Modeling Integrated Public Health and Health Care Delivery System Response to Anthrax

Nathaniel Hupert, MD, MPH
Departments of Pubic Health and Medicine
Weill Cornell Medical College
Cornell University

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Pre-Publication Sensitive Material

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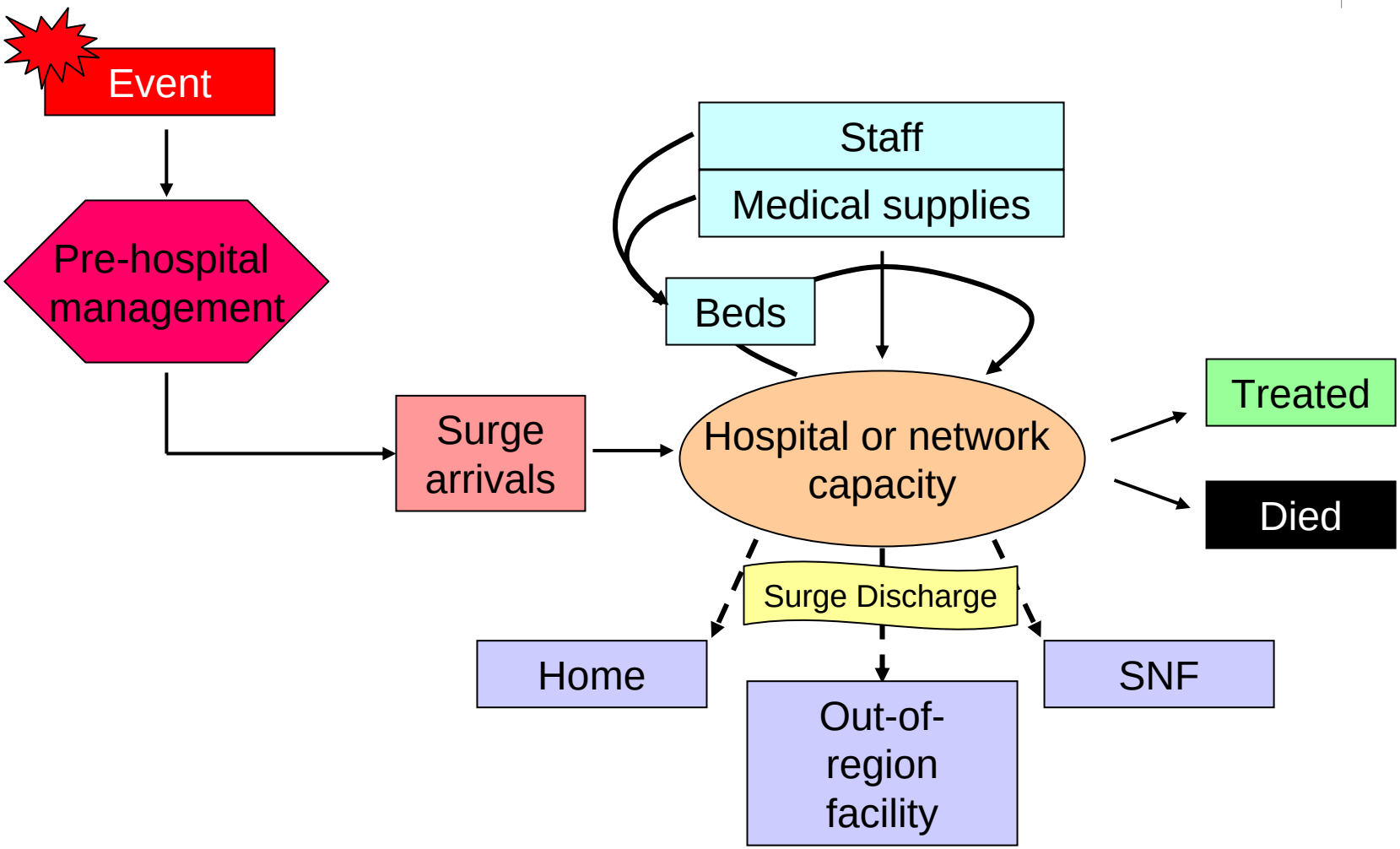
Goals of Mass Prophylaxis

- 48 Hours! (the “when”)
- Maximize “Pills in People” (the “what”)
- Multiple secondary goals (the “why”):
  - → Prevent illness
  - → Social stability
  - → Prevent surge on medical treatment facilities
  - → Supply chain stability

What outcome metrics can define operational parameters for successful campaigns?

Modeling Schema



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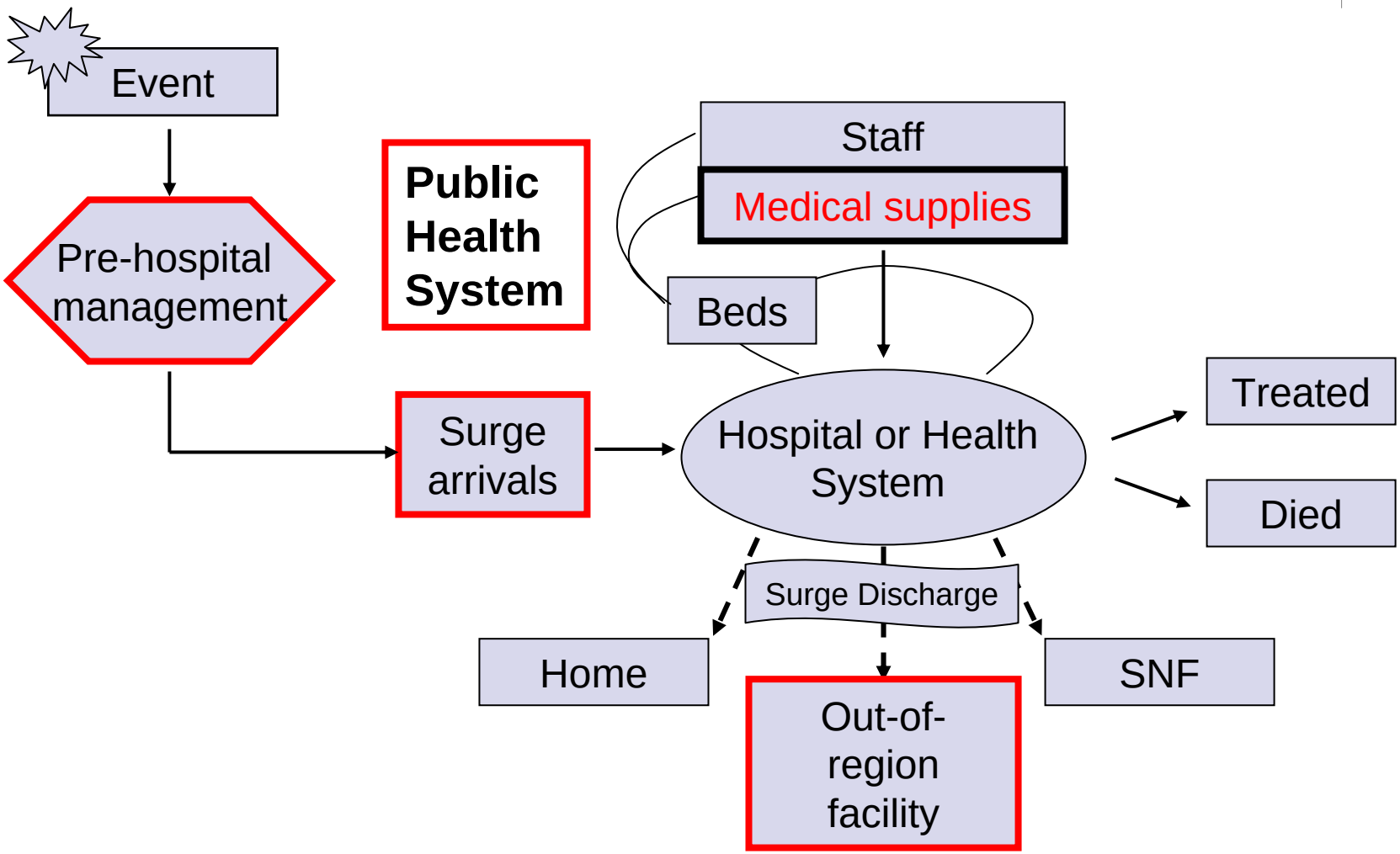
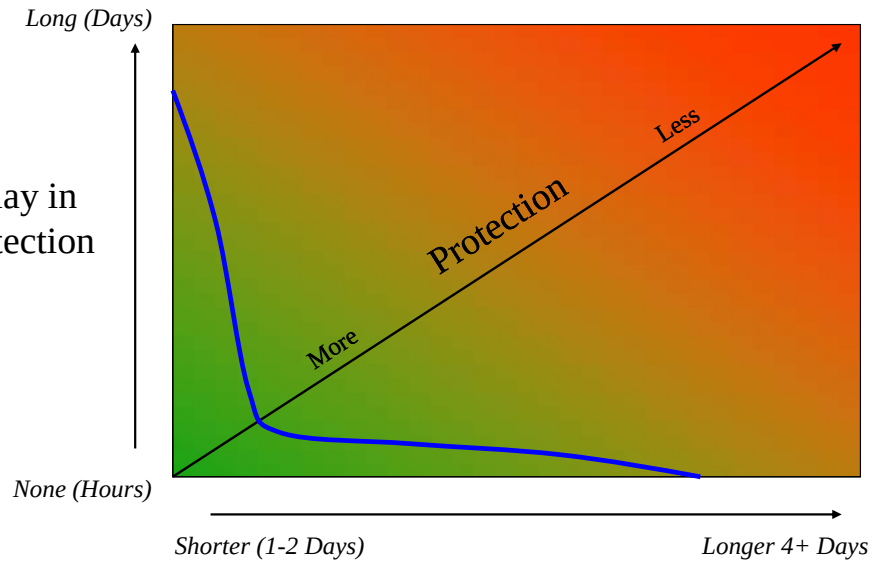


Weill Cornell Regional Hospital Caseload Calculator (AHRQ, 2003)

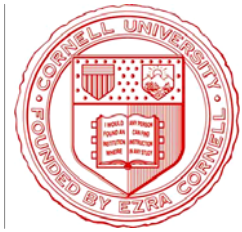
- State transition (compartment) model
- Excel-based, end-user oriented
- Contributed to 48h goal for CRI



Weill/Cornell Regional Hospital Caseload Calculator (RHCC) Model

Created by Christopher Neukermans, Jason Cuomo MPH, Mary Koshy MPA, and Nathaniel Hupert MD MPH

Under Contract 290-00-0013 from the DHHS Agency for Healthcare Research and Quality (AHRQ)



Caseload Calculator Inputs

Caseload Calculator Results ➡

1.Please select the disease and incidence curve from the list below.

2

1. Anthrax, USA-USSR Normal curve (mean 8.3, st. dev. 3.0)
2. Anthrax, (Brookmeyer) Log-normal curve (mean 2.398, st. dev. 0.713)
3. Anthrax, Log-normal curve (mean 6, st. dev. 2)
4. Anthrax, Normal curve (mean 6, st. dev. 2)
5. Anthrax, Gamma curve (alpha 9, beta 0.666)
6. Anthrax, Poisson distribution (mean 6)
7. Anthrax, Weibull curve (Brookmeyer, alpha 0.00785, beta 1.67)
8. Bubonic Plague, Log-normal curve (mean 4.3, st. dev. 1.8)
9. Bubonic Plague, Log-normal curve (mean 2.5, st. dev. 1.2)

2.What is your total population/community size?

2,000,000 people

3.How many people are exposed to the pathogen? (e.g. What is the attack size?)

50,000 people exposed

4.What percentage of exposed people develop symptoms if no treatment?

85%

5.How many days after the attack can the prophylaxis campaign begin? (i.e.1 = day of attack)

2 day(s) after the attack

6.From the start of the campaign, how many days does it take to reach maximum prophylaxis capacity?

1 day(s) after the attack

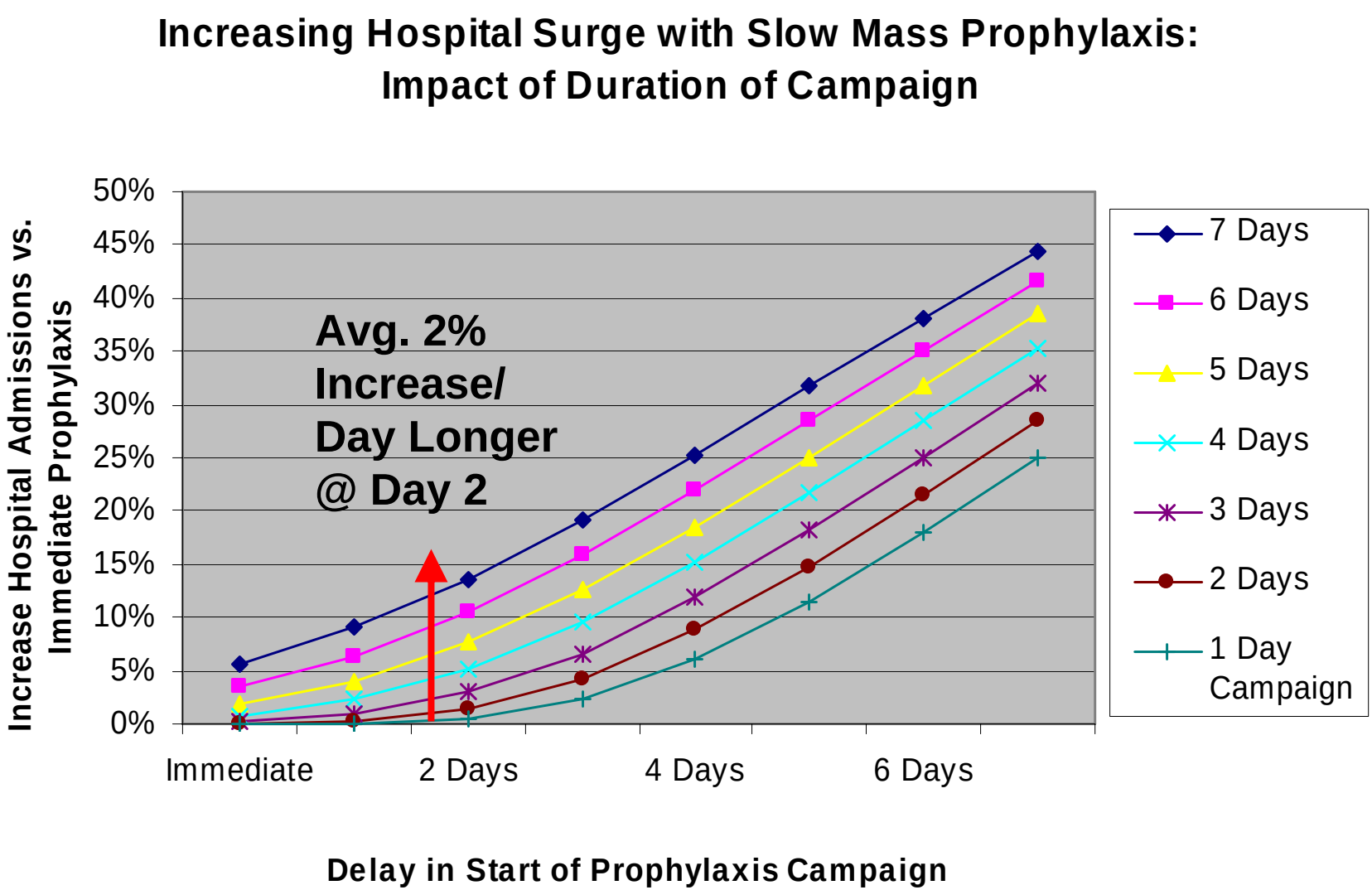
7.What is the maximum number of people to whom you could deliver prophylactic antibiotics per day at peak operational capacity?

1,000,000 people per day which equals a **2** day campaign

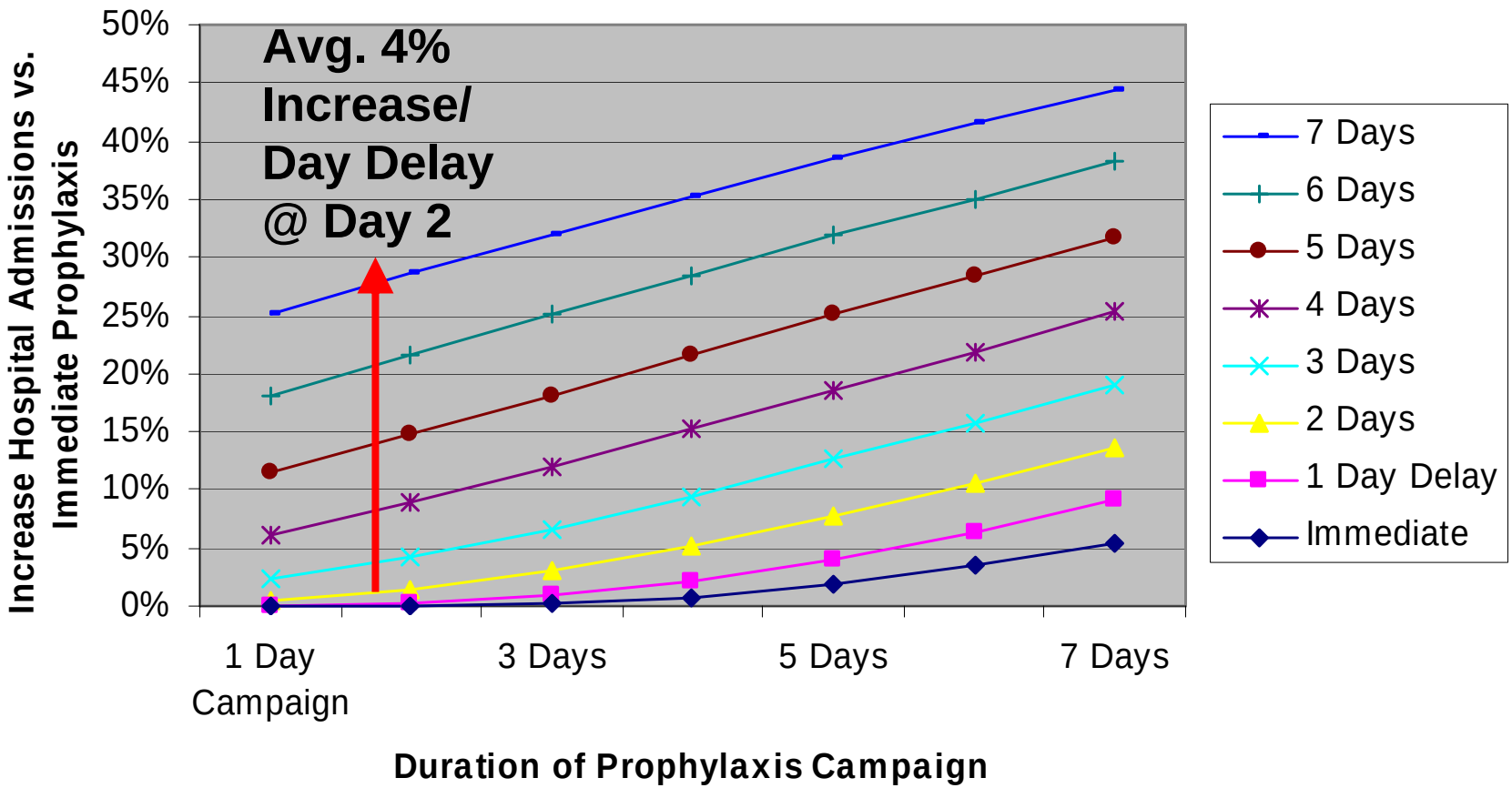
Protection via Prophylaxis with Brookmeyer Anthrax Incidence Curve (Optimal Case)

Campaign Duration	Delay in Detection							
	Immediate	1 Day	2 Days	3 Days	4 Days	5 Days	6 Days	7 Days
10 Days	84%	80%	74%	69%	63%	57%	51%	46%
9 Days	87%	83%	77%	72%	66%	60%	54%	48%
8 Days	90%	86%	81%	75%	69%	62%	56%	50%
7 Days	93%	89%	84%	78%	72%	65%	59%	53%
6 Days	95%	92%	87%	81%	75%	68%	62%	56%
5 Days	97%	94%	90%	85%	78%	72%	65%	59%
4 Days	99%	96%	93%	88%	82%	75%	68%	62%
3 Days	99%	98%	95%	91%	85%	78%	72%	65%
2 Days	100%	99%	97%	94%	88%	82%	75%	68%
1 Days	100%	100%	99%	96%	91%	85%	79%	72%

Weill Cornell Regional Hospital Caseload Calculator Output



Weill Cornell Regional Hospital Caseload Calculator Output



RHCC Operational Parameters

- For every day that an ideally-deployed anthrax mass prophylaxis campaign is shortened, there may be a 2-6% decrease in overall hospitalizations
- To accomplish this in the first week, POD efficacy must be increased by anywhere from 14% (7→6d) to 33% (3→2 days)
- *These are large increases in POD efficacy!*

Determinants of POD Efficacy

1. "**Fill** correctly"
   - Inter-POD network load balancing
   - Intra-POD load balancing
2. "**Process** efficiently"
   - Staff availability and effectiveness
3. "**Sustain** appropriately"
   - Supply chain responsiveness and resiliency

Evaluation of Alternative POD Designs

- Construct a stochastic simulation model that dynamically measures throughput capacity and patient flow times
- Experiment with alternative POD design strategies considering the effects of:
  - Timing of the demand for service over the planning horizon
  - Quantity of demand over time at each POD
  - Capacity (quantity and capabilities) of POD staff

1a. External Load Balancing

POD			*1*	*2*	*3*	*4*	*Per POD Per hour*
Balanced	**Throughput**	Unadjusted	5911(±13)	5901(±15)	5912(±12)	5918(±14)	**493**
		Adjusted	5993(±16)	5979(±15)	5946(±15)	5888(±19)	**496**
	Average number of people	Unadjusted	62.57(±7)	59.59(±7)	55.29(±7)	61.98(±8)	**60**
		Adjusted	32.75(±5)	32.50(±5)	32.25(±5)	32.01(±5)	**33**
Moderately Unbalanced	**Throughput**	Unadjusted	5991(±14)	6001(±18)	4793(±14)	3603(±12)	**425**
		Adjusted	5984(±15)	5981(±16)	5943(±15)	5903(±19)	**496**
	Average number waiting	Unadjusted	1206(±14)	605(±14)	3.17(±0.10)	0.89(±0.02)	**454**
		Adjusted	31.07(±3)	30.82(±3)	30.57(±3)	30.32(±3)	**31**
Significantly Unbalanced	**Throughput**	Unadjusted	6012(±18)	5993(±16)	4794(±13)	2389(±11)	**400**
		Adjusted	5983(±16)	5980(±16)	5951(±16)	5903(±19)	**496**
	Average number people	Unadjusted	1791(±16)	593(±13)	3.16(±0.1)	0.26(±0.01)	**597**
		Adjusted	28.05(±3)	27.80(±3)	27.54(3)	27.30(±3)	**28**

1a. External Load Balancing

POD			1	2	3	4	Per POD Per hour
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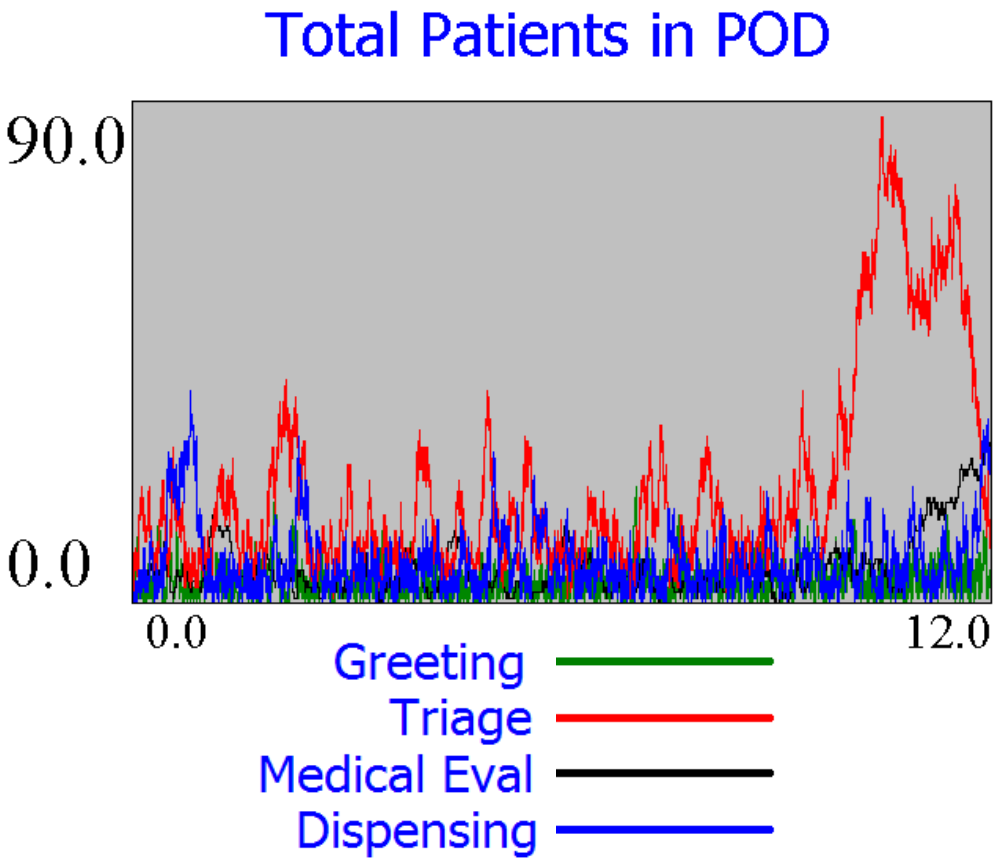
Role for Direct-to-Population Communications

Traditional 500pph POD

- Classic station set-up
  - Greeting, Triage, Medical Evaluation, Dispensing
  - 5% G→ME, 5% T→ME
- Exponential processing times
  - G (20sec), T(1min), ME(5min), D(30sec)
- Optimized staffing using BERM
  - 4 Greeters, 9 Triage, 5 Med Eval, 5 Dispensers
- (G, T, D) considered cross-trainable
- 12-hour shift

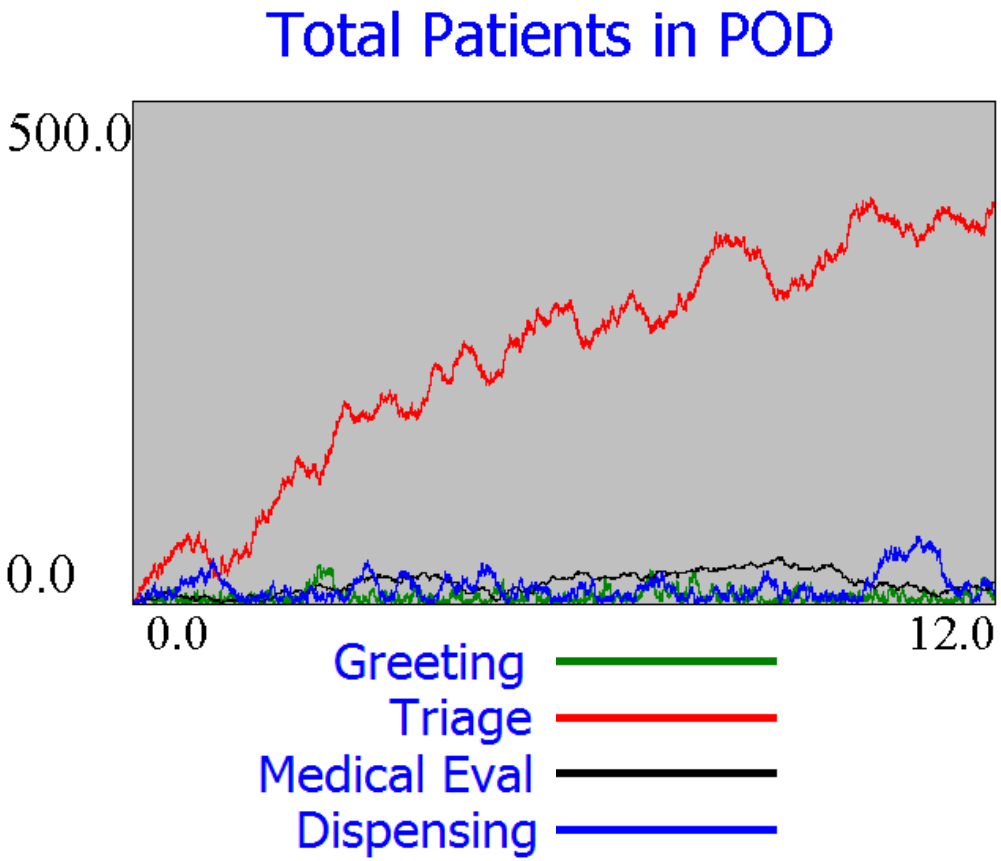
1b. Internal Load Balancing: Baseline POD @500pph



- Throughput
  - 497.3pph (+/- 1.3)
- Flow time
  - 3.5 minutes
- Average # in Queue

Greet	0.9 +/- 0.03
Triage	4.6 +/- 0.3
MedEval	2.3 +/- 0.3
Dispense	2.9 +/- 0.1

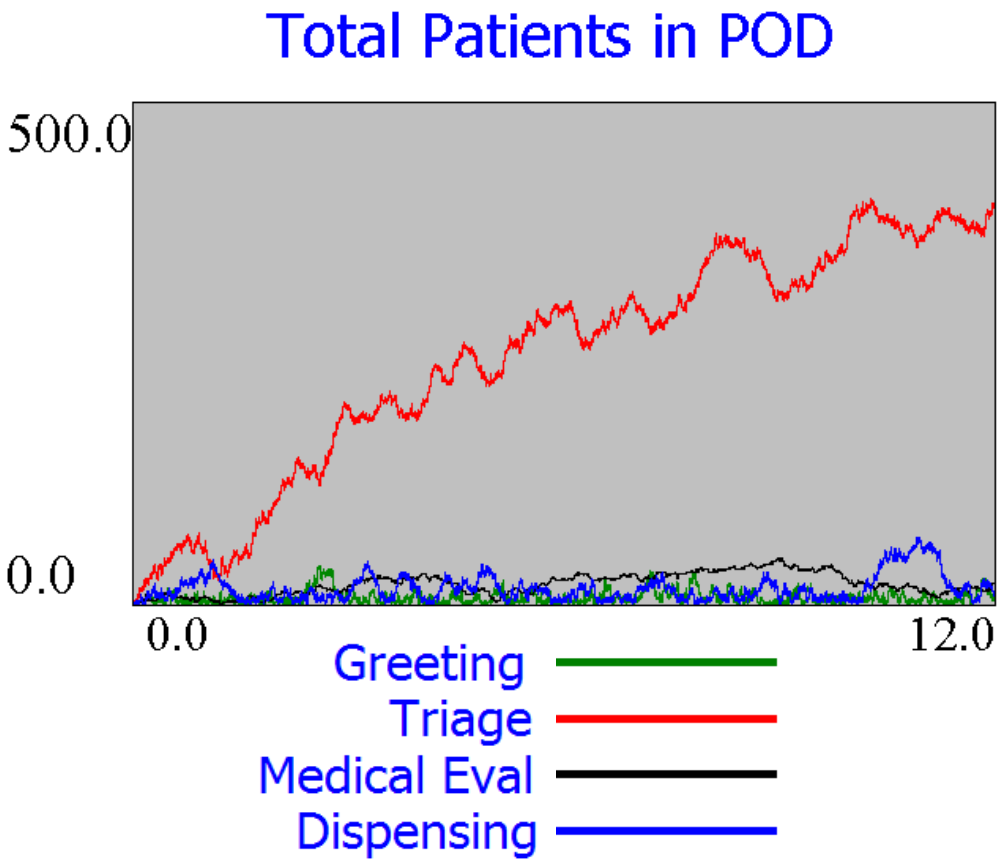
1b. Internal Load Balancing: Baseline POD @600pph



- Throughput
  - 563.8pph (+/- 1.3)
- Flow time
  - 24.3 min. (0→45 m)
- Average # in Queue

Greet	3.0 +/- 0.12
Triage	195.9 +/- 12.7
MedEval	8.9 +/- 1.3
Dispense	12.6 +/- 1.0

1b. Internal Load Balancing: Baseline POD @600pph



Throughput

563.8pph (+/- 1.3)

Flow time

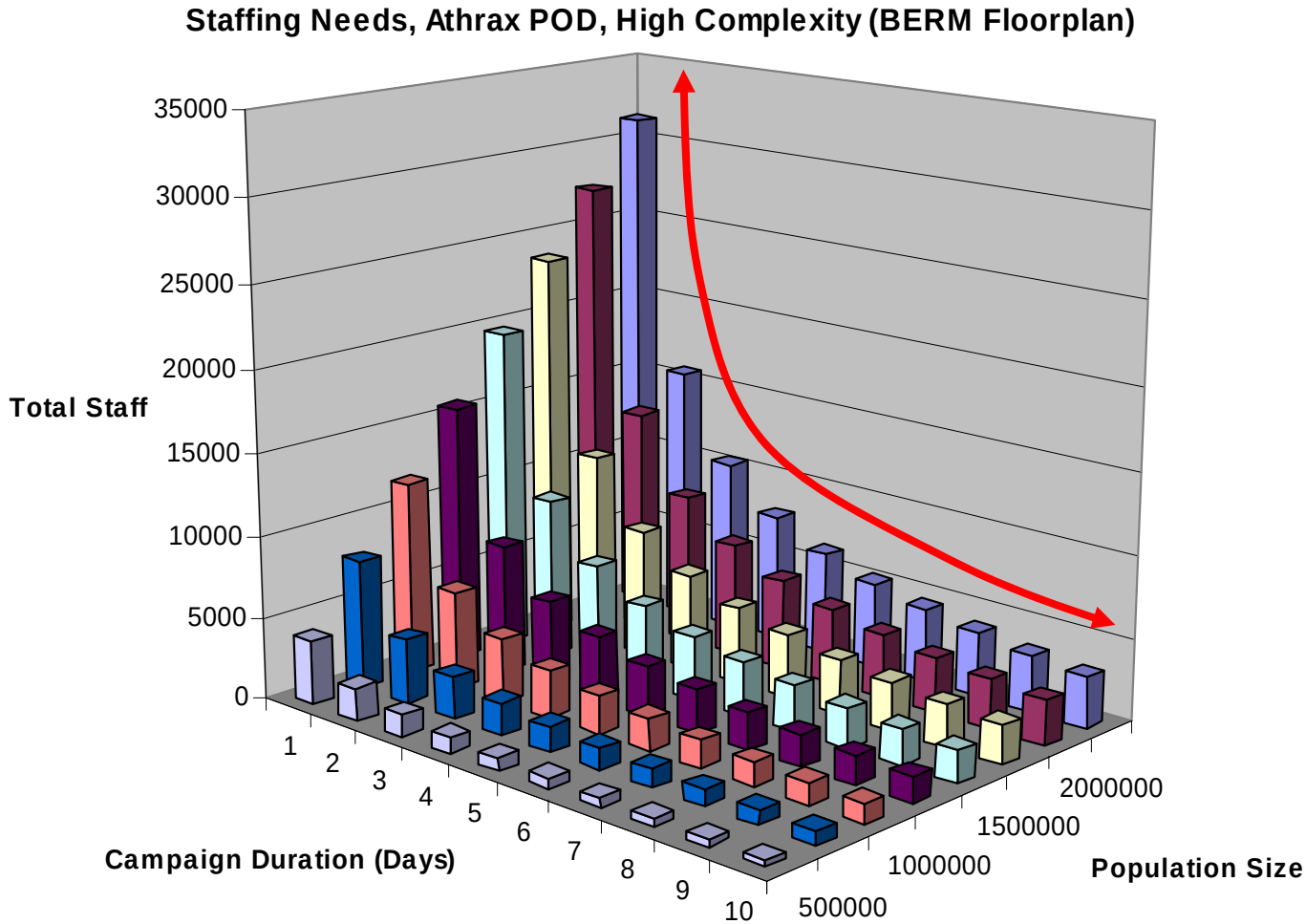
34.3min (0.943 hr)

Average # in Queue

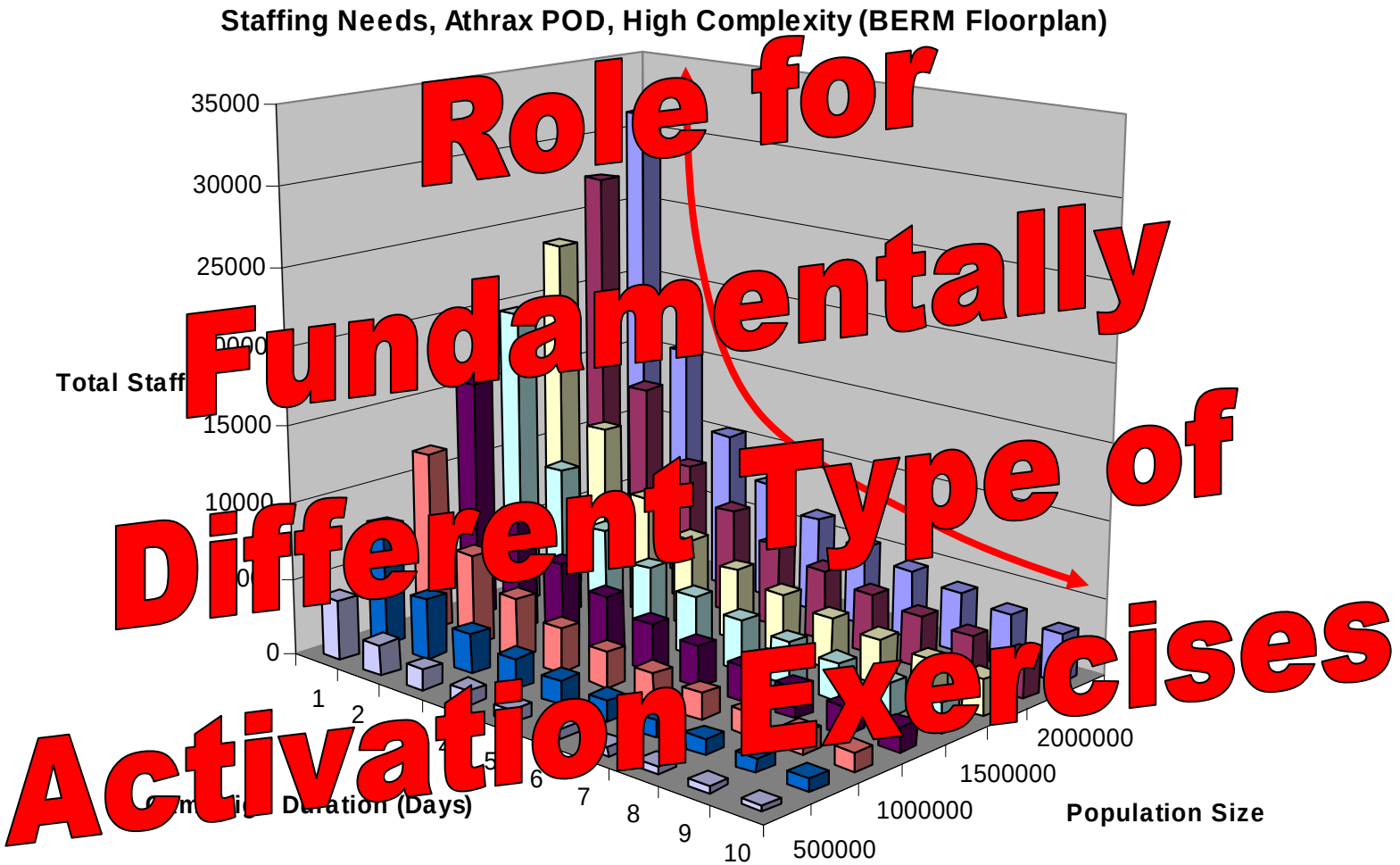
Triage	3.0 +/- 0.12
MedEval	8.9 +/- 1.3
Dispense	12.6 +/- 1.0

Role for Improved POD Design and Mgmt

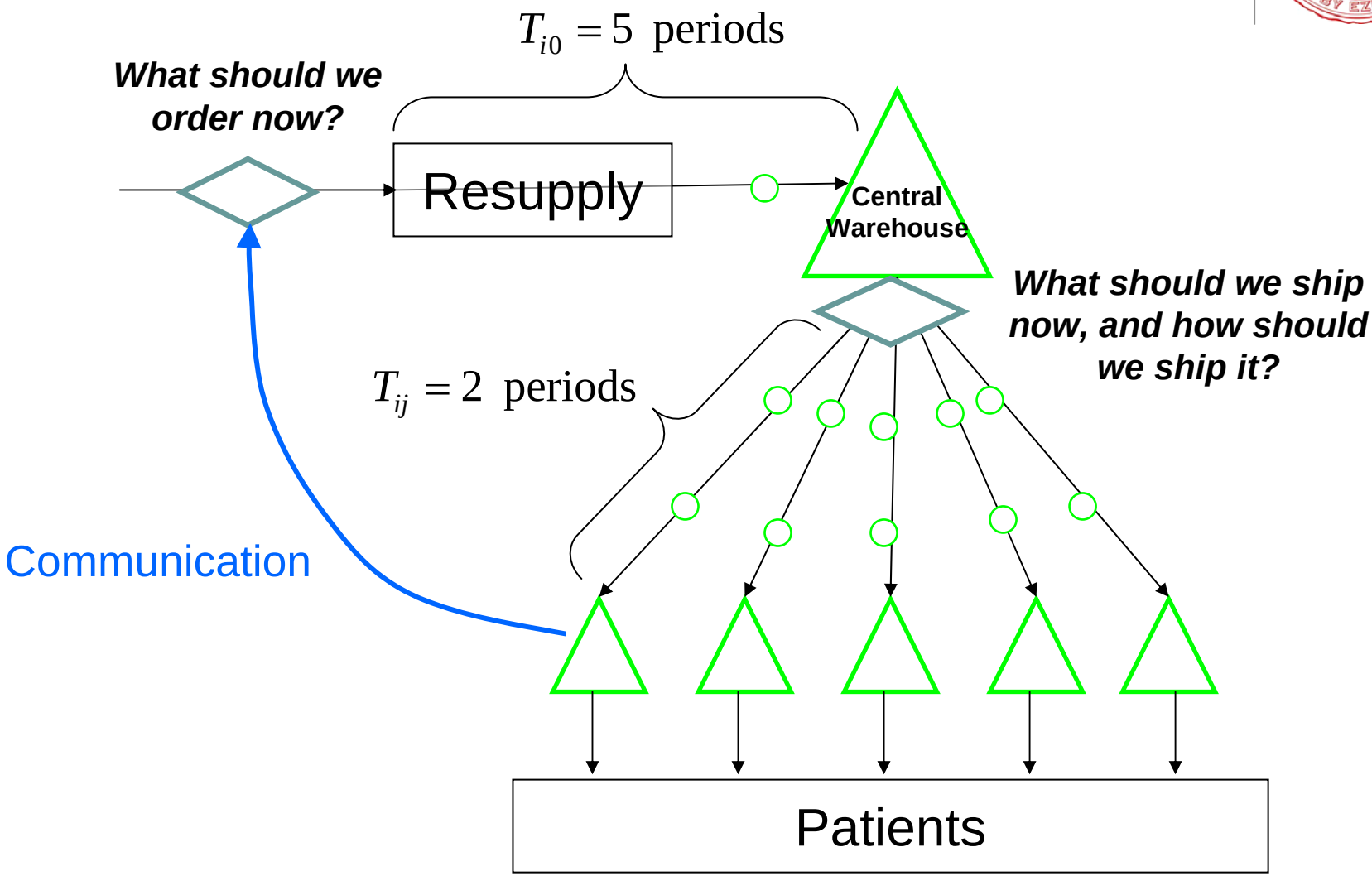
2. Time = Staff


Staffing Needs, Athrax POD, High Complexity (BERM Floorplan)
Total Staff
35000
30000
25000
20000
15000
10000
5000
0
1
2
3
4
5
6
7
8
9
10
Campaign Duration (Days)
500000
1000000
1500000
2000000
Population Size

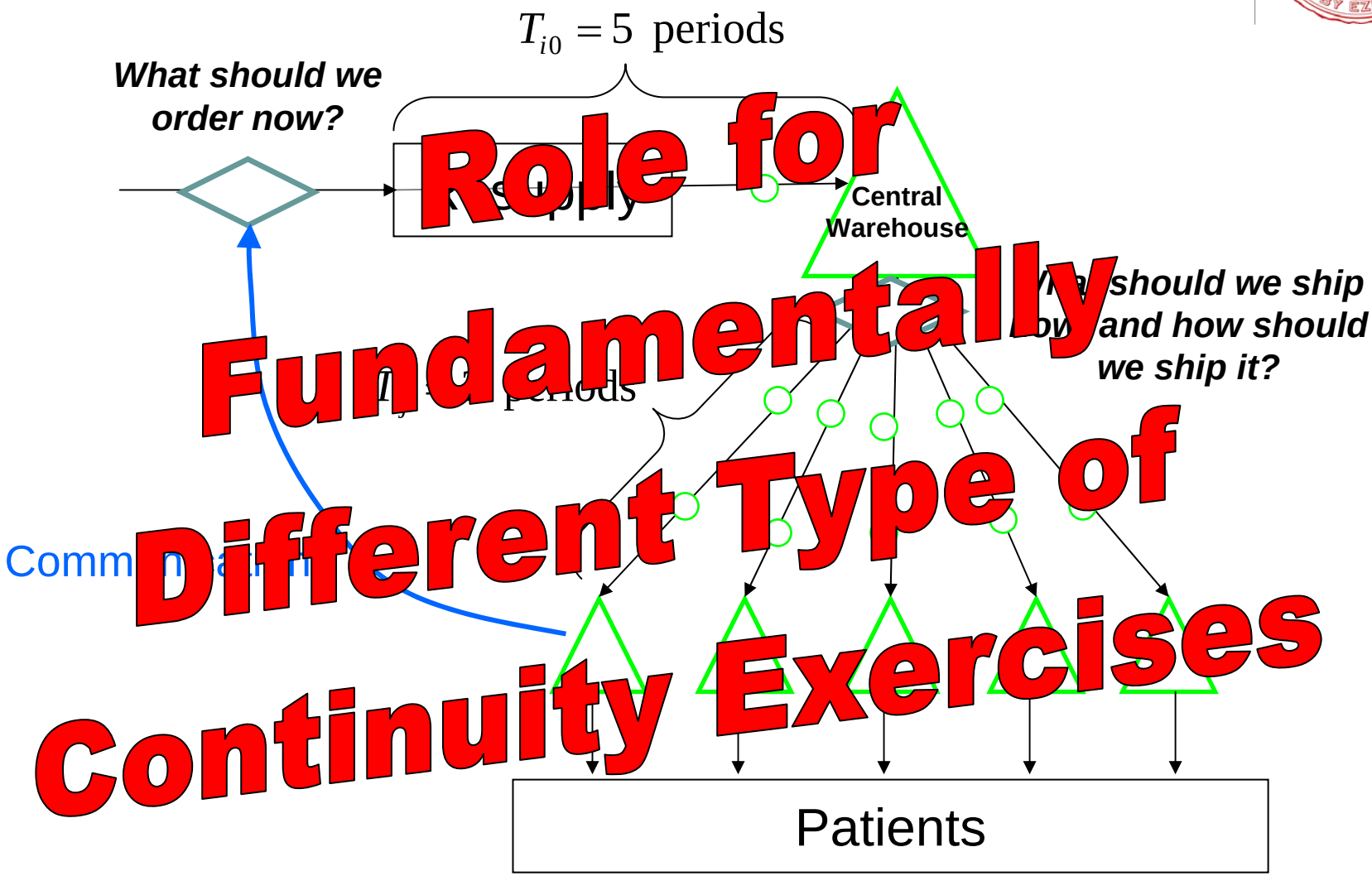
2. Time = Staff


Staffing Needs, Athrax POD, High Complexity (BERM Floorplan)
Total Staff
35000
30000
25000
15000
10000
0
1
2
5
6
7
8
9
10
Duration (Days)
500000
1000000
1500000
2000000
Population Size
Role for Fundamentally Different Type of Activation Exercises

3. Inventory (Re-)Allocation



3. Inventory (Re-)Allocation

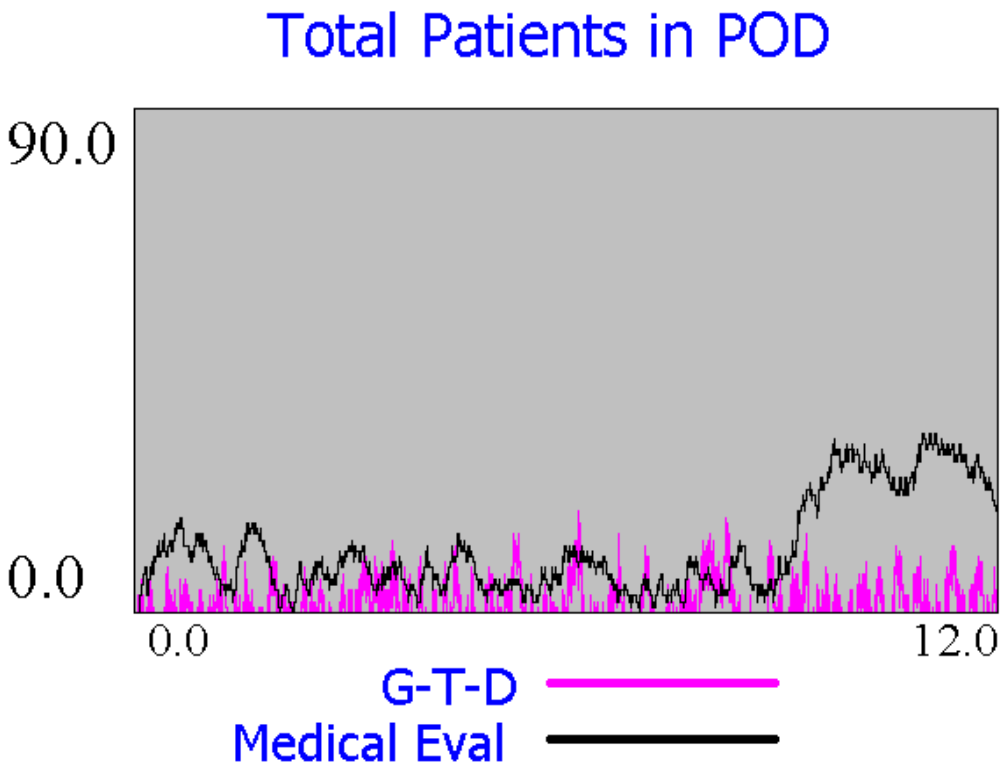


Role for Fundamentally Different Type of Continuity Exercises

POD Alternatives

- "One-Stop Shop" in the POD
  - Eliminate the standard multi-station approach to internal POD design (goes further than
  - Extensive cross-training required
  - Drive-through may be variant of this
  - Certain stations may remain distinct due to different cadre of worker

One-Stop-Shop POD @600pph (Same total # staff)



- Throughput
  - 597.3pph (+/- 1.4)
- Flow time
  - 3.2 minutes
- Average # in Queue

G-T-D	3.2 +/- 0.2
MedEval	7.4 +/- 0.9

Other Alternatives

- Assortment of POD and non-POD approaches
  - Primary Care Provider Sites
  - Med Kit
  - Postal
  - Others to be discussed

Modeling Realistic PODs

- Though the effects of uncertainty can be mitigated *to some extent* through collaboration and communication, fundamental uncertainty will always exist.
- Systems need to be designed so that they are robust in the presence of this uncertainty
- Models should capture and represent the implications of uncertainty on outcomes

POD Planning Goal

POD systems needs to be *maximally effective and efficient* under conditions of *extreme uncertainty* relating to *care-seeking* and *resource availability*.

BERM +

- We are creating a collection of interacting models for **designing** POD systems that
  - Represent the dynamic nature of arriving care-seekers and calculate optimal time-varying POD resource requirements
  - Allocate arriving care-seekers optimally among PODs so as to minimize POD resource requirements and service times
  - Establish POD layout strategies that minimize care-seeker service times (maximize POD worker effectiveness)
- We are determining corresponding heuristics for **managing** real time POD operations
- Much of this work remains contingent on funding

Final Comment

Strategic, tactical, and operational decision making with:

awareness of the uncertain nature of the operational environment, and

the interaction of that environment with response mechanisms employed

will lead to improved outcomes.

New web site for BERM and associated models

- www.simfluenza.org

Research Team & Collaborators

- Weill Cornell Medical Center and Cornell University Operations Research and Information Engineering
  - Jack Muckstadt, PhD
  - Wei Xiong, PhD
  - Shirish Chinchalkar, PhD
  - Peter Jackson, PhD
  - Shane Henderson, PhD
  - Huseyin Topaloglu, PhD
- College of William and Mary
  - David Murray, PhD
- DHHS, Agency for Healthcare Research and Quality
  - Sally Phillips, RN, PhD
- DHHS, NIGMS
  - Irene Eckstrand, PhD
- DHHS, NIH/NIAID
  - Richard Hatchett, MD
- New York-Presbyterian Hospital
  - Jaclyn van lieu Vorenkamp, MD
  - Nick Cagliuso, PhD
  - Eliot Lazar, MD
  - Laura Forese, MD
- Cayuga Medical Center
  - David Evelyn, M.D.
- Cornell Operations Research Students
  - Kathleen King Andrew Lazar
  - Antoine Cossart Lei Yao
  - Stephen Bakke Ji Kim
  - Jeff Schvey Caitlin Hawkins
  - James Sanders James Codella