Biological Event Modeling for Response Planning

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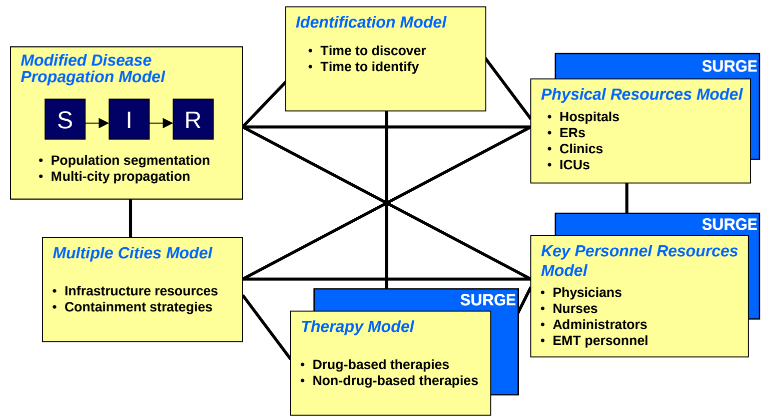
MORS Workshop: HLS/HLD
November 16, 2005

Modeling a Bio-Event

- CONTEXT: 2003 United Nations report:
  - [The Al Qaeda terrorist network has] *already taken the decision to use chemical and bio-weapons in their forthcoming attacks…The only restraint they are facing is the technical complexity to operate them…effectively.*
- PURPOSE:
  - See the relative effectiveness of different prevention and mitigation strategies
  - Identify critical leverage points – <u>where policies or actions will make a substantial difference</u>
  - Help establish links between strategy and operational planning
  - Identify requirements for needed capabilities
    - <u>Infer from insertions into scenarios that improve outcomes</u>
- MODEL:
  - Developed in Mitretek IRAD
  - Built in System Dynamics [iThink 38 Mb]
    - User interface allows non-modelers to experiment
      - 118 settable parameters
  - Excel interface for easier input, sensitivity analyses, improved output
  - GMU grad students extending model for a class project

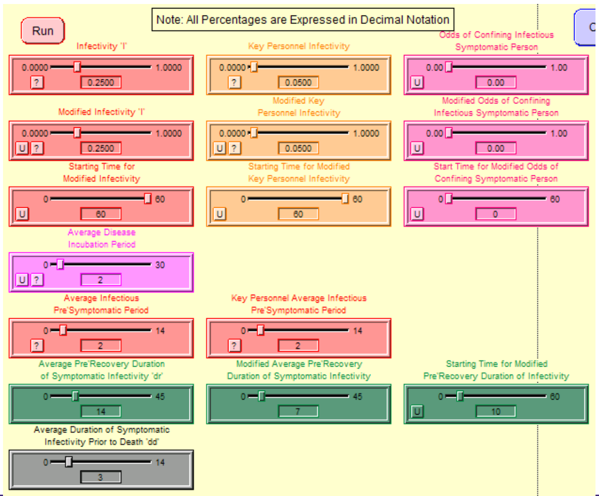
Bio-Event Systems Dynamics Model



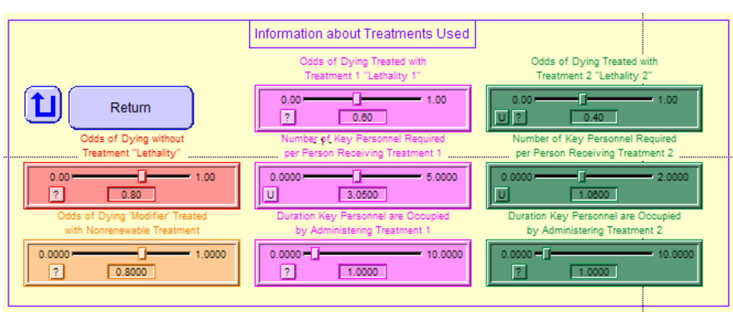
Bio-Event Model

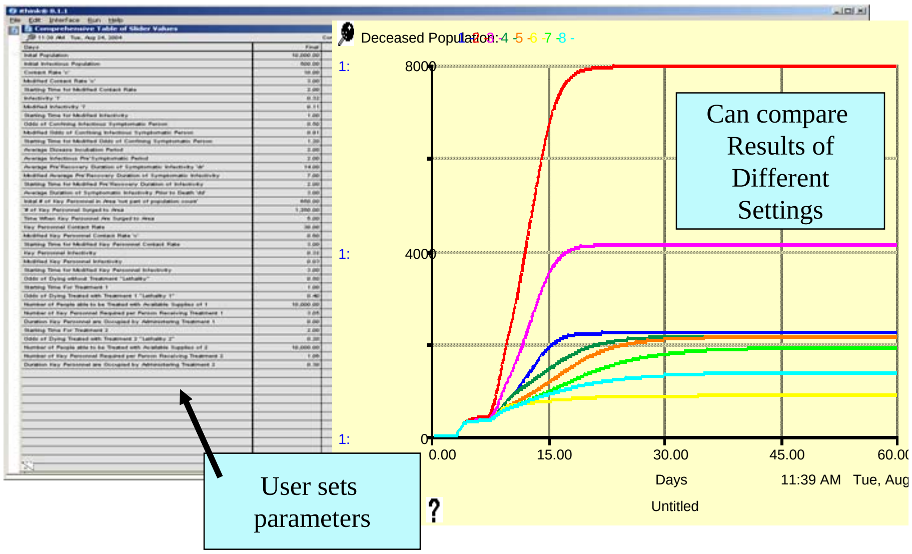
- Model the spread of a biological agent (disease)
  - Set Parameters to simulate different disease (and available treatments)
- Reflect dependencies on Resources – initial amounts and effectiveness
  - Renewable (e.g., involving ICUs)
  - Non-renewable (e.g., medicines)
  - Key personnel
    - Surge Issues: Timing and Amount of Resources
- Provide for strategies that may limit the spread and impact of a disease :
  - Confinement of symptomatic people
  - Modifying the contact rate and/or disease infectivity at a specified time
    - (e.g., public “stay at home” messages and use of surgical masks)
  - Surging in additional supplies for treatments as well as key personnel
- Can develop Scenarios that involve population movement among distinct areas (cities)

User Sets Disease Characteristics

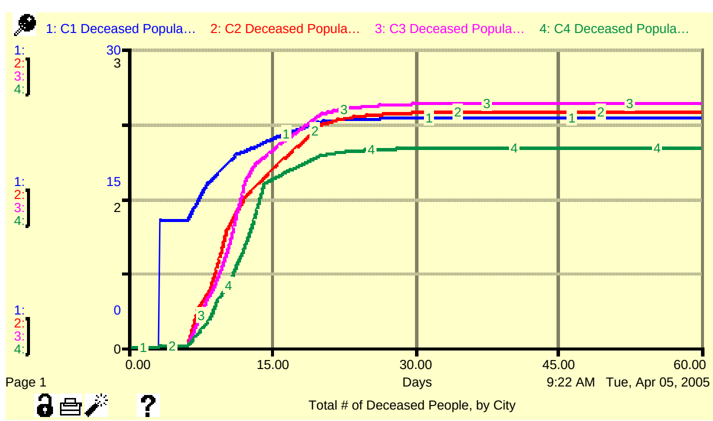


Use Sets Parameters for Treatments





Spread of Disease to Other Cities



System Dynamics

- Developed (circa 1960) by Jay W Forrester at Sloan School of Management, MIT.
- Applied concepts of control systems and cybernetics (with a primitive programming language DYNAMO)
  - Really a form of standard mathematical modelling
- Many applications
  - Industrial Dynamics (SimCity)
  - Limits to Growth (Club of Rome)
- Barry Richmond (Dartmouth) developed graphical programming language iThink/Stella (initially for the Mac)
  - Now a number of graphical programming languages for System Dynamics
- Forrester (2001):
  - "The most important use of system dynamics should be for the design of policies"
    - Candidate: Surge response to Bio-terrorist Event

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Features of the Model

- Disease (user settable characteristics) TIMING
  - Stages (S + Incubation + Pre-Symptomatic + Symptomatic + R)
- Treatments TIMING
  - Renewable
  - Non-renewable
  - Confinement (Odds of = success rate)
  - Modify
    - Contact rate
    - Infectivity
- Key Personnel
- Surge TIMING
  - Resources and Personnel
- Multi-area (Four Cities)
  - User settable Movement
- Sensitivity Analyses

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Model Components

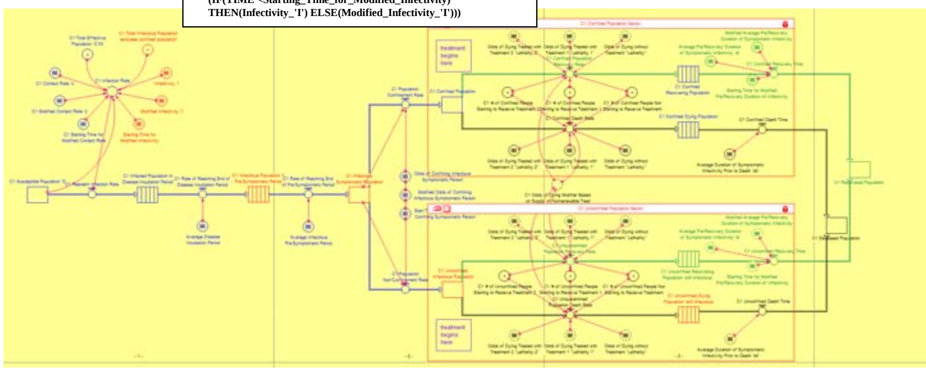
- DISEASE
  - Infectivity
  - Incubation Period
  - Infectious Pre-Symptomatic Period
  - Duration of Symptomatic Infectivity
  - Duration of Symptomatic Infectivity Prior to Death
  - Odd of Confining
- TREATMENTS [1,2]
  - Odds of dying with
  - Odds of dying without
  - Key Personnel needed
  - Amount of Time Key Personnel needed
  - Odds of dying treated with nonrenewable resource

Model Components

- CITIES
  - Initial Population
  - Initial Infectious
  - <u>Contact Rate</u>
  - Modified Contact Rate
  - Starting time for Modified Contact Rate
  - # Key Personnel
  - Key Personnel Contact Rate
- SURGE
  - # Key Personnel
  - Time when Key Personnel Arrive
  - Nonrenewable Treatment
- MODIFY
  - Contact Rates
  - Odds of Confining

Disease Progression (Stages) (for City C1)

C1_Infection_Rate =
(C1_Susceptible_Population_'S' *
(IF(TIME < C1_Starting_Time_for_Modified_Contact_Rate)
THEN(C1_Contact_Rate_'c') ELSE(C1_Modified_Contact_Rate_'c')) *
(IF(TIME <Starting_Time_for_Modified_Infectivity)
THEN(Infectivity_'I') ELSE(Modified_Infectivity_'I')))



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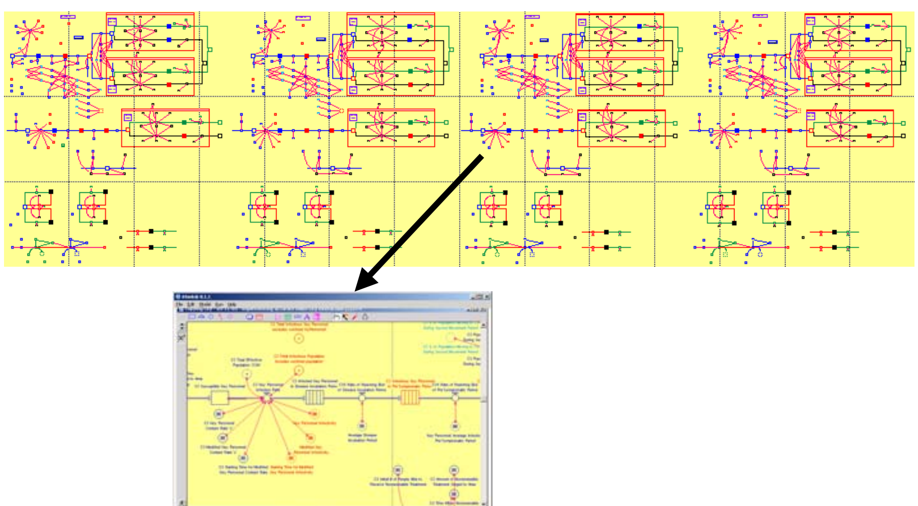
Four City Model



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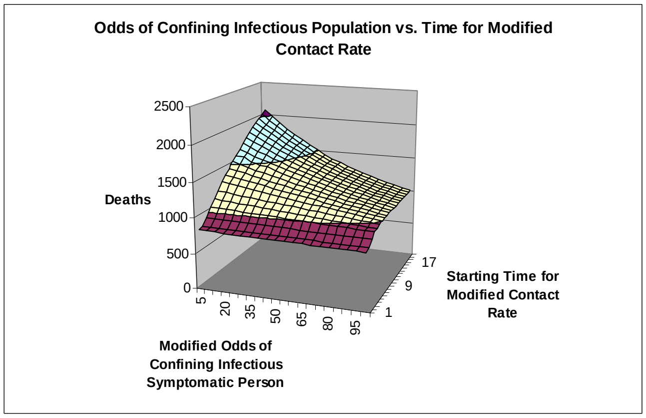
Modifying the Contact Rate Early is Better Than Near Perfection in Confining the Infectious



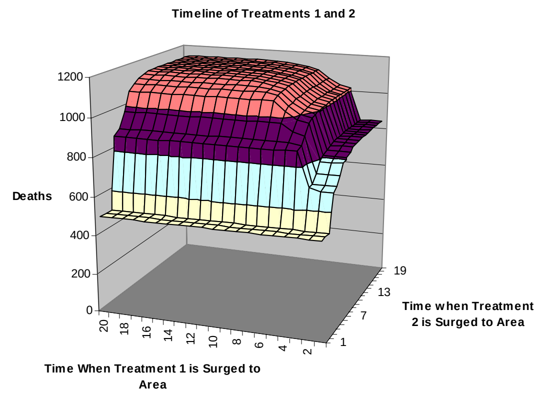
Plague 80% Lethal
Contact Rate = 5 people per day
Modified Contact Rate = 0.6 people per day

Surge and City Options

- Surge
  - Set time (of arrival and availability) as well as amounts of
    - Treatments
    - Key Personnel
      - Always receive best available treatment
- Cities
  - Set size of initial infected population
  - Set amount of movement between cities C_x and C_z

Importance of Surging an Effective Treatment Early

(Early Use of Even a Limited Effective Treatment Makes a Difference)



Lethality of Disease (Plague) = 80% ***Odds of Dying without Treatment if Infected***
Odds of Dying Treated with Treatment 1 = 50%
Odds of Dying Treated with Treatment 2 = 20%

Bioterrorism Policy Issue: Forecasting (pre-positioning) versus (rapid) Resupply

Forecasting (push)	Resupply (pull)
Assumes: Accurate Forecasts. **Wrong Forecasts => Shortages and Surpluses (warehousing)**	**Assumes: Timely resupply.** **Delayed resupply => Shortages** **(Transport is crucial)**
Pre-position based on forecasts	**Pre-position based on resupply time**
Accuracy of forecast degrades as geographical units get more local or the time frame longer	**Accuracy depends on real-time visibility into the status of the node you resupply**
Invest in sophisticated forecasts and surplus resources (enough to deal with forecasts)	**Invest in transport, sufficient resources, and real-time visibility**
Many unused resources in order to ensure a level of service	**Lower total inventory without degrading service**