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Assessing the Effectiveness of Biosurveillance via Discrete Event Simulation (Student Research Briefing)

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Assessing the Effectiveness of Biosurveillance via Discrete Event Simulation

DTRA Briefing

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WWW.NPS.EDU

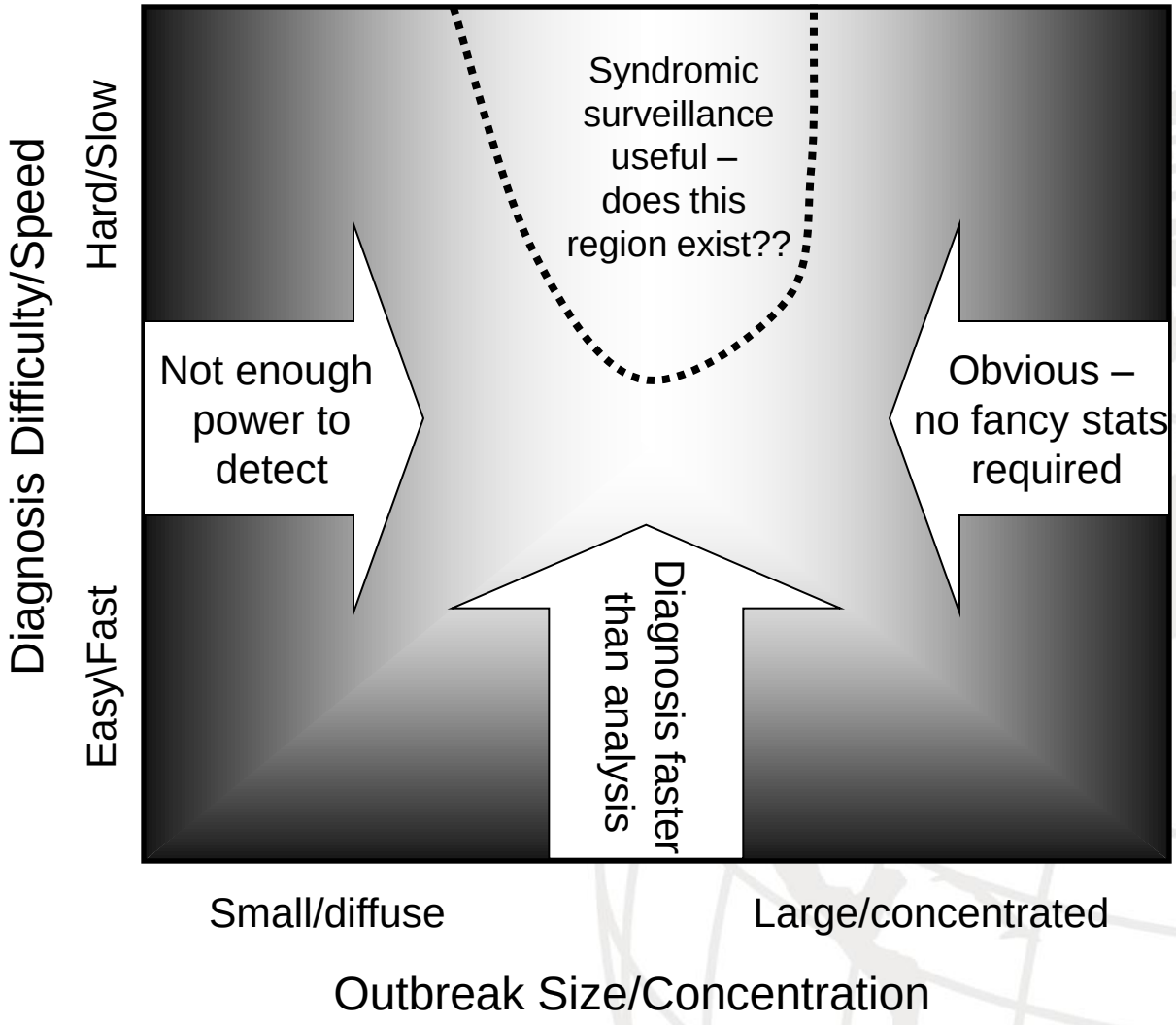
Agenda

- Research questions
- Smallpox overview
- A simple simulation
- A more realistic simulation
- Future steps

Research Questions

- Are biosurveillance statistical algorithms useful/effective for early event detection in comparison to medical personnel?
  - If so, under what conditions?
- What factors most affect performance?
  - I.e., under what conditions are medical personnel significantly better than the statistical algorithms and vice versa?

When Are Statistical Methods Useful for Outbreak Detection?



Fricker, R.D., Jr., and H.R. Rolka (2006). Protecting Against Biological Terrorism: Statistical Issues in Electronic Biosurveillance, *Chance*, **19**, 4-13.

Scope of Thesis

- Develop a discrete event simulation of a bioterrorism attack
  - Idealized in terms of the health behaviors and outcomes of the affected population
- Analyze and interpret the simulation outcomes, to answer the question: Under what conditions do statistical algorithms "add value" to the existing (traditional) medical infrastructure?

Smallpox Overview

- An orthopoxvirus , human only known reservoir, person-to-person transmission
- 2 variants:
  - Variola major: mortality rate of 30-35%
  - Variola minor: mortality rate of 1%
- Average incubation period (the interval between exposure and first symptoms) is 10-14 days
  - Range is as short as 7 days and as long as 17 days

Source: Center for Disease and Control Prevention website. http://www.bt.cdc.gov/agent/smallpox/training/overview/

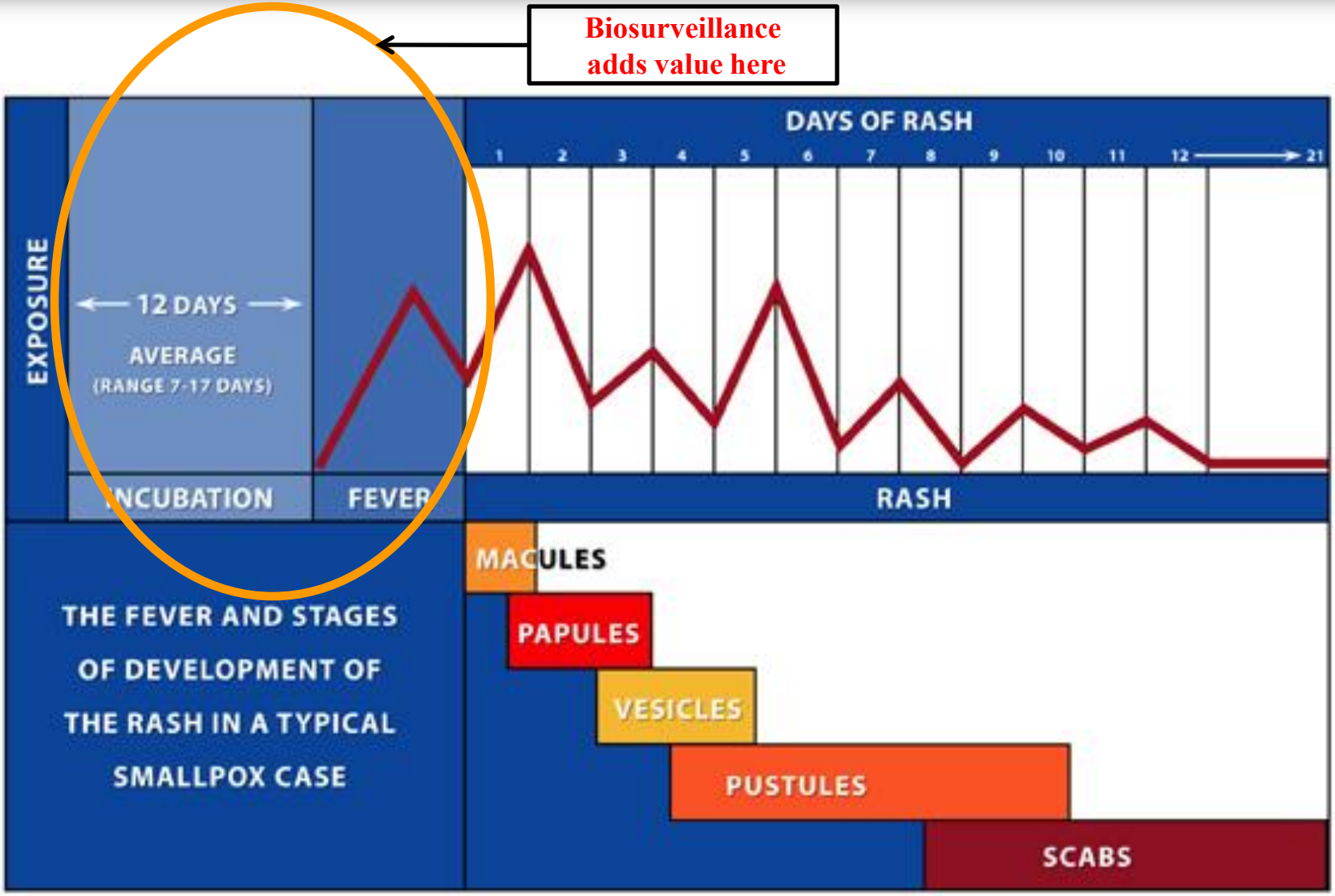
Smallpox Symptoms

- First symptoms include fever, malaise, head and body aches and sometimes vomiting
- Fever is usually high in the range of

  101º- 104º F
- Rash development following fever
- Rash emerges first as small red spots on the tongue and in the mouth
  - Develop into sores in mouth and throat (most contagious)

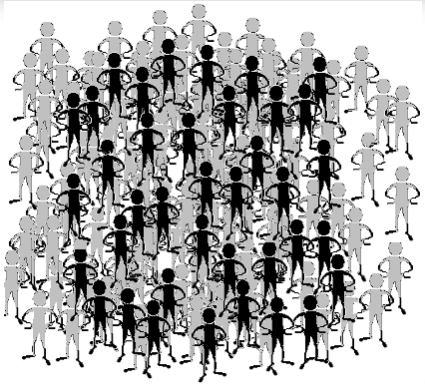
Source: Center for Disease and Control Prevention website. http://www.bt.cdc.gov/agent/smallpox/training/overview/

Smallpox Progression

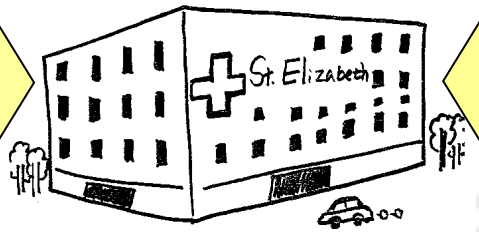


Source: Foege, Lane, and Millar, Am J. Epi, 1969

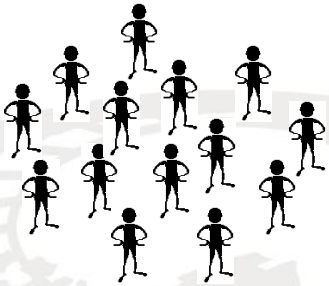
A Simple Simulation

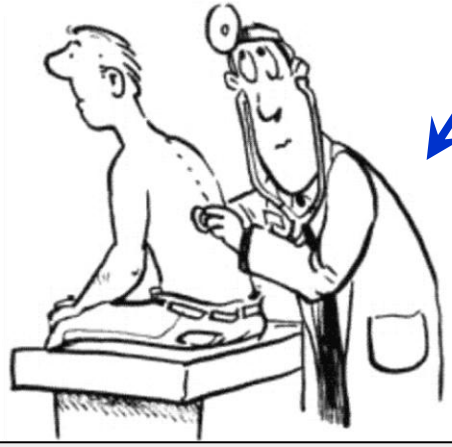


On average, 100 people (std. dev. 20) go to the hospital each day with flu

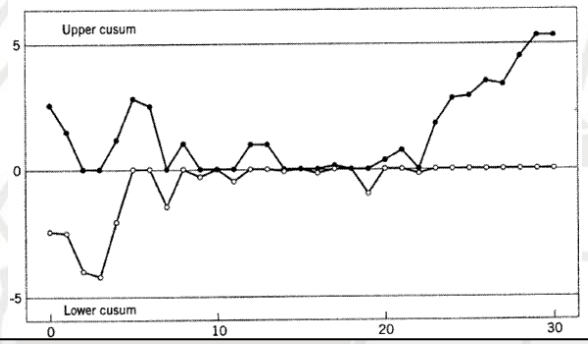


Bioterror attack results in *X* more going to hospital with flu-like symptoms





- ***Doctors see each patient and make a diagnosis***
- ***For those exposed to bio-agent, there is some probability p that the doctor will correctly diagnose***



- ***Algorithm monitors the average number of people going to the hospital with flu-like symptoms***
- ***Signals if there is a statistically unusual increase***

- Question: *What is the probability clinician diagnoses a case of the bio-agent before statistical method signals?*

Fricker, R.D., Jr., "Methodological Issues in Biosurveillance," invited short course for the Twelfth Biennial CDC/ATSDR Symposium on Statistical Methods, Decatur, GA, April 2009.

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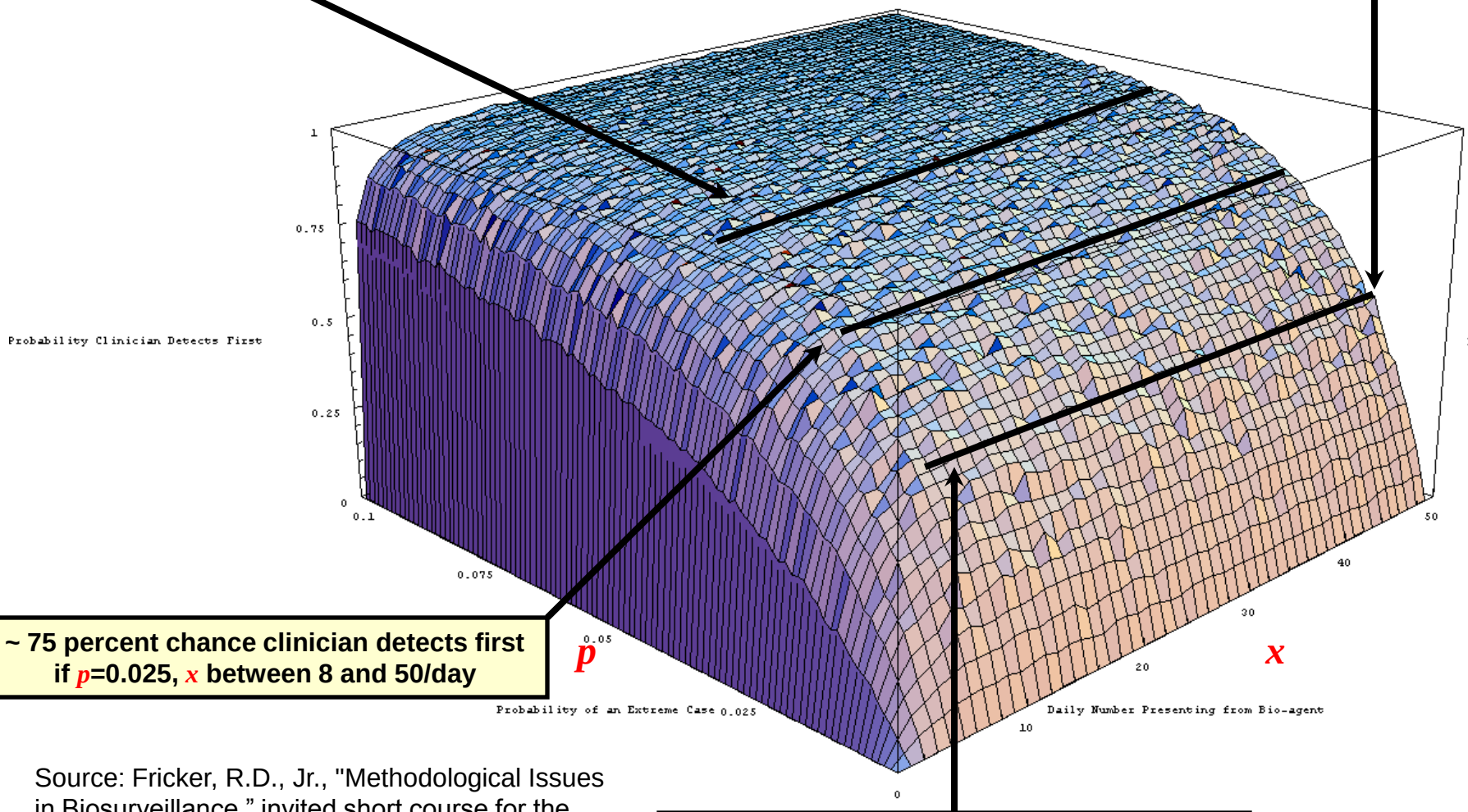
Simulation Results (clinicians vs. CUSUM algorithm)

~ 90-95 percent chance clinician detects first if p=0.05, x between 10 and 50/day

~ 50 percent chance clinician detects first if probability of an extreme case p=0.01 and number presenting from bio-agent x=50/day



~ 75 percent chance clinician detects first if p=0.025, x between 8 and 50/day

~ 50 percent chance clinician detects first if p=0.01, x between 8 and 50/day

Source: Fricker, R.D., Jr., "Methodological Issues in Biosurveillance," invited short course for the Twelfth Biennial CDC/ATSDR Symposium on Statistical Methods, Decatur, GA, April 2009.

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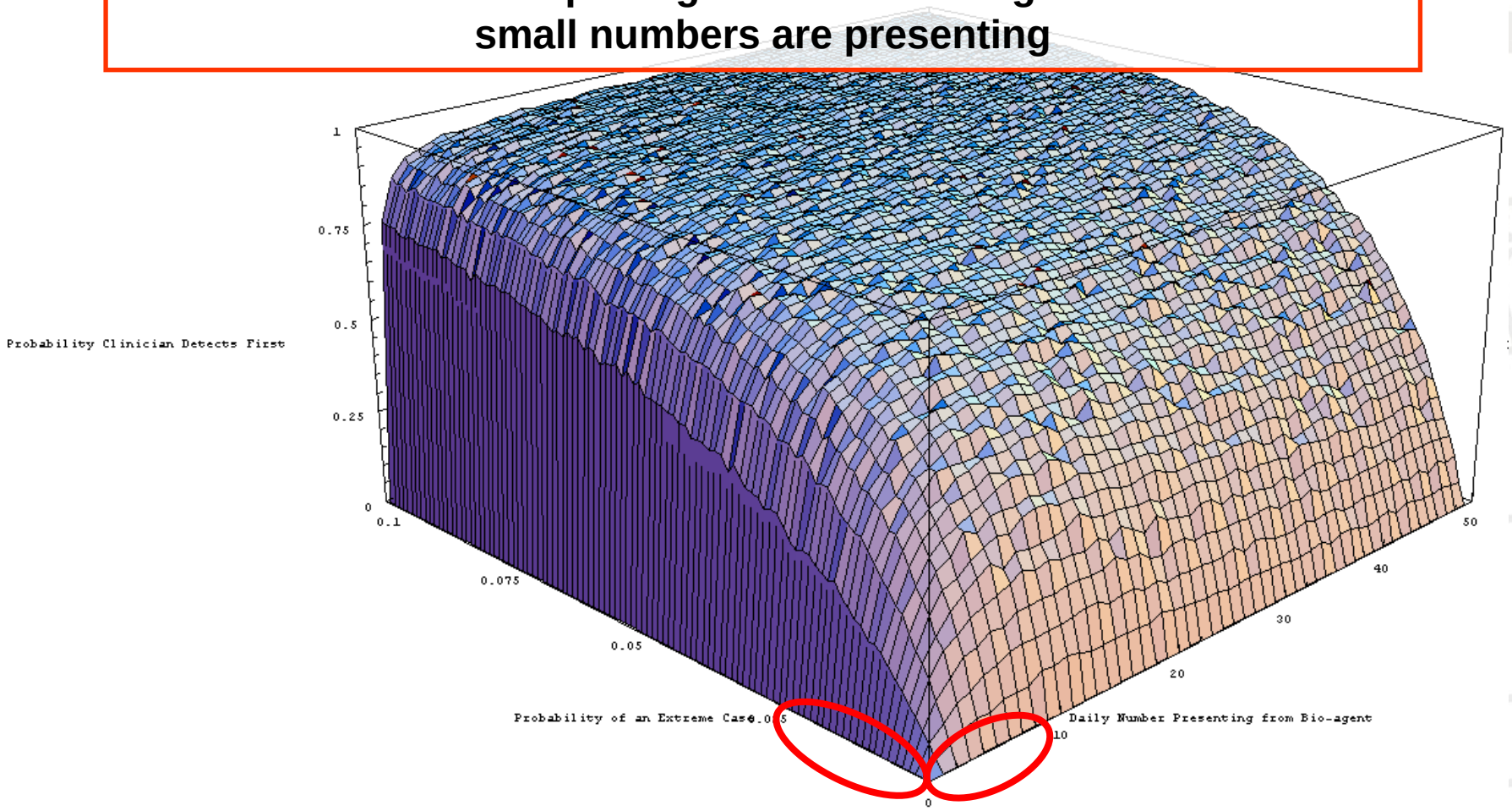
Simulation Results (clinicians vs. CUSUM algorithm)

Simulations suggest there is a role for statistical algorithms in biosurveillance when pathogen is hard to diagnose and/or when small numbers are presenting



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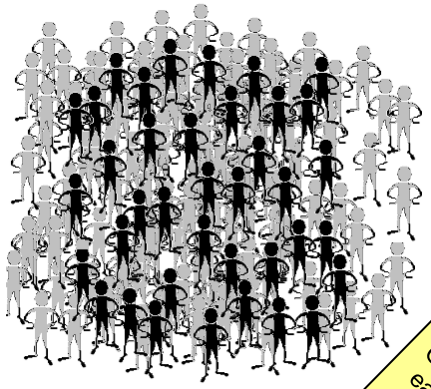
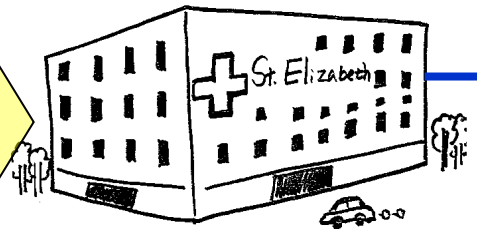
A More Realistic Simulation

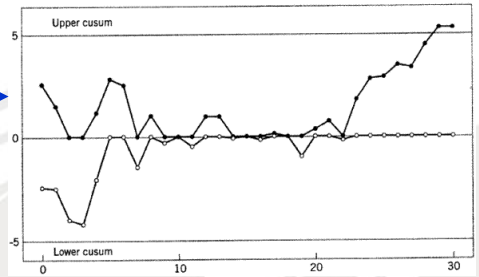
Susceptible Population



Each day, with **Pr(flu)**, each susceptible goes to hospital with flu



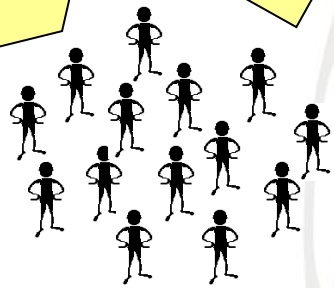
- ***Algorithm monitors the average number of people going to the hospital with flu-like symptoms***
- ***Signals if there is a statistically unusual increase***



Given bioterror attack, each person infected with probability **Pr(infected | t)**

Infected go to the hospital with probability **Pr(hospital | infect, t)**

- ***Doctors see each patient and make a diagnosis***
- ***For those exposed to bio-agent, there is some probability Pr(bioagent | t) that the doctor will correctly diagnose***

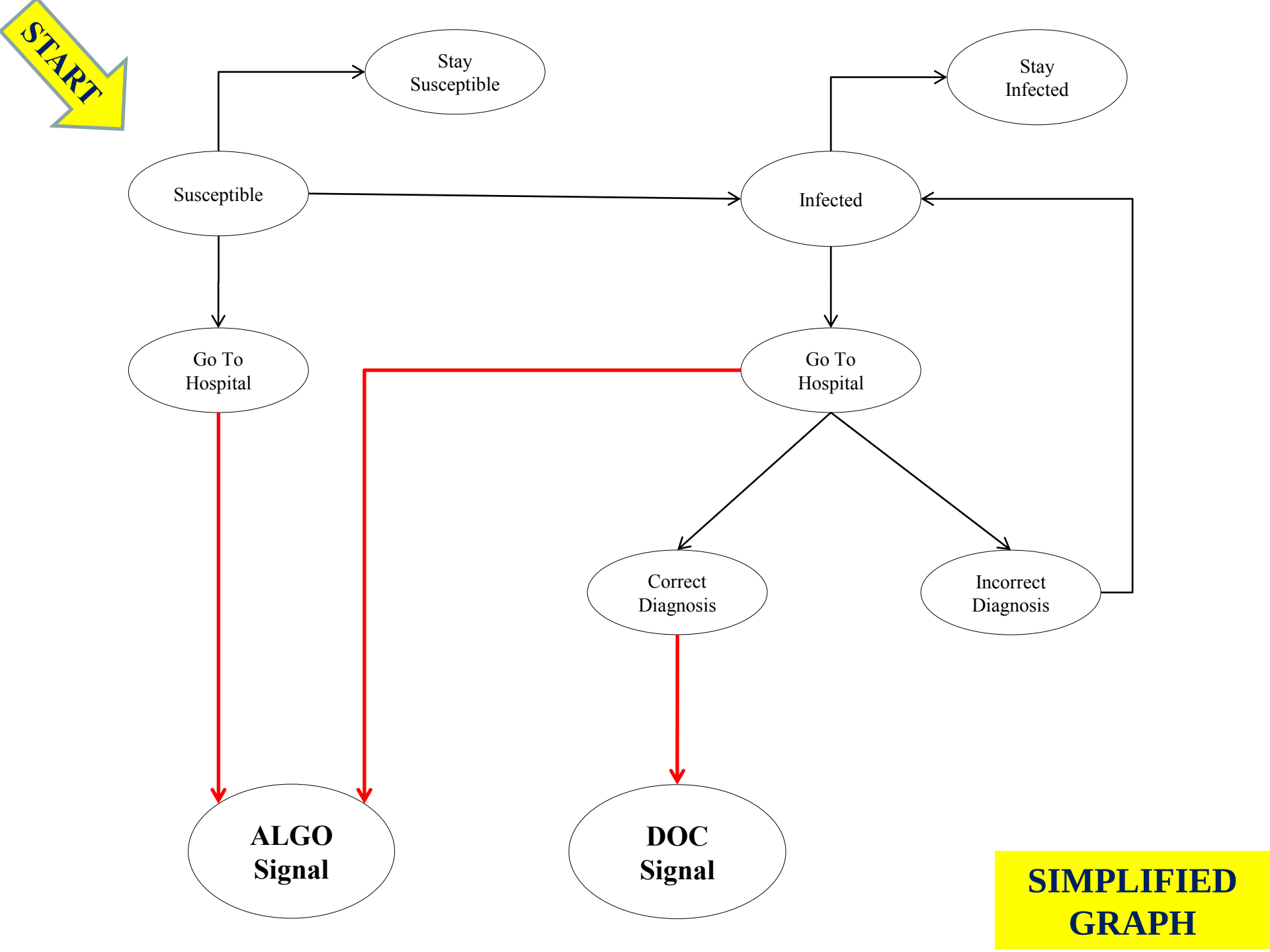


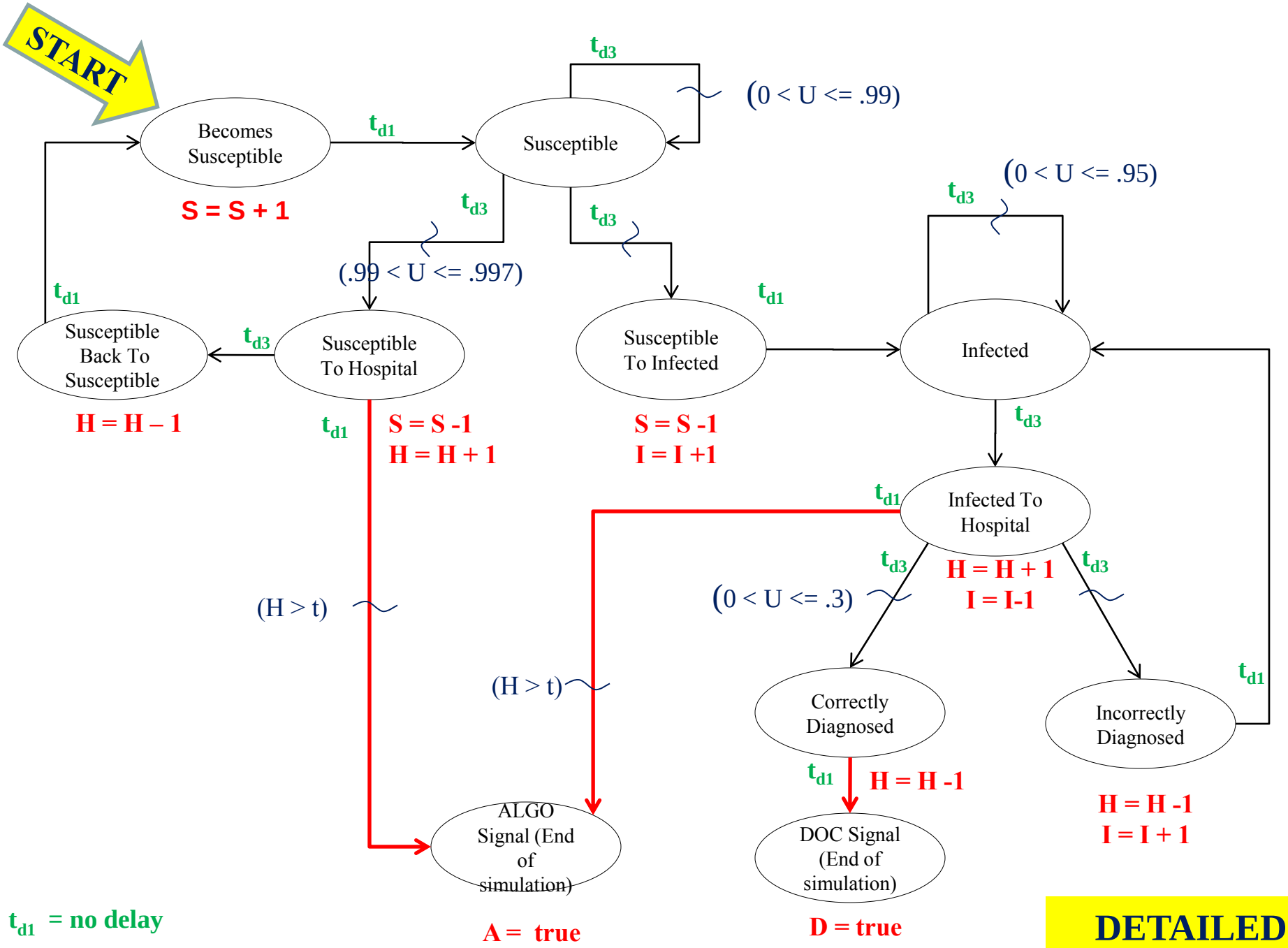
(Bio-agent) Infected Population

Doctor misdiagnoses bioagent with **1-Pr(bioagent | t)**, person still infected

Simulation Design as of 10NOV10

- **Goal:** Design more realistic simulation to gain insight into which outbreak signal occurs first given certain parameters
  - ALGORITHM: use aggregate data i.e. total number of people showing up at hospital
  - DOCTOR: use the individual patient data i.e. how long has the patient been infected
- **Tools:**
  - JAVA with Simulation Kit
  - Parameters:
    - Population size, threshold, number of days
  - State variables:
    - Daily count of patient in various states: Susceptible, Infected, or At Hospital
    - Aggregate count of patient various states: Susceptible, Infected, or At Hospital


START
Stay Susceptible
Stay Infected
Susceptible
Infected
Go To Hospital
Go To Hospital
Correct Diagnosis
Incorrect Diagnosis
ALGO Signal
DOC Signal
SIMPLIFIED GRAPH


START
Becomes Susceptible
S = S + 1
Susceptible
(0 < U <= .99)
(.99 < U <= .997)
Susceptible Back To Susceptible
H = H – 1
Susceptible To Hospital
S = S -1
H = H + 1
Susceptible To Infected
S = S -1
I = I +1
(0 < U <= .95)
Infected
Infected To Hospital
H = H + 1
I = I-1
(0 < U <= .3)
(H > t)
(H > t)
Correctly Diagnosed
H = H -1
Incorrectly Diagnosed
H = H -1
I = I + 1
ALGO Signal (End of simulation)
A = true
DOC Signal (End of simulation)
D = true
t_{d1} = no delay
t_{d3} = delay of 1 day (24 hrs)
DETAILED GRAPH

Future Steps

- November: Complete literature review (to parameterize model)
- December: Complete simulation model:
  - Implement the functions for transitional probabilities
  - Incorporate statistical algorithms into the simulation
- January-March: Run simulations and analyze output

Questions?