

# Computer-Aided Design of Mass Prophylaxis Strategies for Bioterrorism Response

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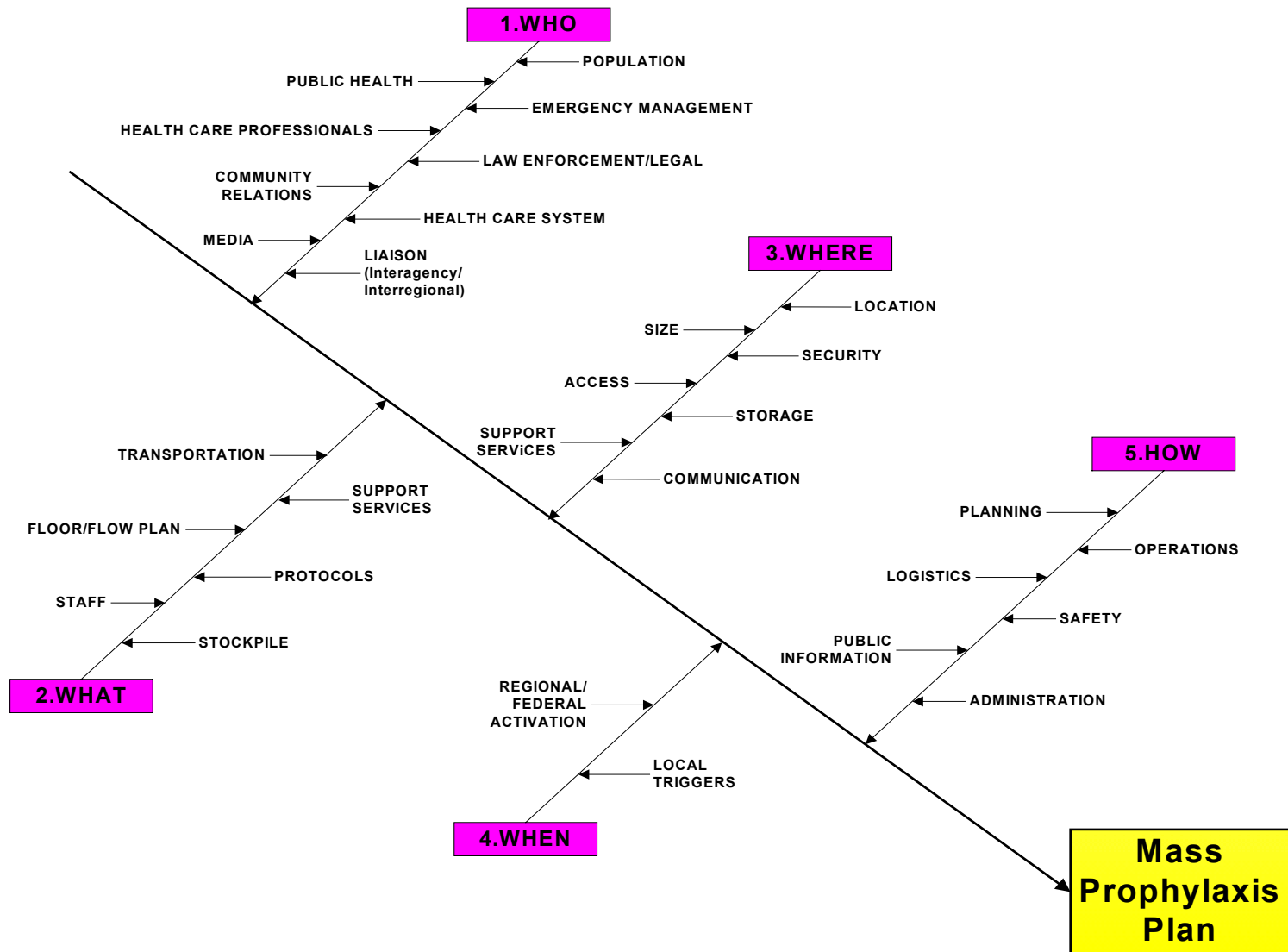
**Division of Outcomes and Effectiveness Research  
Weill Medical College of Cornell University**

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# Guiding Questions

- What components of mass prophylaxis planning are amenable to modeling?
- How should they be modeled?
- How can models assist in mass prophylaxis planning?
- What are the limitations of such computer models of mass prophylaxis?

# Components of Mass Prophylaxis Plan



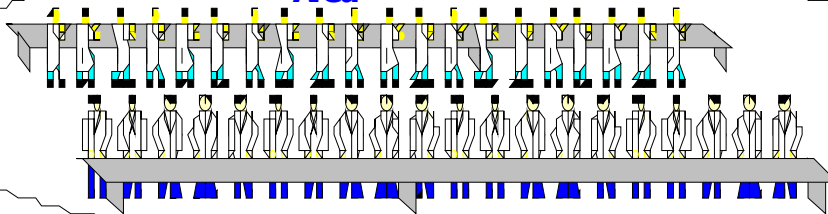
# SAMPLE PATIENT FLOW DIAGRAM FOR MASS ANTIBIOTIC DISPENSING

Airport

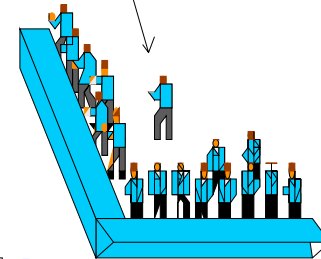


Drug Delivery

Triage Area

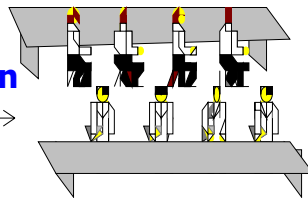


Drug Dispensing



Exit

Medical Evaluation

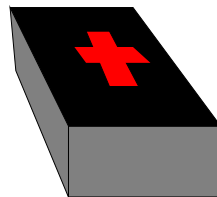


HEALTHY PEOPLE GET PROPHYLAXIS  
AMBULATORY SICK GET TREATMENT

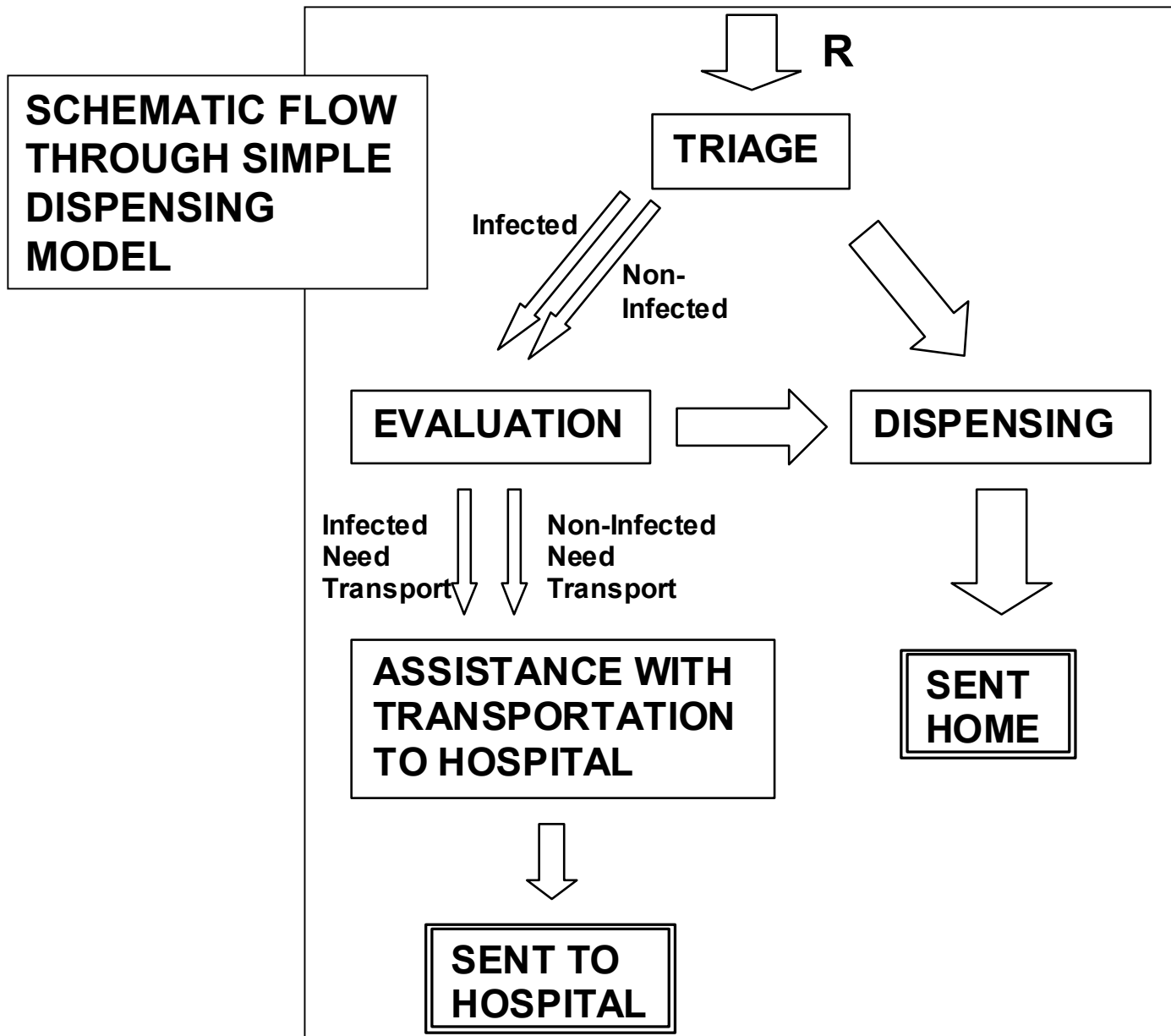
VERY SICK GET TRANSPORT  
TO MEDICAL FACILITY

Hospital

Ambulance  
Bus



Created by the Department of Public Health, Weill Medical College of Cornell University, NYCOEM, and NYCDOHMH



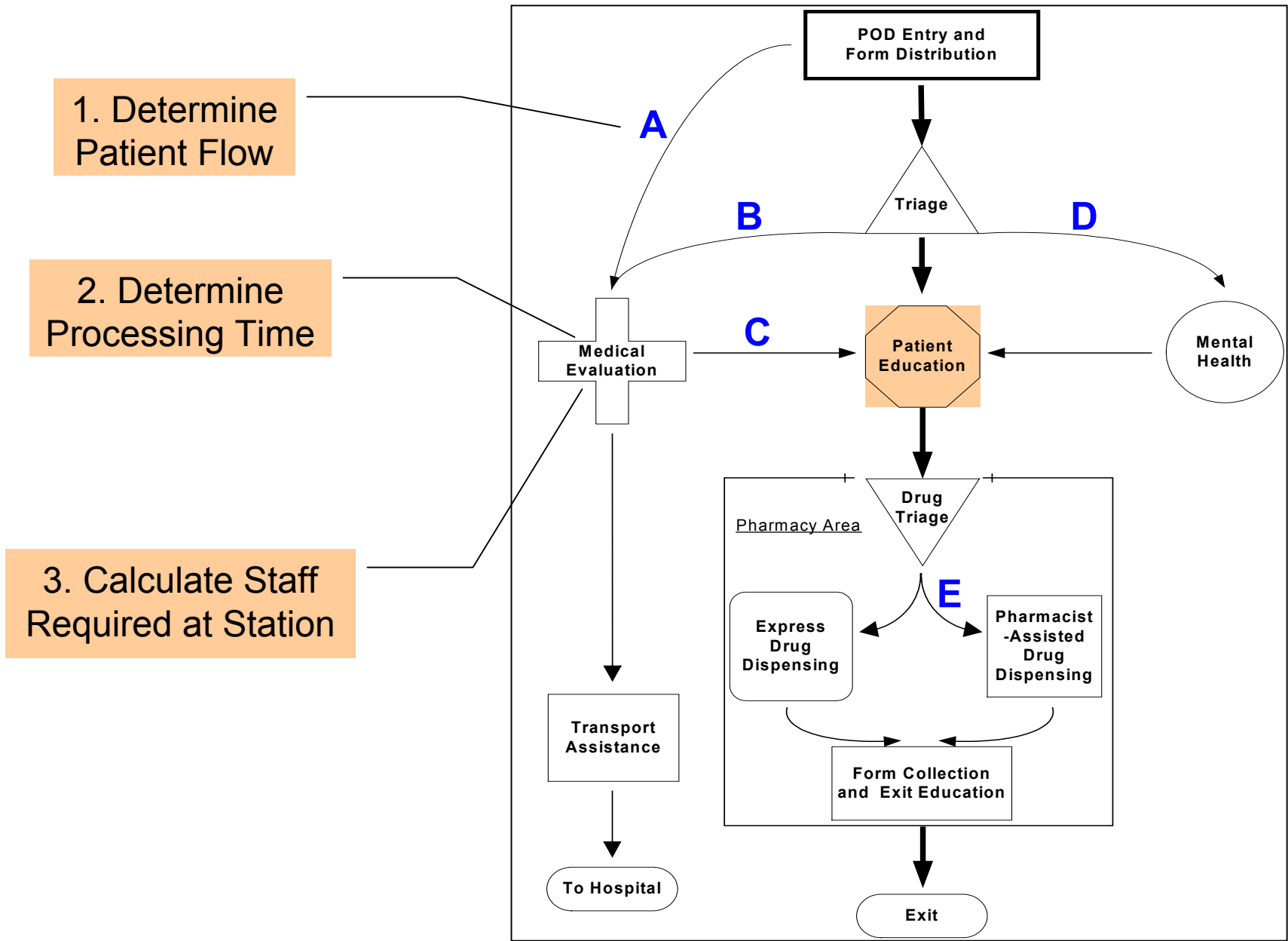
# Operations Research Concepts

- Extensive OR literature on modeling discrete systems, but little related to mass prophylaxis
- 1<sup>st</sup> Order Approach: Deterministic Analysis
  - Suitable for most planning needs
- 2<sup>nd</sup> Order: Stochastic Processes
  - Can get very complex, expensive programs
  - Hupert, et al., Modeling the public health response to bioterrorism: using discrete event simulation to design antibiotic distribution centers. *Med Decis Making* 2002;22(Suppl):S17-25

# Deterministic Modeling: using a steady-state assumption

- Steady state develops if  $\rho = R/ST \leq 1$ ,  
where  
    R = patient arrival rate  
    S = # staff  
    T = mean service time
- When  $\rho = 1$ , then  $S = RT$ , or

Staff required at a station	=	Rate of patient arrival at that station	X	Mean station processing time per patient
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Microsoft Excel - Appendix B Nine Station POD Model

File Edit View Insert Format Tools Data Window Help

Type a question for help

C84 = (C69\*((C73+C74+C77+C78+C80)+(C59\*(C75+C81-C74-C77-C78-C80)))+(C60\*(C75+C81-C77-C78-C80))-(C59\*C60\*C75)+((C59\*C61)\*(C77+C80-C81))+((C60\*C61)\*(C77+C78+C80-C81))-((C59\*C60\*C61)\*(C77+C78+C80-C81))+((C62\*(C76\*(1-C59-C60+(C59\*C60))))+(C63\*(C79-C78+(C78-C79)))+(C60\*(C78-C79))+((C59\*C61)\*(C79-C78))+((C60\*C61)\*(C79-C78))+((C59\*C60\*C61)\*(C78-C79))))

E. Estimated time for	
F. Estimated time EX	
G. Estimated time PHARMACIST-ASSISTED DRUG DISPENSING:	4.0 minutes
H. Estimated time for FORM COLLECTION	0.5 minutes
I. Estimated time for TRANSPORT ASSISTANCE:	10.0 minutes

9. With this information you can now see the staff needed to be working at any given time while your PODs are in operation at these nine "core" stations. This total needs to be increased to account for "down-time" per shift, number of shifts, and size of the support (or "non-core") staff.

A. Preliminary estimate of core staff working at these nine stations at any given time required to accomplish your specified prophylaxis campaign	107 Core Staff
B. Estimated percentage "down-time" per shift	30%
C. Revised total core staff working at any given time assuming this specified "down-time":	139 Core Staff
D. Breakdown of this total core staff by station:	
1. GREETING/FORM DISTRIBUTION	4 Greet Staff/POD
2. TRIAGE	32 Triage Staff/POD
3. MEDICAL EVALUATION	34 Evaluation Staff/POD
4. MENTAL HEALTH EVALUATION	20 MH Eval. Staff/POD
5. DRUG TRIAGE	15 Drug Triage Staff/POD
6. EXPRESS DRUG DISPENSING	10 Express Rx Staff/POD
7. PHARMACIST-ASSISTED DRUG DISPENSING	
8. FORM COLLECTION	7 Collection Staff/POD
9. TRANSPORTATION ASSISTANCE	17 Transport Staff/POD

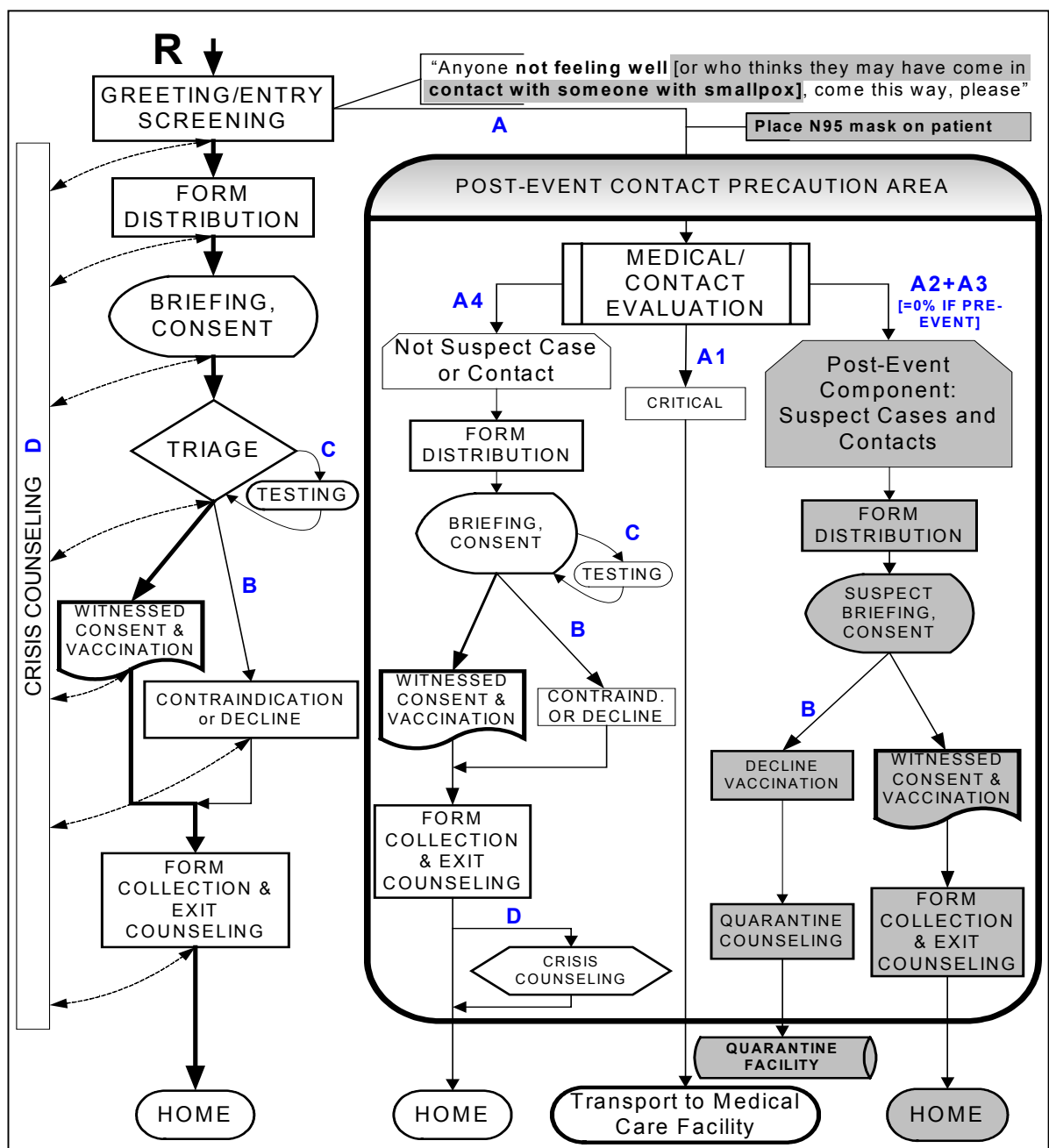
Appendix B

Draw AutoShapes

Ready

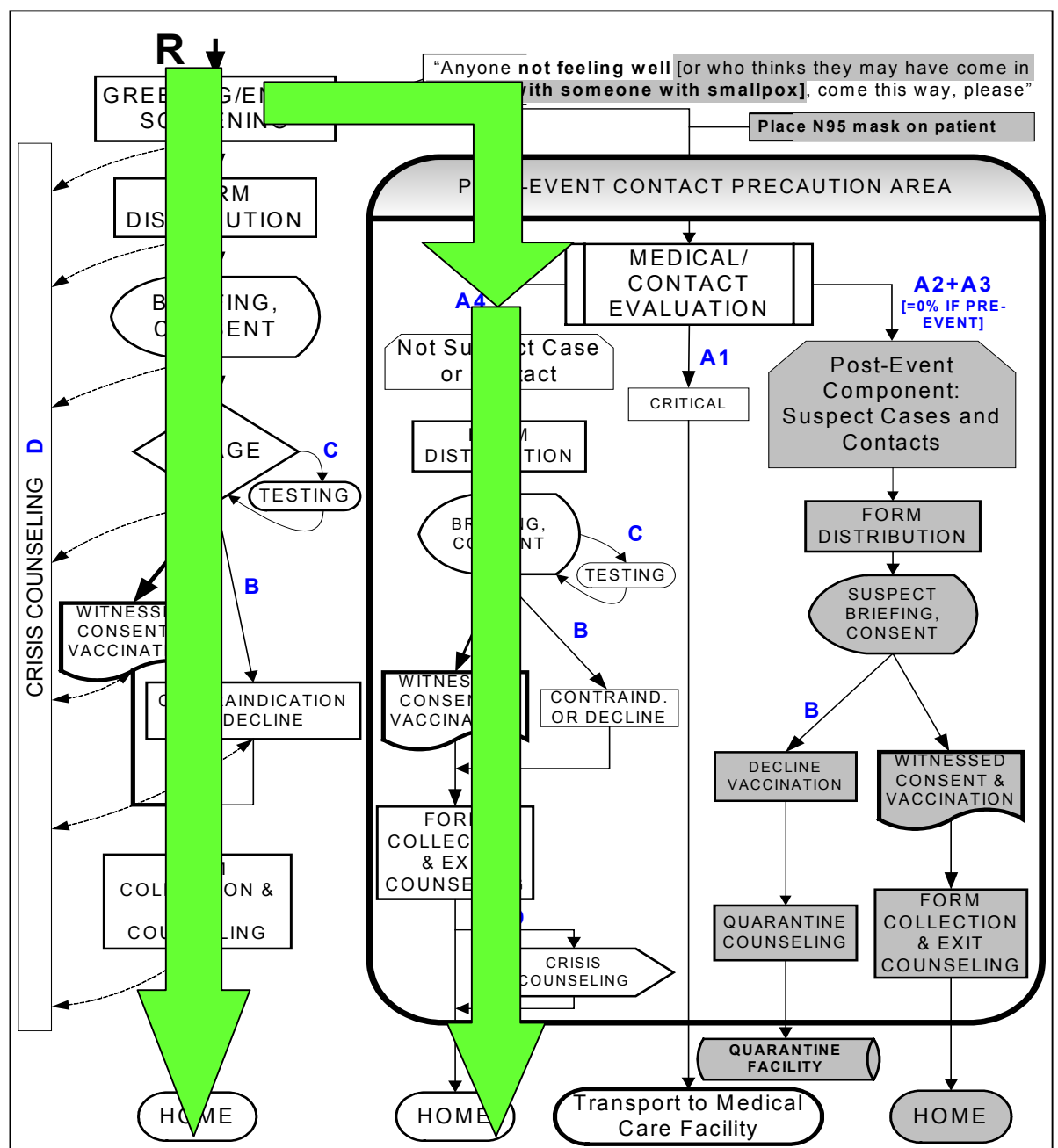
4. Calculate Staff Required at All Stations

# SCHEMATIC FLOW THROUGH WEILL/CORNELL SMALLPOX VACCINATION MODEL



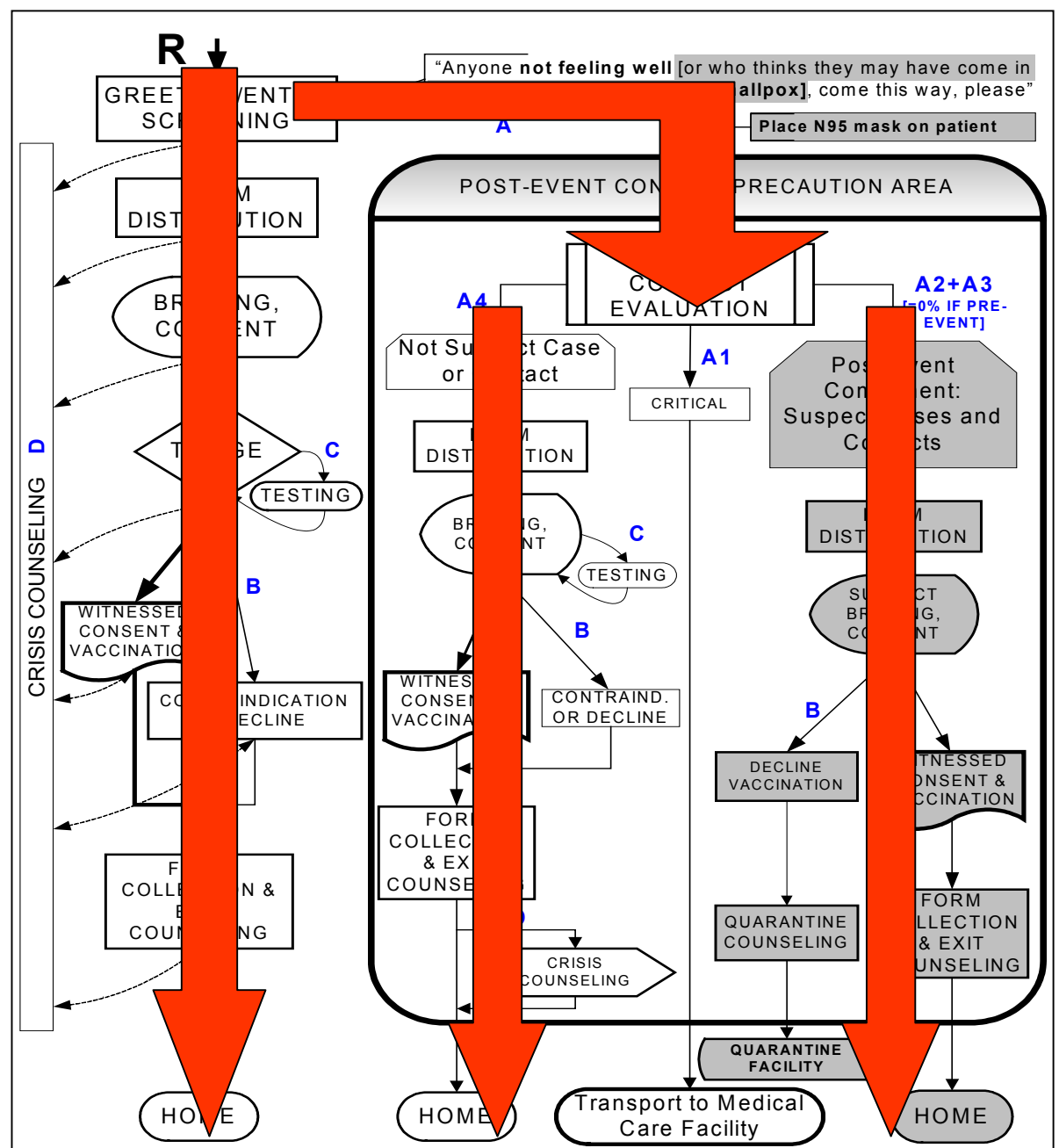
# Weill/Cornell Smallpox Vaccination Staffing Model

**PRE-EVENT**



# Weill/Cornell Smallpox Vaccination Staffing Model

**POST-EVENT**



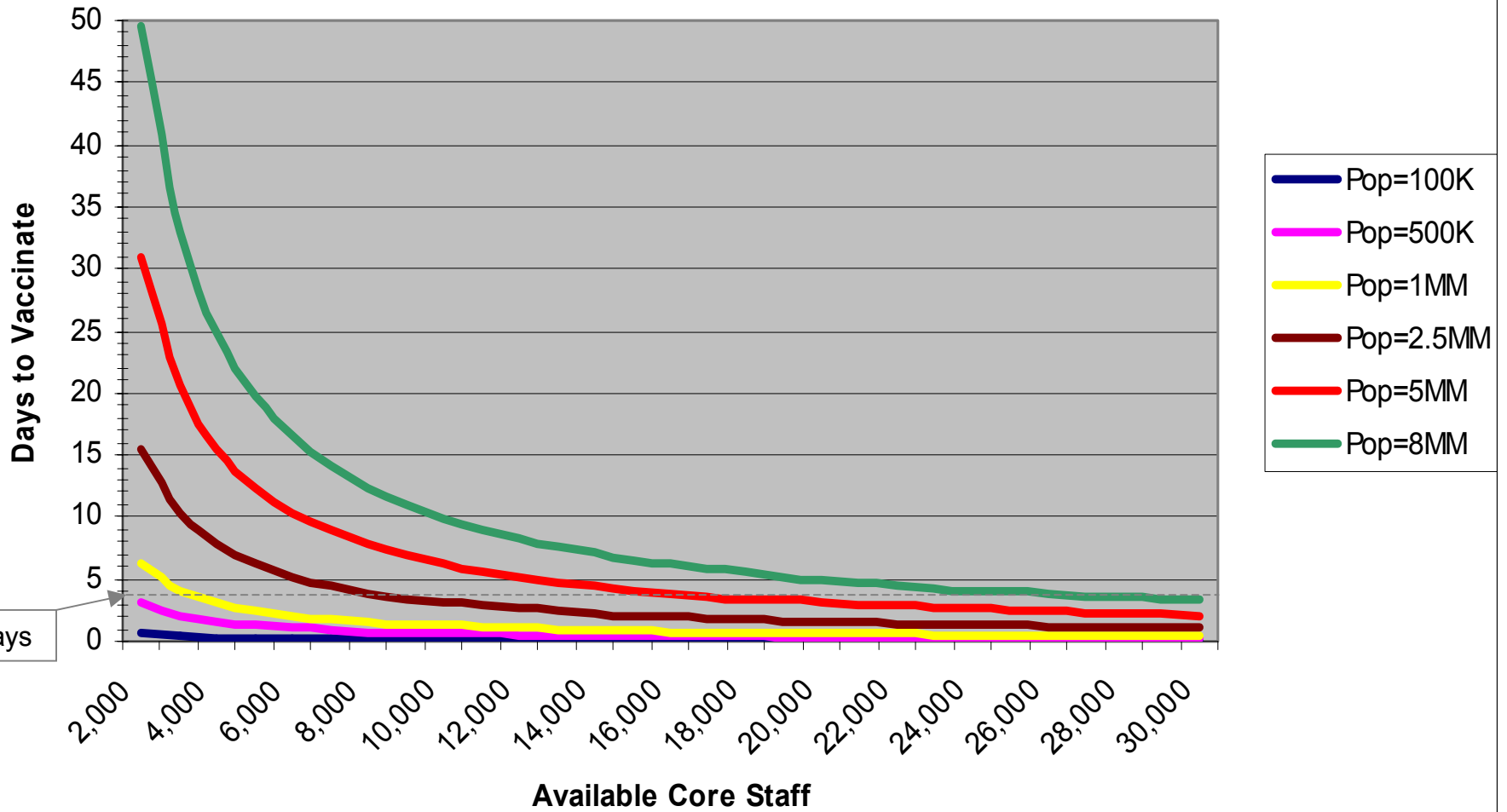
**SAMPLE  
OUTPUT OF  
WEILL/CORNELL  
SMALLPOX  
VACCINATION  
MODEL**

<b>PRE-EVENT</b>		
<b>Slow</b>	Target Length of Campaign:	<b>14.0 days</b>
	Maximum Total Core Staff Available:	<b>500.00 Total Core Staff</b>
	Targetable Population:	<b>793,181 People</b>
	Maximum Total Core Staff Available	<b>500.00 Total Core Staff</b>
	Targeted Population:	<b>1,000,000 People</b>
	Estimated Length of Campaign:	<b>18 days</b>
<b>Baseline</b>	Target Length of Campaign:	<b>14.0 days</b>
	Maximum Total Core Staff Available:	<b>500.00 Total Core Staff</b>
	Targetable Population:	<b>1,140,400 People</b>
	Maximum Total Core Staff Available	<b>500.00 Total Core Staff</b>
	Targeted Population:	<b>1,000,000 People</b>
	Estimated Length of Campaign:	<b>12 days</b>
<b>Fast</b>	Target Length of Campaign:	<b>14.0 days</b>
	Maximum Total Core Staff Available:	<b>500.00 Total Core Staff</b>
	Targetable Population:	<b>1,871,308 People</b>
	Maximum Total Core Staff Available	<b>500.00 Total Core Staff</b>
	Targeted Population:	<b>1,000,000 People</b>
	Estimated Length of Campaign:	<b>7 days</b>

**SAMPLE  
OUTPUT OF  
WEILL/CORNELL  
SMALLPOX  
VACCINATION  
MODEL**

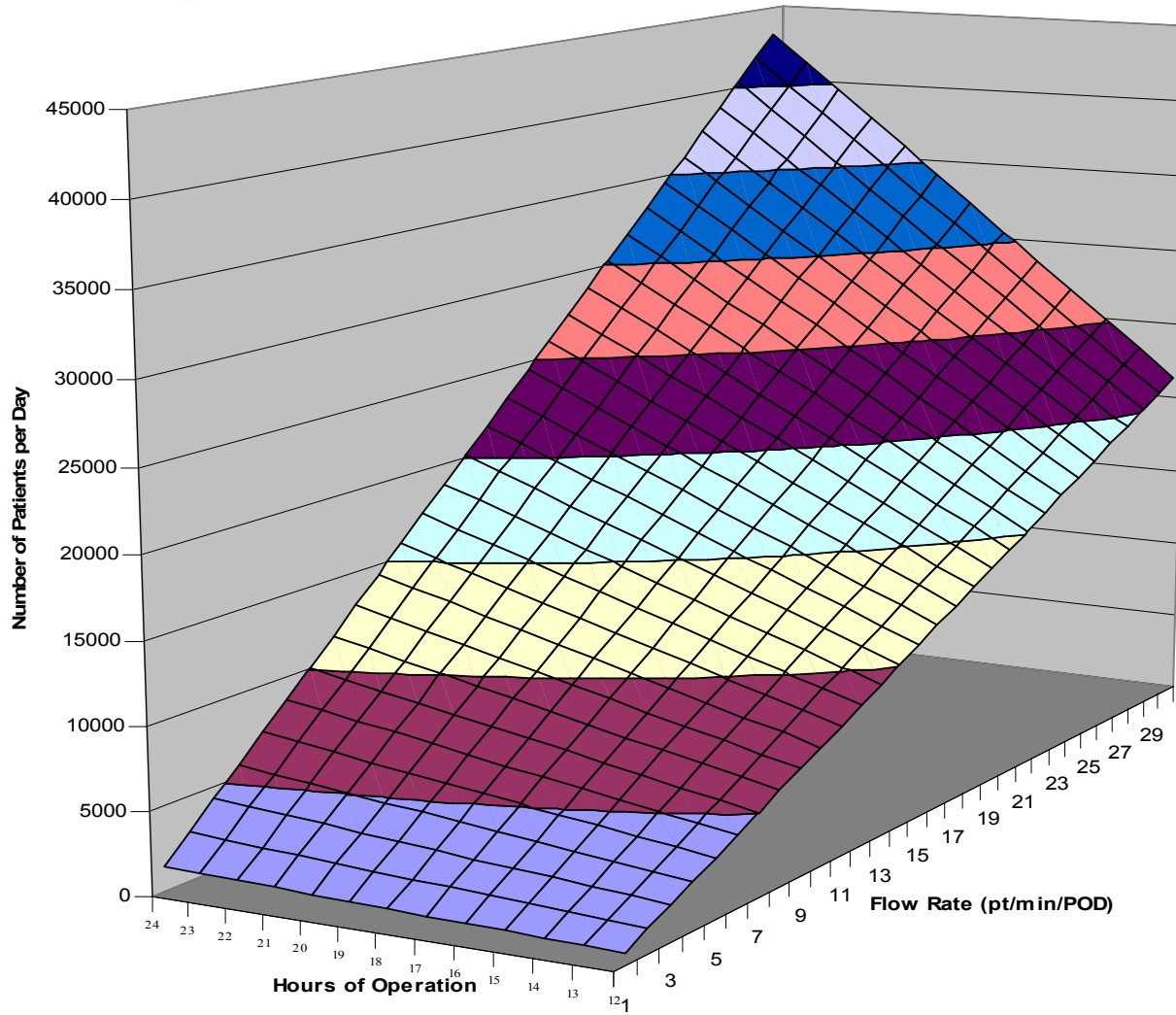
<b>Large-Scale Event</b>	
<b>Slow</b>	Target Length of Campaign: <b>5.0 days</b>
	Maximum Total Core Staff Available: <b>6,669.00 Total Core Staff</b>
	Targetable Population: <b>3,503,294 People</b>
	Maximum Total Core Staff Available: <b>6,669.00 Total Core Staff</b>
	Targeted Population: <b>5,000,000 People</b>
	Estimated Length of Campaign: <b>7 days</b>
<b>Baseline</b>	Target Length of Campaign: <b>5.0 days</b>
	Maximum Total Core Staff Available: <b>6,669.00 Total Core Staff</b>
	Targetable Population: <b>5,000,555 People</b>
	Maximum Total Core Staff Available: <b>6,669.00 Total Core Staff</b>
	Targeted Population: <b>5,000,000 People</b>
	Estimated Length of Campaign: <b>5 days</b>
<b>Fast</b>	Target Length of Campaign: <b>5.0 days</b>
	Maximum Total Core Staff Available: <b>6,669.00 Total Core Staff</b>
	Targetable Population: <b>8,103,224 People</b>
	Maximum Total Core Staff Available: <b>6,669.00 Total Core Staff</b>
	Targeted Population: <b>5,000,000 People</b>
	Estimated Length of Campaign: <b>3 days</b>

# Predicted Length of Vaccination Campaign as a Function of Available Core Staff and Population Size



**Trend in Number of Patients Served by POD per Day of Vaccination Campaign as a Function of POD Flow Rate (pt/min/POD) and POD Hours of Operation\***

\*Assumes a campaign targeting 8MM people over 4 days  
people over 4 days





# Next Step: Modeling Hospital Capacity

- Mass prophylaxis is the second to last step in unified bioterrorism response plan

Surveillance → Distribution → Dispensing → Follow-up

Stockpile 

- What happens to individuals after they get their antibiotics or shot?

# Mass Vaccination Adverse Events

## Population Inputs:

Size of population to vaccinate:	2,500,000 people
Duration of vaccination campaign:	7 days

## Hospital Inputs:

Total staff:	40,000 staff
ER beds available:	400 beds
Inpt beds available:	4,000 beds
ICU beds available:	400 beds

## Adverse Event (AE) Characteristics:

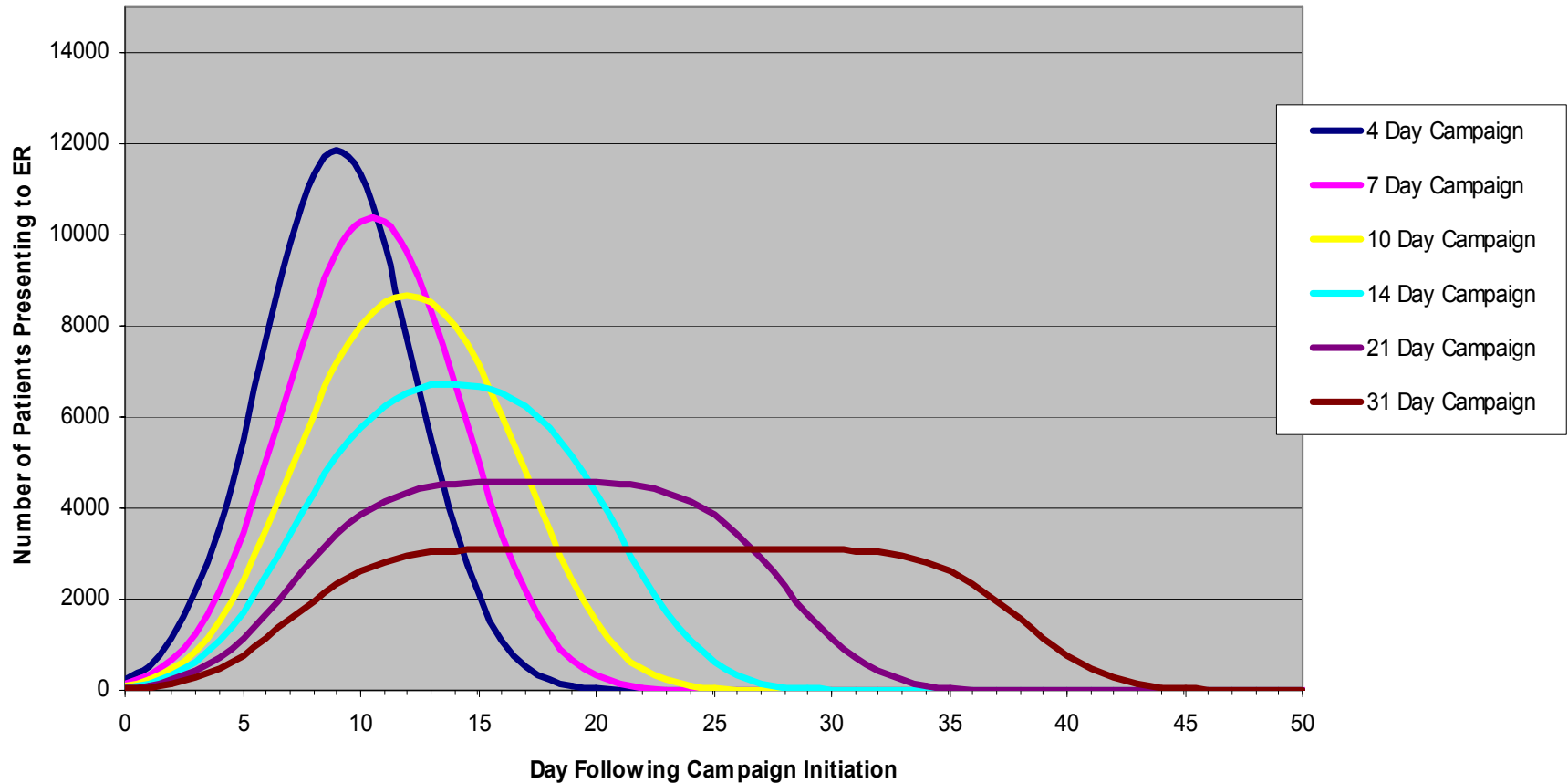
Mean Day of AE Onset:	7 days
Standard Deviation:	3 days
Average Inpt Length of Stay:	4 days
Standard Deviation:	2 days
Average ICU Length of Stay:	10 days
Standard Deviation:	4 days

# Mass Vaccination AEs—Inputs

<b>Population Inputs:</b>						
Size of population to vaccinate:	8,000,000 people					
Duration of vaccination campaign:	7 days					
<b>Hospital Inputs:</b>						
Total staff:	40,000 staff					
ER beds available:	400 beds					
Inpt beds available:	4,000 beds					
ICU beds available:	400 beds					
<b>Adverse Event (AE) Characteristics:</b>						
Mean Day of AE Onset:	7 days					
Standard Deviation:	3 days					
Average Inpt Length of Stay:	4 days					
Standard Deviation:	2 days					
Average ICU Length of Stay:	10 days					
Standard Deviation:	4 days					
<b>A) Minor Events:</b>						
EVENT	% Occurrence	% to ER	% from ER to Inpt	% from ER to ICU		
1. Muscle aches	50%	5%	0%	0%		
2. Fatigue	48%	1%	0%	0%		
3. Headache	40%	1%	1%	0%		
4. Nausea	14%	5%	1%	0%		
5. Fever	12%	10%	5%	1%		
<b>B) Moderate to Severe</b>						
EVENT	# (per million)	(Expressed as %)	% to ER	% from ER to Inpt	% to ICU	
1. Inadvertent inoculation	250 per 1MM	(0.0250%)	100%	50%	0%	
2. Generalized vaccinia	241 per 1MM	(0.0241%)	100%	50%	0%	
3. Vaccinia necrosum	1.5 per 1MM	(0.0002%)	100%	10%	90%	
4. Post-vaccination encephalopathy	12.5 per 1MM	(0.0013%)	100%	0%	100%	
5. Eczema vaccinatum	38 per 1MM	(0.0038%)	100%	75%	25%	

# Expected ER Visits Resulting from Fever (>100 °F) As A Result of a Mass Smallpox Vaccination Campaign Targeting 8 MM People

(Assumes 12% vaccinees develop clinically noted fever and 10% of these go to hospital ER)



# Mass Vaccination AEs—ER Use

TYPE OF ADVERSE EVENT

1.TOTAL NUMBER OF PATIENTS PRESENTING TO HOSPITAL ER BASED ON A PROGRAM TO VACCINATE 8000000 PEOPLE IN 7 DAYS:

1A.DAY FOLLOWING CAMPAIGN INITIATION ON WHICH MAXIMUM NUMBER OF PATIENTS WILL PRESENT TO THE ER:

1B. MAXIMUM NUMBER OF PATIENTS PRESENTING TO ER ON ANY GIVEN DAY:



(N.B. AEs are not mutually exclusive. These totals represent patients suffering from *at least* the respective AE and include patients suffering from other AEs -included those listed here- as well. **Consequently, the number of patients cannot be totaled across AEs as this will lead to 'double-counting' and an overestimation)**

(N.B. Day "0" equals the first day of the vaccination campaign.)

(i.e. The number of patients presenting to the ER on the day listed in column 1A.)

FEVER (>100 °F)

96,000 total patients

10th day following campaign initiation

10,288

INADVERTENT INNOCULATION

2,000 total patients

11th day following campaign initiation

215

GENERALIZED VACCINIA

1,928 total patients

10th day following campaign initiation

207

VACCINIA NECROSUM

12 total patients

10th day following campaign initiation

02

POST-VACCINATION ENCEPHALITIS

100 total patients

10th day following campaign initiation

11

ECZEMA VACCINATUM

304 total patients

11th day following campaign initiation

33

Moderate to Severe Events

# Mass Vaccination AEs—Hospital Use

2.TOTAL NUMBER OF PATIENTS NEEDING HOSPITAL ADMITTANCE BASED ON A PROGRAM TO VACCINATE 8000000 PEOPLE IN 7 DAYS:	2A.DAY FOLLOWING CAMPAIGN INITIATION WITH HIGHEST ESTIMATED INPATIENT BED OCCUPANCY:	2B. MAXIMUM INPATIENT BED OCCUPANCY ON ANY GIVEN DAY:	3B. MAXIMUM ICU BED OCCUPANCY ON ANY GIVEN DAY:
<p>(N.B. AEs are not mutually exclusive. These totals represent patients requiring hospital admittance from <i>at least</i> the respective AE and include patients suffering from other AEs - included those listed here- as well. <b>Consequently, the number of patients cannot be totaled <i>across</i> AEs as this will lead to 'double-counting' and an overestimation)</b></p> <p>(N.B. Day "0" equals the first day of the vaccination campaign.)</p> <p>(i.e. The number of inpatient occupied beds on the day listed in column 2A.)</p> <p>(i.e. The number of occupied ICU beds on the day listed in column 3A.)</p>			
4,800 total patients	13th day following campaign initiation	2,087	732
1,000 total patients	13th day following campaign initiation	435	00
964 total patients	13th day following campaign initiation	420	735
02 total patients	13th day following campaign initiation	01	09
00 total patients	0th day following campaign initiation	00	77
228 total patients	13th day following campaign initiation	100	58

# Limitations

- Accuracy of any model depends on the quality of the underlying data
  - Processing times are critical variable
- Output is flow plan-specific
  - A prophylaxis clinic with a different patient flow or floor plan will give a different result
- Multiple scalable centers with externally controlled patient flow
  - Feasible but requires law enforcement input
- These numbers reflect only critical dispensing staff and do not include support staff for the centers or distribution/logistics staff

# Conclusions

- Spreadsheet modeling allows planners to “think with numbers” when designing mass prophylaxis response strategies
- Modeling forces critical examination of:
  - Assumptions about vaccination center layout and processes
  - Availability of resources
- Model estimates are useful data to guide planning but do not replace the real thing:  
**LIVE, REALISTIC EXERCISES**



# Acknowledgments

- **NYC Office of Emergency Management**  
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