BioWar

A Scalable Multi-Agent Model for Biological and Chemical Incidents

BioWar Group

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Center for Computational Analysis of Social and Organizational Systems

http://www.casos.cs.cmu.edu/

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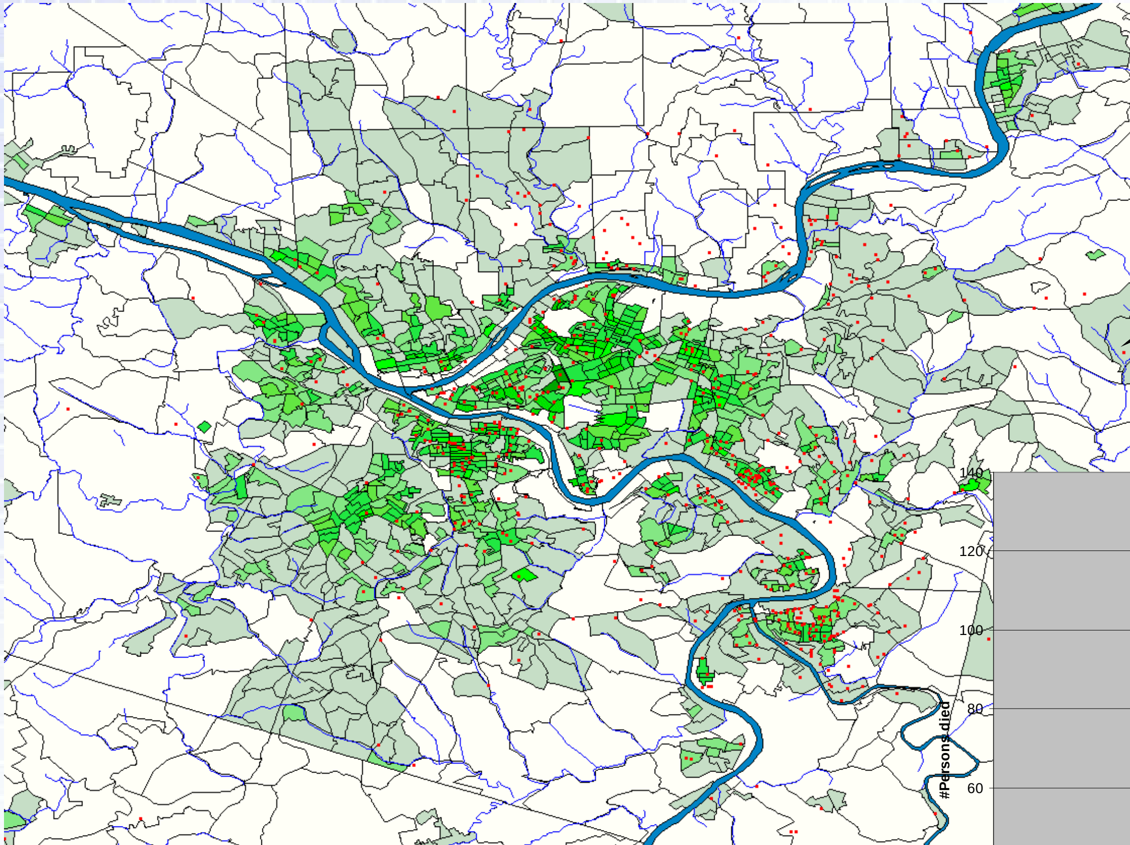
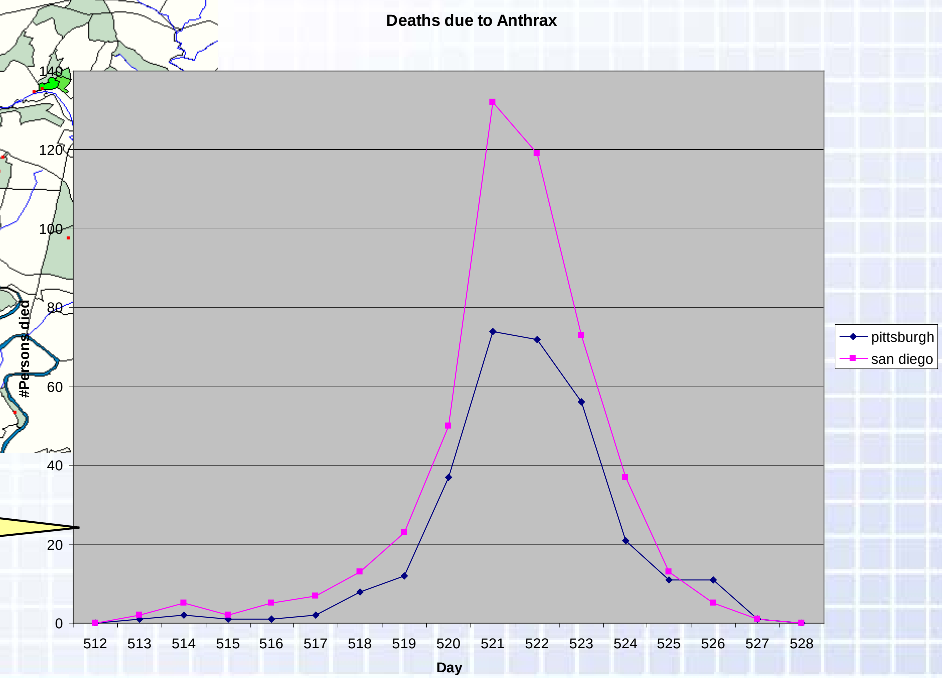
BioWar – Conceptualization

City Scale Multi-Agent Network Model of WMD Attacks



Movement of Smallpox infected agents in Pittsburgh



Comparative death rates due to Anthrax in Pittsburgh and San Diego

BioWar
Inputs and Outputs

- Realistic input
  - Census data, climate history,…
  - Varied by location
  - Scaleable
- Need-based outputs
  - Matched to real-world prototypes
    - Aggregate information
    - Imprecise
    - Useful for testing algorithms, training,...
  - Providing exact insights into simulation
    - Precise timings
    - Complete accuracy
    - Useful for “what-if” and effectiveness studies

Agents move in networks which influence what they do, where, with whom, what they know, what diseases they get, when, and how they respond to them.

Major difference in network and disease effects are based on race, gender and age.

BioWar Model

- Autonomous agents
  - Individual variation
  - Connected by social networks
- Scaleable architecture
  - Multithreaded execution
  - Scaleable population size
- Symptom driven ailment model
  - Disease spread and progression on a per-disease basis
  - Agents respond to perceived symptoms
  - Medical diagnosis response based on symptoms and tests
    - Diagnosis may be incorrect
    - Symptom profile is coded for likelihood and evoking strength
- Dynamic responses
  - Event or time based response injection during runs
  - Pre-scripted for batch runs or interactive

Current City Models

	Pittsburgh	San Diego	San Francisco	Hampton Roads		Washington DC+
				Norfolk	Hampton*	
POPULATION	2,332,823	2,699,582	745,377	1,530,908	? 146,431	559,258
○ Medical▪	? 70,730	? 57,170	? 33,340	? 38,080	? 38,080	? 29,690
LOCATIONS	59,498	67,335	31,532	34,407	2,459	19,438
○ Clinics	2,032	1,917	783	905	78	632
○ Hospitals	50	33	14	19	3	18
○ Pharmacies	479	274	123	199	16	92
○ Restaurants	4,383	4,886	2,862	2,504	203	1,476
○ Schools	645	112	541	346	34	147
○ Stadiums	200	143	33	97	8	15
○ Stores	9,088	9,182	3,827	5,825	445	1,963
○ Theaters	551	516	294	307	25	134
○ Other Work	42,070	50,272	23,055	24,205	1,647	14,961

*Hampton City is a subset of the entire Hampton Roads/Norfolk metro area.
+Washington, DC is limited to the District of Columbia.
▪Need to revise these numbers based on simulation runs.

Ailments

- Diseases
  - Distribution of occurrence
    - Background – present more or less continuously in simulation
    - Outbreak – “bursts” due to natural events or attacks
  - Spread modes
    - Non-contagious – contracted from attacks, outbreaks and background
    - Contagious – as above, but also spread by agent to agent contacts
  - New diseases and variations possible
- Chemical agents
  - Types
    - Sarin – war agent
      - Actual events for comparison (Aum Shinrikyo, Japan)
      - Fairly well studied
    - Chlorine – industrial chemical
      - Used in large quantities commercially
      - Release may occur deliberately or accidentally
  - Spread by wind
    - Plume – for continuous releases
    - Puff – for burst releases

Current Diseases – Contagious

Bacterial Pharyngitis Acute Non Streptococcal
Non Gonoccocal
Botulism
Bubonic Plague
Campylobacter Enteritis
Cutaneous Atypical Mycobacterial Infection
Encephalitis Acute Viral
Giardiasis Intestinal
Gram Negative Pneumonia Non Klebsiella
Hepatitis A Acute
Herpes Simplex Encephalitis
Immunice Deficiency Syndrome Acquired (Aids)
Infectious Mononucleosis
Influenza
Influenza Pneumonia
Malaria
Meningococcal Meningitis
Mycoplasma Pneumonia
Plague Meningitis
Plague Pneumonia
Pneumococcla Pneumonia
Pulmonary Legionellosis
Salmonella Enterocolitis Non Typhi
Schistosomiasis Systemic Shigellosis
Staphylococcal Pneumonia
Staphylococcal Scarlet Fever
Toxic Shock Syndrome
Streptococcal Pharyngitis Acute
Streptococcus Pyogenes Pneumonia
Syphilis Primary
Smallpox
Tuberculosis Chronic Pulmonary
Tuberculosis Disseminated
Varicella Pneumonia
Viral Gastroenteritis
Viral Pharyngitis Acute Non Herpetic

Actually, this list was carried across from the Ver. 1.5 presentation and needs to be checked.

Current Diseases – Noncontagious

- Anthrax, Cutaneous
- Anthrax, Inhalational
- Angina Pectoris
- Anxiety Neurosis
- Arteriolar Nephrosclerosis Benign Essential Hypertension
- Arteriosclerotic Heart Disease
- Bronchial Asthma
- Bronchitis Chronic Simple
- Brucellosis
- Cardiogenic Shock Acute
- Chronic Fatigue Syndrome
- Depression
- Diabetes Mellitus
- Disseminated Intravascular Coagulation
- Fibromyalgia Syndrome
- Heat Exhaustion
- Hypertensive Heart Disease
- Hypovolemic Shock
- Myocardial Infarction Acute
- Obsessive Compulsive Neurosis
- Pulmonary Emphysema
- Somatization Disorder Hysteria
- Staphylococcal Gastroenteritis Food Poisoning Tension Headache
- Tularemia
- Tularemia Menigitis

Actually, this list was carried across from the Ver. 1.5 presentation and needs to be checked.

Interventions

- Interventions change simulator state during the run
- Currently two types supported
  - Attacks – inject chemical or diseases "incidents"
    - Time triggered
    - May utilize any chemical agent or disease
  - Responses – dynamically change simulator state
    - Event triggered
    - Allow policy decisions to be simulated
- Additional "quasi-interventions" mechanisms available
  - Support simulation of naturally occurring diseases
    - Outbreaks – model periodic events (e.g. flu)
    - Background – model "steady state" diseases (e.g. heart disease)
  - Sensible defaults provided, but user may modify

Responses

- Dynamically change simulator state based on events
  - Medical interventions: vaccinate, prophylaxis
  - Public health responses: quarantine, isolate, evacuate, shelter in place
  - Simulator control: pause simulation, activate/deactivate locations
- May be invoked automatically or manually.
- Rule based, with the general form:

  <trigger> [<delay>] <target> <response>

```
on(<trigger>) [wait (<delay>)] for(<target>) do(<response>);
```

- Example: On May 13, order agents to shelter in place for 24 hours.

```
on(5/13) for(agent all) do(shelter_in_place for(1d));
```

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Wind Model

- Attack agents (chemical and disease) are wind dispersed
  - Wind models utilize location specific climatic information
  - Weather is randomized, but matches historical profiles for modeled cities
- Several wind models are provided, optimized for ailment type and release duration
  - Gaussian Puff
    - Puff-A – suspended particles (e.g. anthrax spore dispersal).
    - Puff-B – molecular transport (burst dispersal of chemicals)
  - Gaussian Plume
    - Plume-A – molecular transport (continuous release of chemicals)

Plume-A: Gaussian Plume Dispersion Model

$$C(x,y,z,t) = \frac{Q}{2\pi u \sigma_y \sigma_z} \exp\left[-\frac{y^2}{2\sigma_y^2}\right]\left[\exp\left(-\frac{(z-H)^2}{2\sigma_z^2}\right) + \exp\left(-\frac{(z+H)^2}{2\sigma_z^2}\right)\right]$$

where

C - concentration of pollutant;

Q – fixed mass of poisoning material;

u – air velocity;

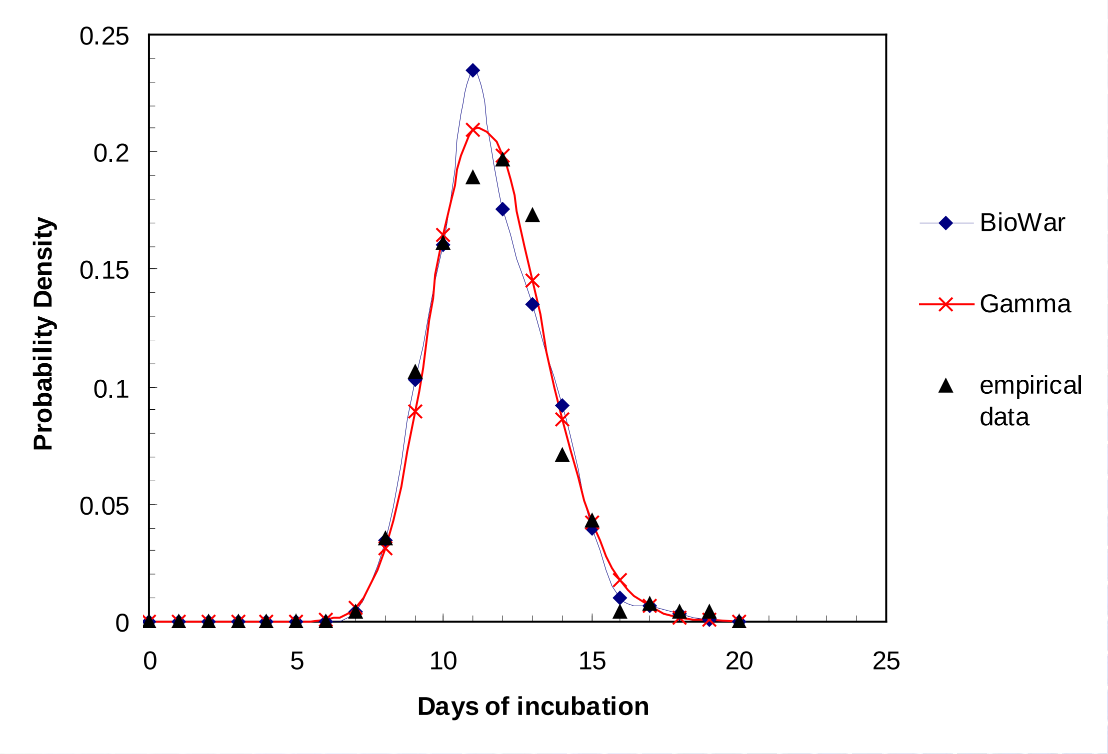
H – height of puff release;

x, y, z – distance from the release;

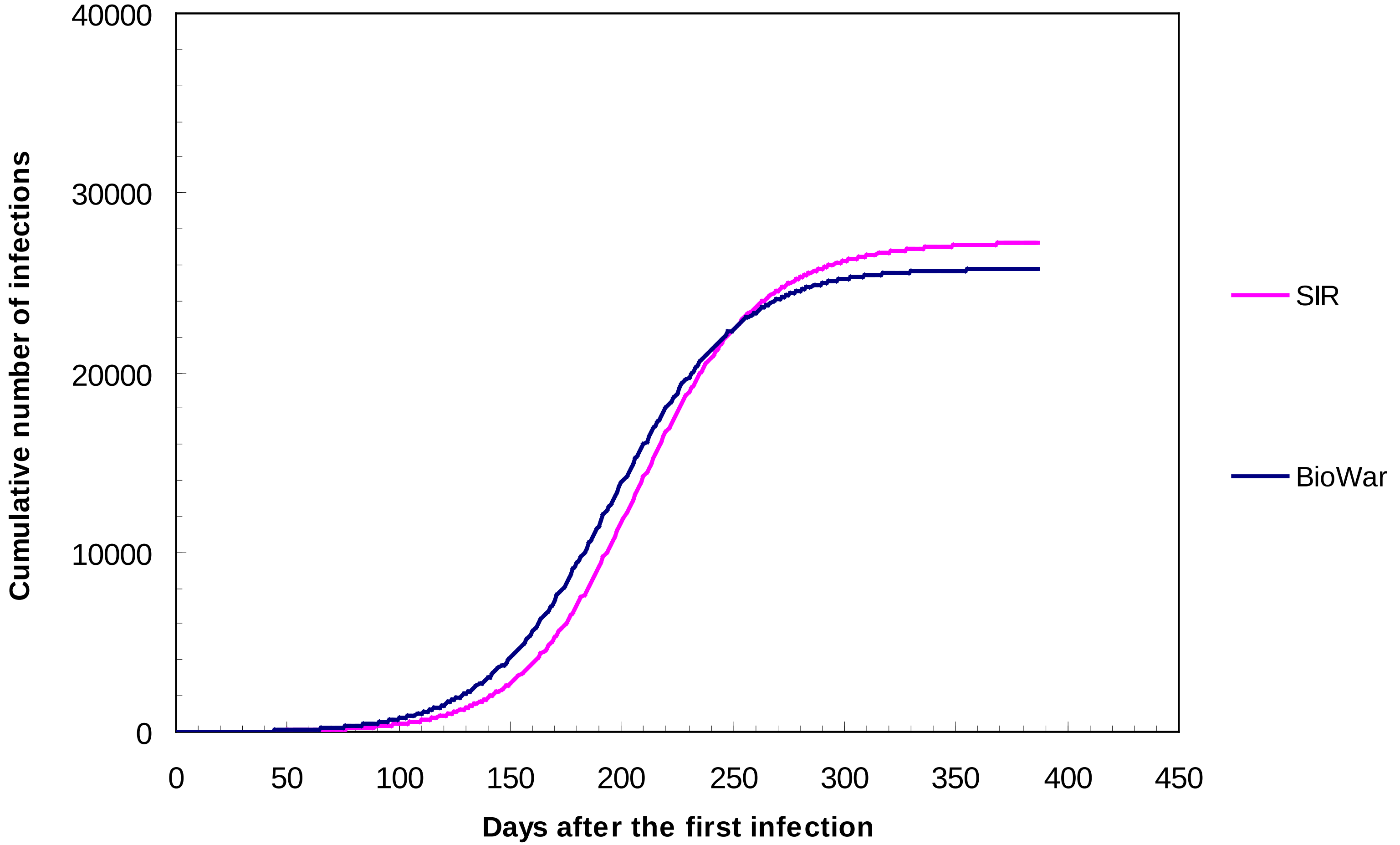
$\sigma_x, \sigma_y, \sigma_z$ **- standard deviations along the axis**

Disease Model - Smallpox

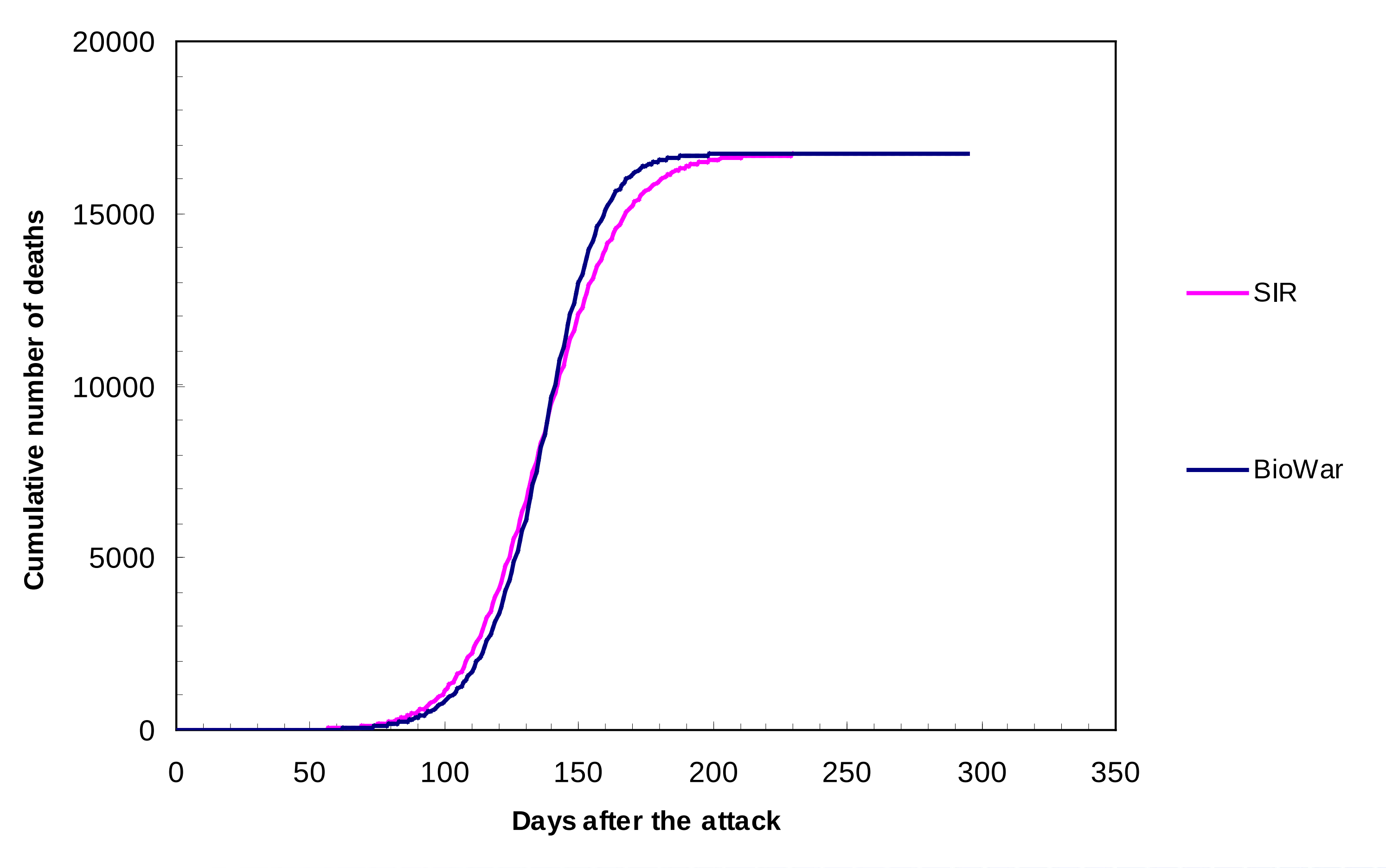
- Generic disease model can be enhanced for specific diseases.
- Smallpox example
  - Incubation and infectious periods well-studied.
  - Considered a significant biological threat.



Smallpox Infections: SIR vs. BioWar



Smallpox Death: SIR vs. BioWar



10) Attack On Hampton Roads

"Impact of small/medium/large anthrax or smallpox attack on Hampton Roads (100% population) outputs to plot number infected, number who die, number first-responders infected, number first responders who die, number military infected number military who die." (KMC)

Will do this later.

11) Performance Specs - From Eric

"Time for a single run generating 6 months of data (or whatever length it was that Eric ran) for some city using a single processor machine, and for same city using a 4 processor machine - note use the data here Eric generated a few months ago - no need to do new runs for this." (KMC)

Deferred first draft to Eric.

Planned Functionality Enhancements

- Simplify emergent threats modeling (e.g. Avian Flu)
- More realistically model medical capacities
  - Standard capacity – set limitations by treatment type.
  - Surge capacity – hospital in extraordinary circumstances
    - Regular hospitals
    - Temporary facilities
- Add first responders interaction with the injured and ill
- Expand interventions
  - Allocation of critical supplies
  - More models of public health interventions
- Model extraordinary agent behavior
  - High threat/stress levels
  - Panic

Acknowledgements

- This is final slide, it repeats the original logo
- Feel free to stick sponsor logos at the bottom or along the side, we need to standardize on one