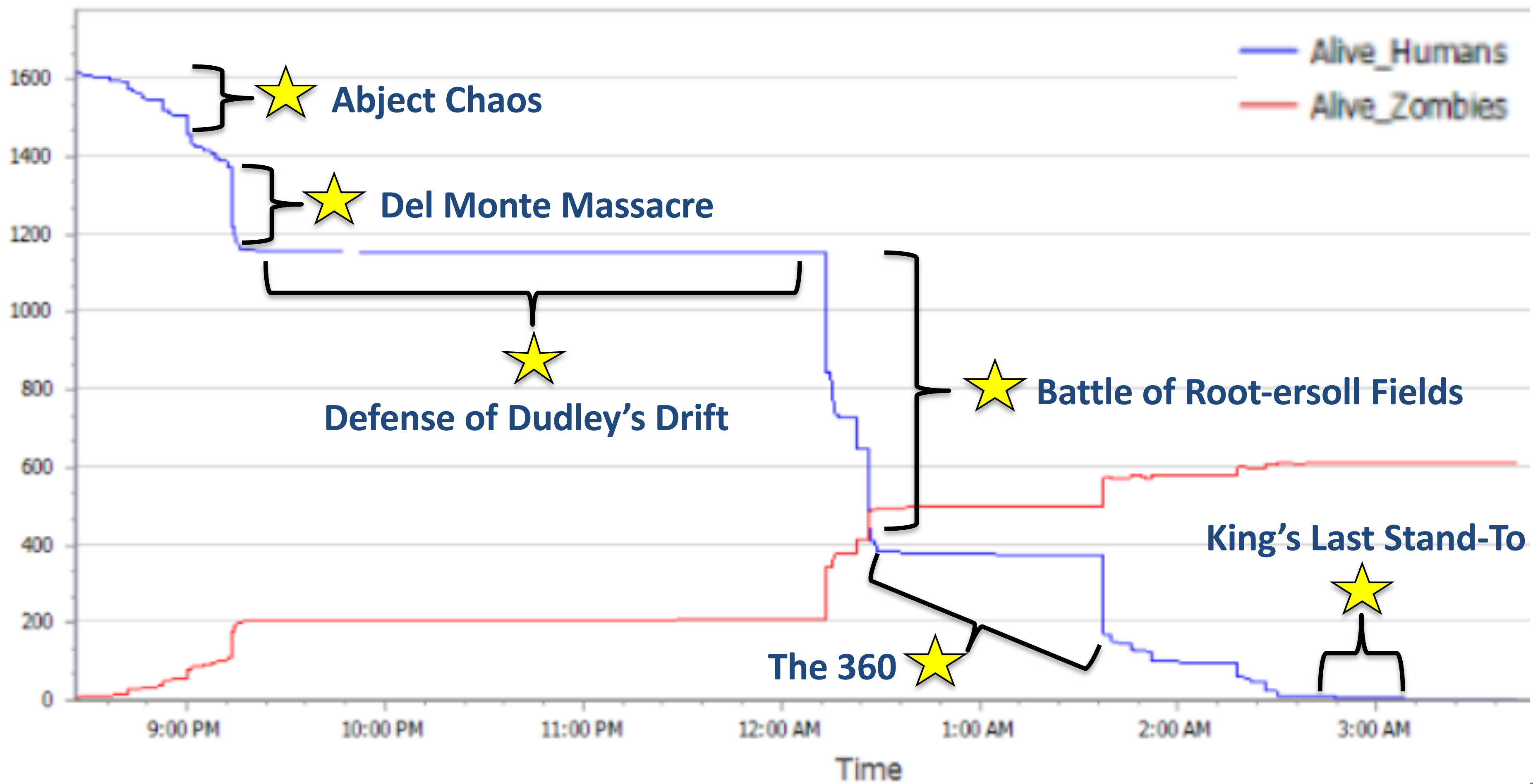
Results

- Time: 15.77 Hours
- Safest BLDG: Glasgow
- Most Dangerous: Del Monte
- Critical Points (% Humans Dead):
  - 25% - 6.12 hours
  - 50% - 6.77 hours
  - 75% - 8.26 hours
- AVG Human Survival – 6.18 hours

Discussion

- Zombie creation rate vs Human death rate
- Large groups are not successful
- Buildings that are isolated are safer
- Buildings that have more attractive routes near them are safer
- The above points remain true for all scenarios
- **Recommendation:**
  - Increase virtual / recorded labs and lectures where feasible. A less dense campus is a safer campus

Human & Zombie Population over Time



Smart Zombies

Parameters

- # of Susceptible – 1616
- # of Zombies – 5
- Infection Rate – 75%
- Break-In – **10%**
- Zombie Kill Rate – 55%
- Human Kill Rate – 45%

Results

- Time: 3.2 Hours
- Safest BLDG: King Hall
- Most Dangerous: Root
- Critical Points (% Humans Dead):
  - 25% -0.71 hours
  - 50% - 0.89 hours
  - 75% - 1.15 hours
- AVG Human Survival – 0.86 hours

Discussion

- By far the most dangerous zombie is the smart zombie
- Operating doors or tearing down barricades makes these zombies difficult to hide from
- **Recommend:**
  - Bringing in less intelligent students to reduce the chance of a “smart” zombie (existing trials already taking place in other curriculums)

Better Infrastructure

Parameters

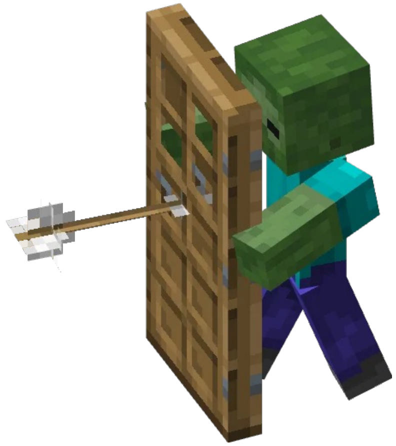
- # of Susceptible – 1616
- # of Zombies – 5
- Infection Rate – 75%
- Break-In – 0.05%
- Zombie Kill Rate – 55%
- Human Kill Rate – 45%

Results

- Time: 96 Hours
- Safest BLDG: Glasgow
- Most Dangerous: Root
- Critical Points (% Humans Dead):
  - 25% - 6.88 hours
  - 50% - 11.3 hours
  - 75% - 15.35 hours
- AVG Human Survival – 9.8 hours

Discussion

- The most critical change for zombie survival
- Reducing the chance of breakthrough by half, drastically changed the outcome
- Recommend:
  - GSA Class 5 vault doors
  - Terror Screen SR4 rolling security shutters
  - 3x DOS Class I prepositioned per student at max classroom capacity



More Lethal Zombies

Parameters

- # of Susceptible – 1616
- # of Zombies – 5
- Infection Rate – 75%
- Break-In – 1%
- Zombie Kill Rate – 75%
- Human Kill Rate – 25%

Results

- Time: 6.8 Hours
- Safest BLDG: Glasgow
- Most Dangerous: Ingersoll
- Critical Points (% Humans Dead):
  - 25% - 1.23 hours
  - 50% - 2.46 hours
  - 75% - 3.02 hours
- AVG Human Survival – 2.56 hours

Discussion

- Not as deadly as "Smart Zombies" but lethal zombies are still dangerous
- Their kill rate best simulates a zombie's performance at night
- Bottom Line: Don't move during the night
- Recommend:
  - Last class scheduled to conclude NLT 1400 IOT probability of outbreak during limited visibility

Less Infection Rate

Parameters

- # of Susceptible – 1616
- # of Zombies – 5
- Infection Rate – **50%**
- Break-In – 1%
- Zombie Kill Rate – 55%
- Human Kill Rate – 45%

Results

- Time: 96 Hours
- Safest BLDG: King
- Most Dangerous: Root
- Critical Points (% Humans Dead):
  - 25% - 2.08 hours
  - 50% - 15.03 hours
  - 75% - N/A
- AVG Human Survival – 4.28 hours

Discussion

- Reducing the chance that a human gets infected after losing a fight with a zombie greatly increases our chances of survival
- If a Human fights a zombie, they must survive or die. Turning is not an option.
- **Recommend:**
  - Invest in Zombie-immunization research and propagate throughout DoD

Larger Class Sizes

Parameters

- # of Susceptible – 1616
- # of Zombies – 40
- Infection Rate – 75%
- Break-In – 1%
- Zombie Kill Rate – 55%
- Human Kill Rate – 45%

Results

- Time: 12.77 Hours
- Safest BLDG: Glasgow
- Most Dangerous BLDG: Ingersoll
  Critical Points (% Humans Dead):
  - 25% - 0.85 hours
  - 50% - 3.2 hours
  - 75% - 4.15 hours
- AVG Human Survival – 3.1 hours

Discussion

- This factor did not make the zombies more deadly
- The zombies gain more interactions per zombie in this run because of their increased starting size
- This leads to a rapid growth in zombies very early
- Recommend:
  - Keep class sizes < 20

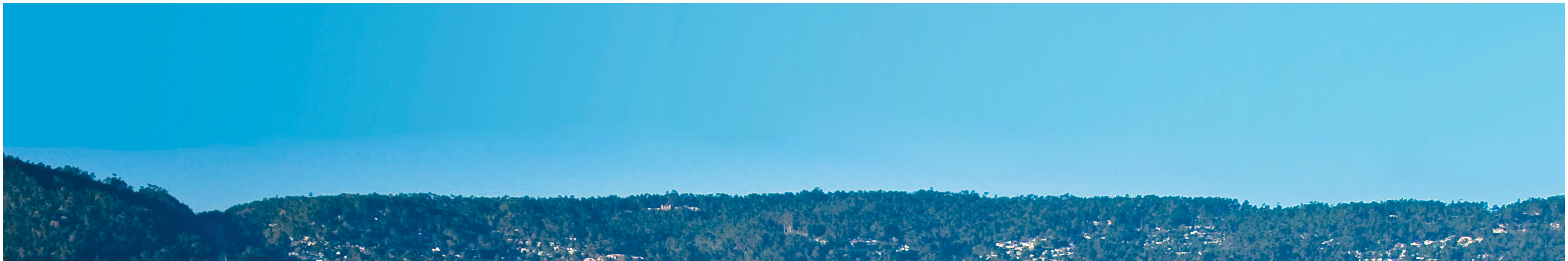
Results

Our model represented the problem well. The rapidly growing death rate and zombie creation rate is expected given the "28 Weeks Later" parameters. Not only do movies agree with this, but other academic studies do as well. Unsurprisingly (and seriously), the academic recommendations for the zombie apocalypse is:

1. Stay in small groups
2. Keeping distance from Zombies is the most important thing
3. Infrastructure is great but agility beats defense
4. Friends are great…until they become enemies

Future work

1. Increase the number of servers to represent different sections of the buildings.
2. Model different types of humans and/or zombies
3. Include speed differences between different types of entities
4. Model learning behavior for humans and/or zombies
5. Model environmental changes like night and day transitions



NAVAL POSTGRADUATE SCHOOL

1 University Circle • Monterey, CA 93943

(831) 656-1068 • www.nps.edu