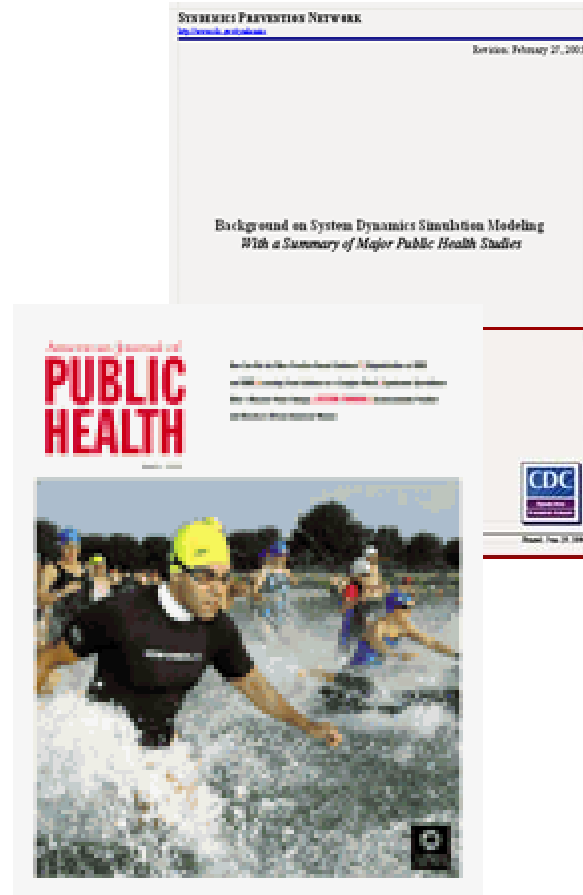
System Dynamics Health Applications
1970s to the Present

- **Disease epidemiology**
  - **Cardiovascular, diabetes, obesity, HIV/AIDS, cervical cancer, chlamydia, dengue fever, drug-resistant infections**
- **Substance abuse epidemiology**
  - **Heroin, cocaine, tobacco**
- **Health care patient flows**
  - **Acute care, extended care**
- **Health care capacity and delivery**
  - **Managed care, dental care, mental health care, disaster preparedness, community health programs**
- **Health system economics**
  - **Interactions of providers, payers, patients, and investors**



Homer J, Hirsch G. System dynamics modeling for public health: Background and opportunities. *American Journal of Public Health* 2006;96(3):452-458.

Milstein B, Homer J. Background on system dynamics simulation modeling, with a summary of major public health studies. Atlanta, GA: Syndemics Prevention Network, Centers for Disease Control and Prevention; May 5, 2006. <http://www.hpsig.com/images/f/f5/SD_background_for_public_health_%284.11.05%29.pdf>

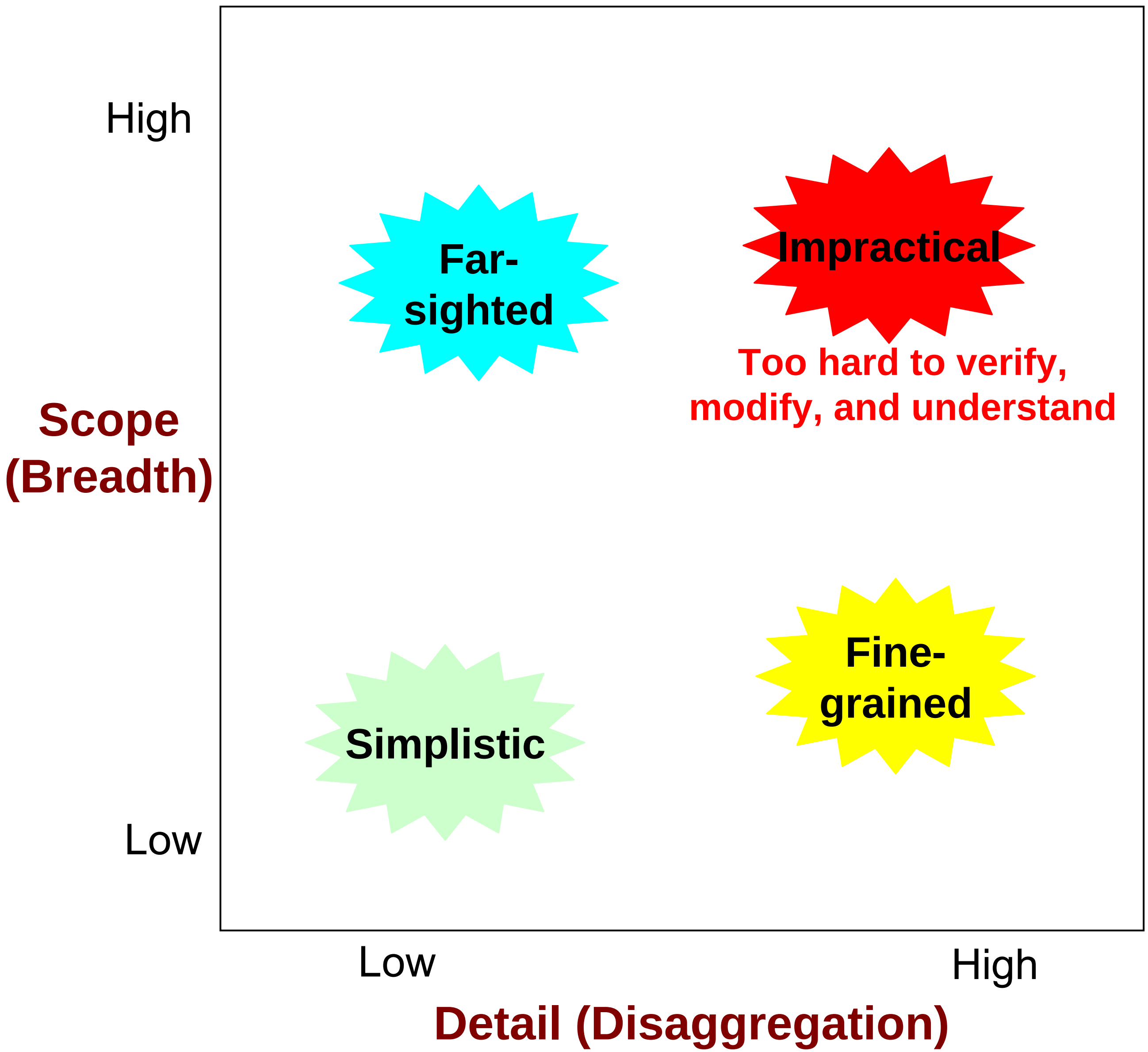
Today's Examples

- Growth of diabetes
- Growth of obesity
- Hospital surge capacity
- Cocaine prevalence dynamics

Model Uses and Audiences

- **Set Better Goals (Planners & Evaluators)**
  - **Identify what is likely and what is possible**
  - **Estimate intervention impact time profiles**
  - **Evaluate resource needs for meeting goals**
- **Support Better Action (Policymakers)**
  - **Explore ways of combining policies for better results**
  - **Evaluate cost-effectiveness over extended time periods**
  - **Increase policymakers' motivation to act differently**
- **Develop Better Theory and Estimates (Researchers)**
  - **Integrate and reconcile diverse data sources**
  - **Identify causal mechanisms driving system behavior**
  - **Improve estimates of hard-to-measure or "hidden" variables**

Practical Options in Causal Modeling



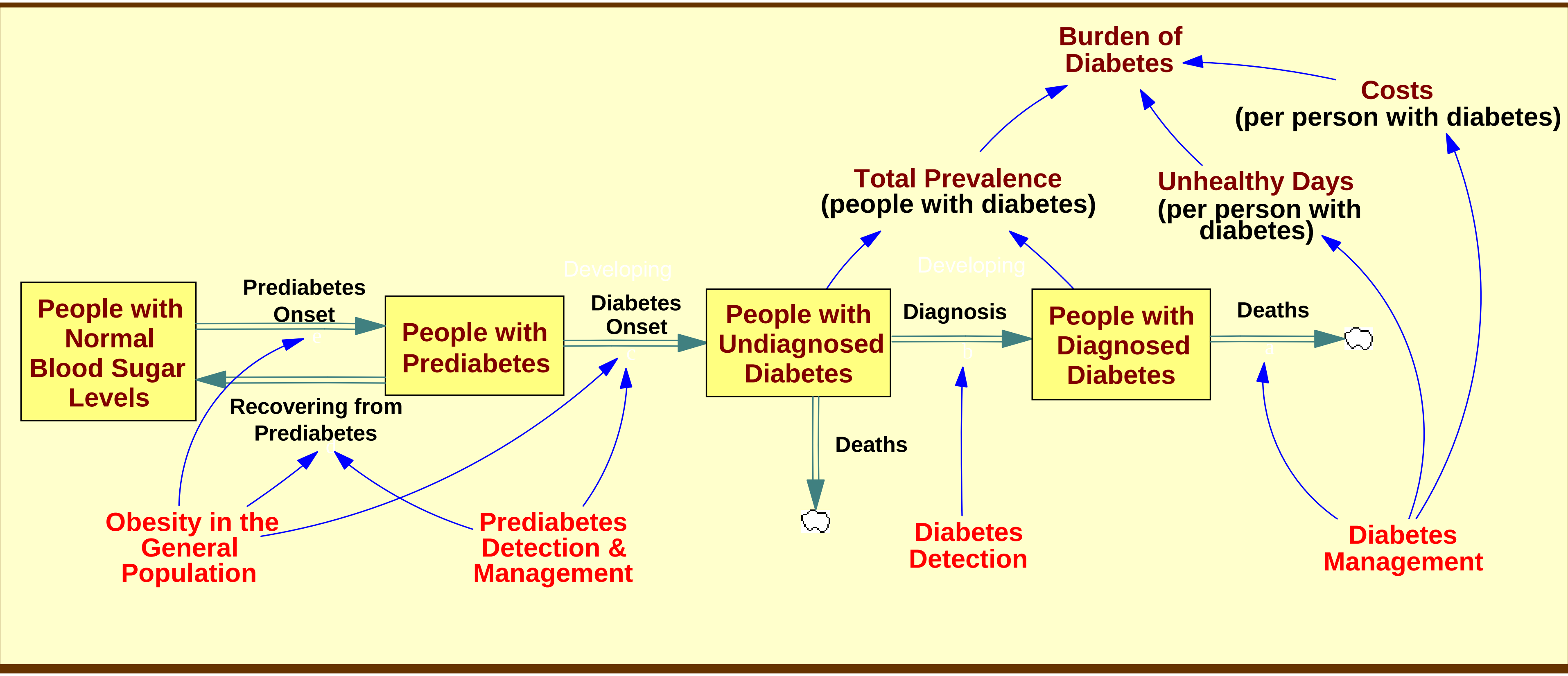
Growth of Diabetes

(with CDC, 2003 to present)

- **Diabetes programs face tough challenges and questions**
  - With rapid growth in prevalence, is improved control good enough?
  - Studies show primary prevention is possible, but how much impact in practice and at what cost?
  - How best to balance interventions?
- **Model developed with program planners, diabetes researchers, and epidemiologists**
- **Model-based “learning lab” workshops for planners—federal, state, and local**

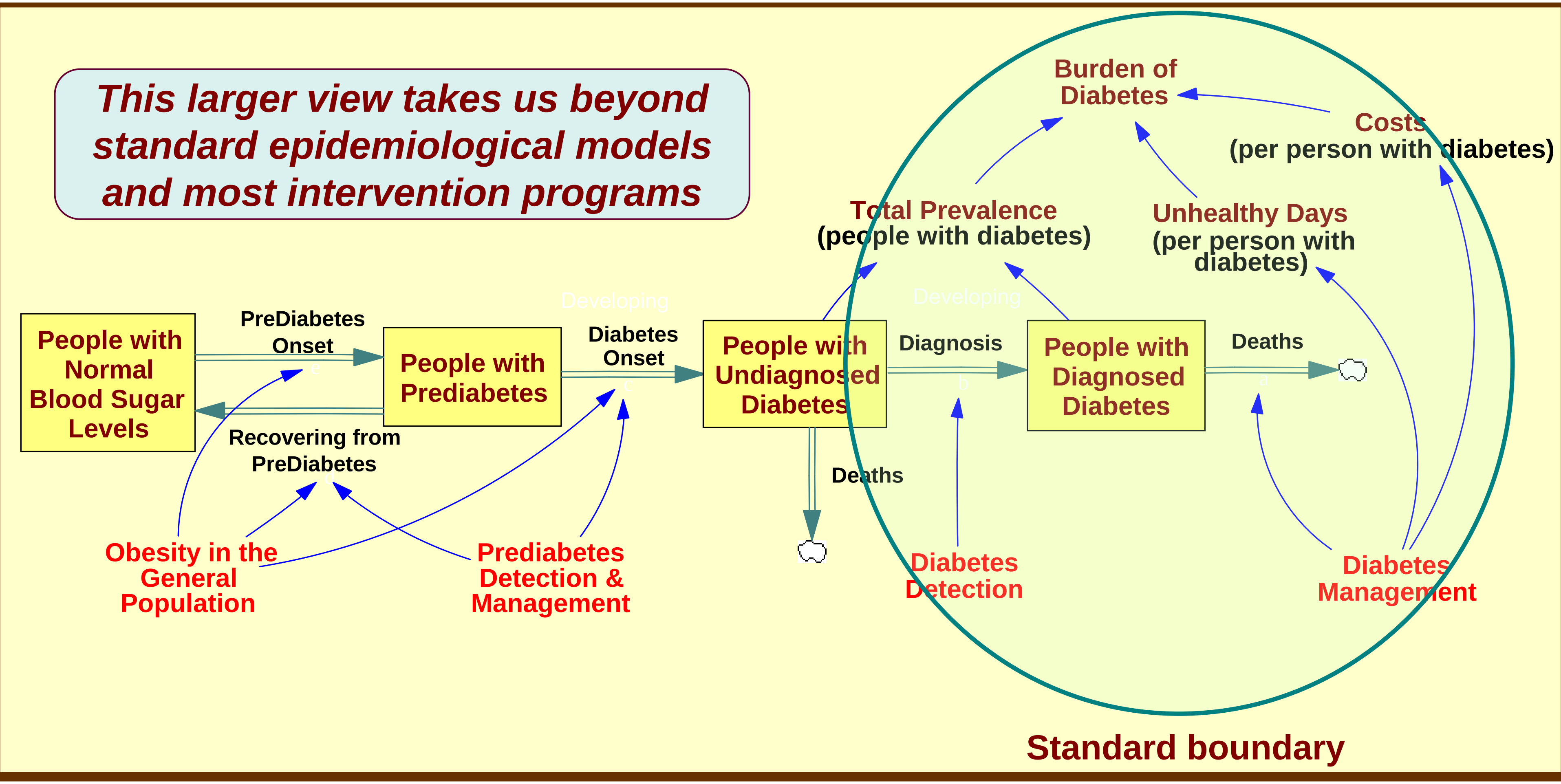
Jones AP, Homer JB, Murphy DL, Essien JDK, Milstein B, Seville DA. Understanding diabetes population dynamics through simulation modeling and experimentation. *American Journal of Public Health* 2006;96(3):488-494.

Diabetes Model Overview



<u>Data sources</u>: NHIS, NHANES, BRFSS, Census, Vital statistics, Clinical studies, Cost studies

Diabetes Model Overview



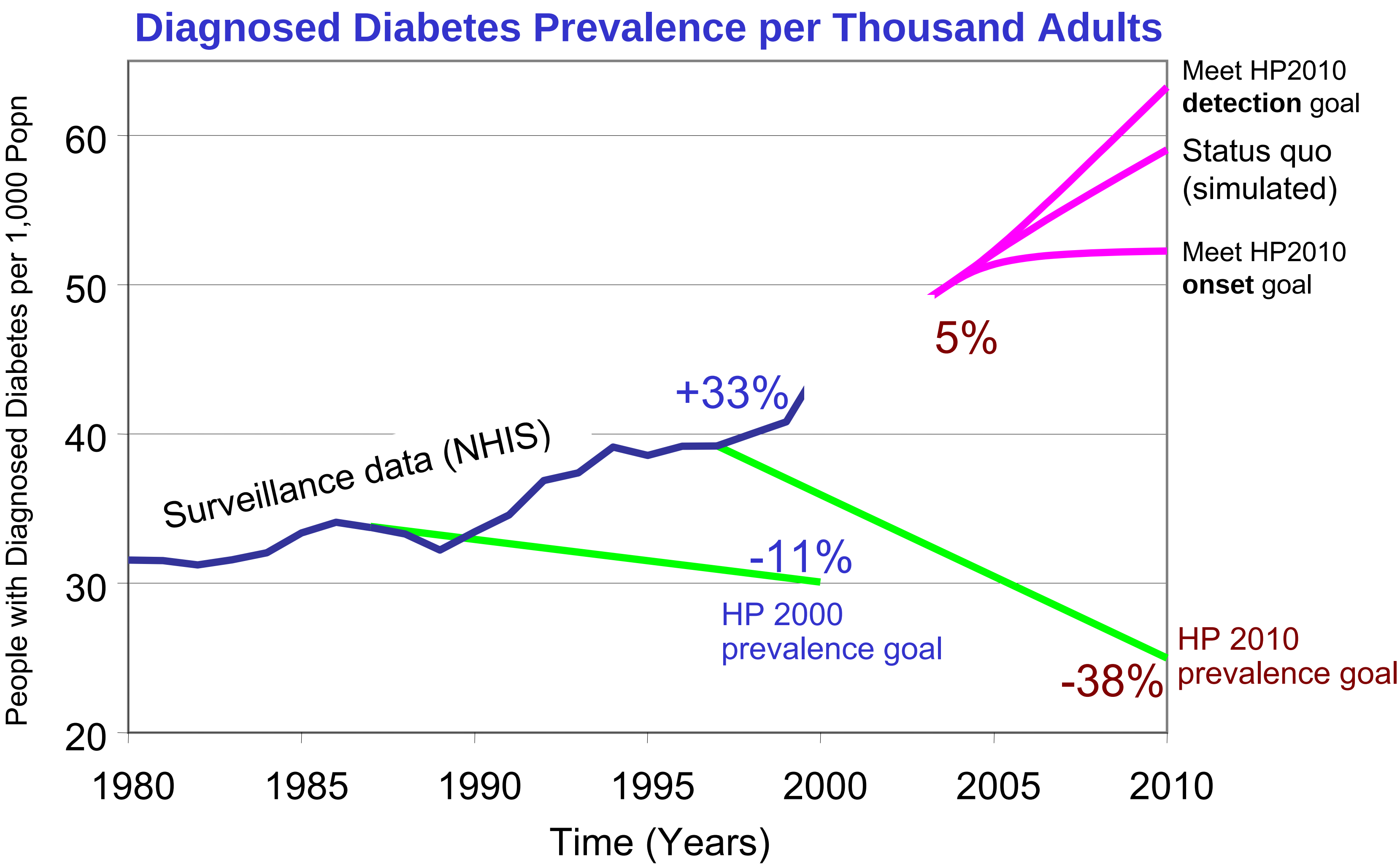
Data sources: NHIS, NHANES, BRFSS, Census, Vital statistics, Clinical studies, Cost studies

Healthy People 2010 Diabetes Goals

	Baseline	HP 2010 Target	Percent Change
Reduce Diabetes–related Deaths Among Diagnosed (5-6)	**8.8 per 1,000**	**7.8**	**-11%**
Increase Diabetes Diagnosis (5-4)	**68%**	**80%**	**+18%**
Reduce New Cases of Diabetes (5-2)	**3.5 per 1,000**	**2.5**	**-29%**
Reduce Prevalence of Diagnosed Diabetes (5-3)	**40 per 1,000**	**25**	**-38%**

U.S. Department of Health and Human Services. *Healthy People 2010*. Washington DC: Office of Disease Prevention and Health Promotion, DHHS; 2000. http://www.healthypeople.gov/Document/HTML/Volume1/05Diabetes.htm

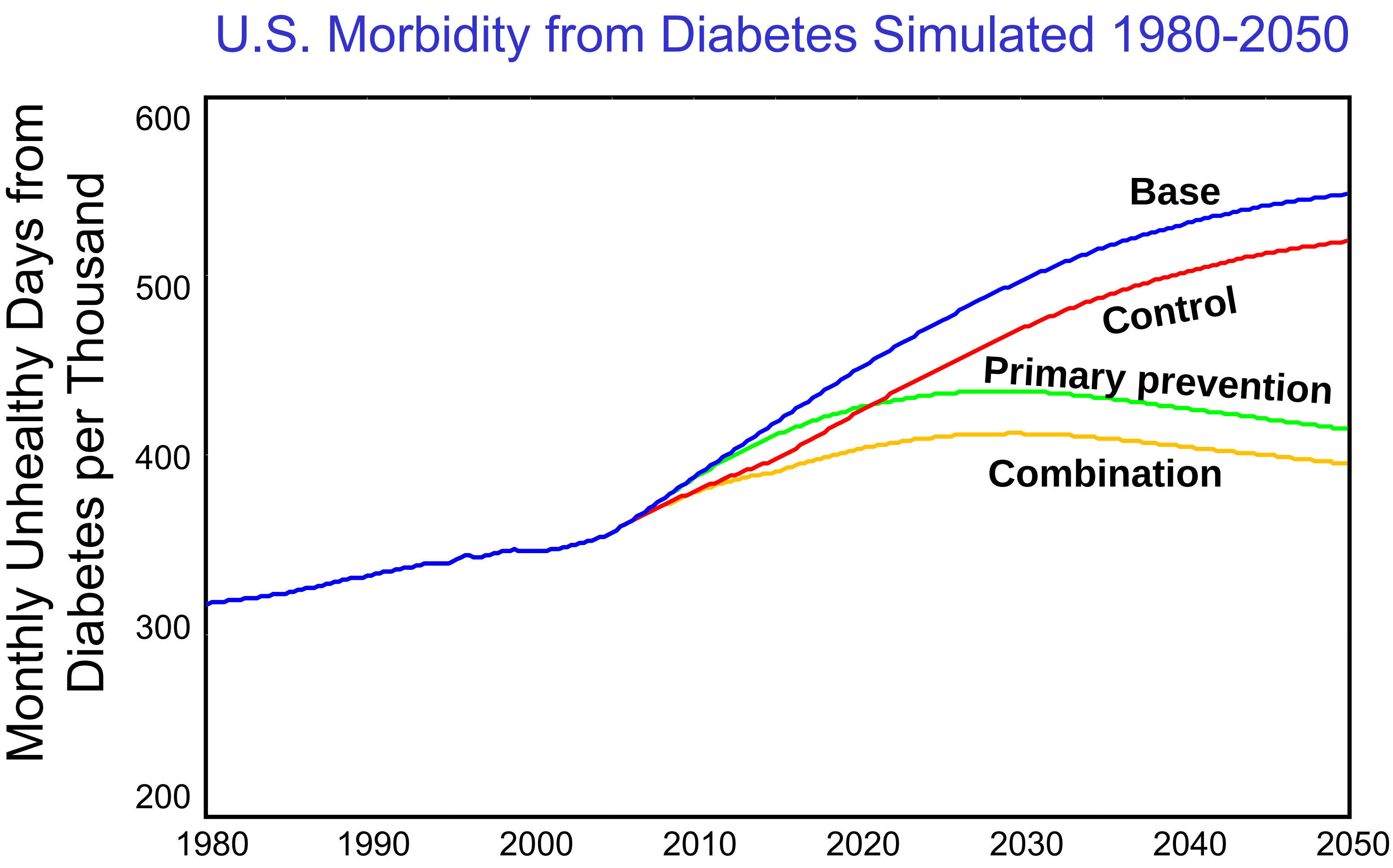
A History of Missed Goals



Simulations have helped diabetes planners set more realistic goals.

Milstein B, Jones A, Homer J, Murphy D, Essien J, Seville D. Charting plausible futures for diabetes prevalence: A role for system dynamics simulation modeling. *Preventing Chronic Disease* July 2007. <http://www.cdc.gov/pcd/issues/2007/jul/06_0070>

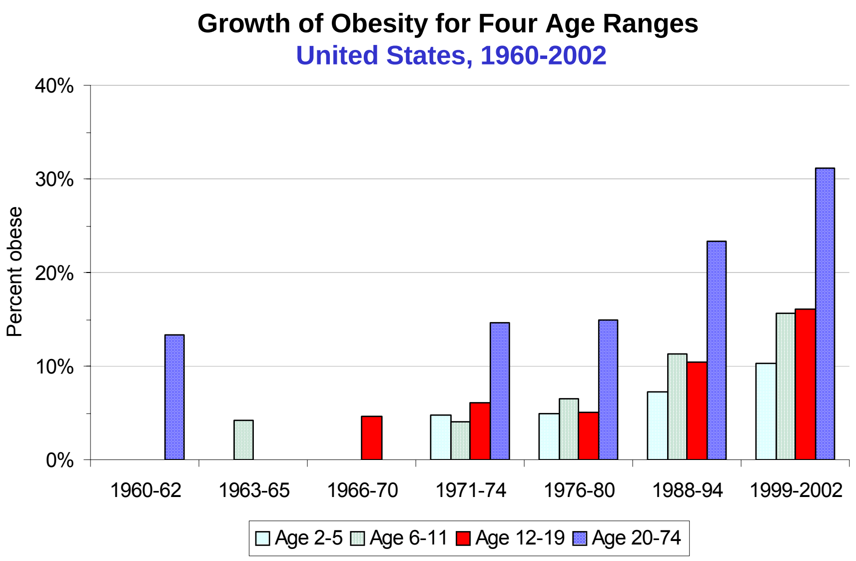
Policy Testing…and Reason for Hope



With a combination of improved control and aggressive primary prevention, growth in the burden of diabetes could be limited for the next 10 years and for decades beyond.

Growth of Obesity
(with CDC, 2005 to present)

- **Explore likely consequences of interventions**
  - How much impact in reducing adult obesity? Over what time frame?
  - What if we target by age? By sex? By weight category?
- **Model interventions only in terms of how they affect a person's caloric balance (intake less expenditure)**
  - Not addressing specific programs
  - Not addressing efficacy and cost
  - Not addressing interpersonal, community, or economic dynamics



Obesity definitions by age

Ages 2-19: BMI>=30 or >=95th percentile on CDC growth chart

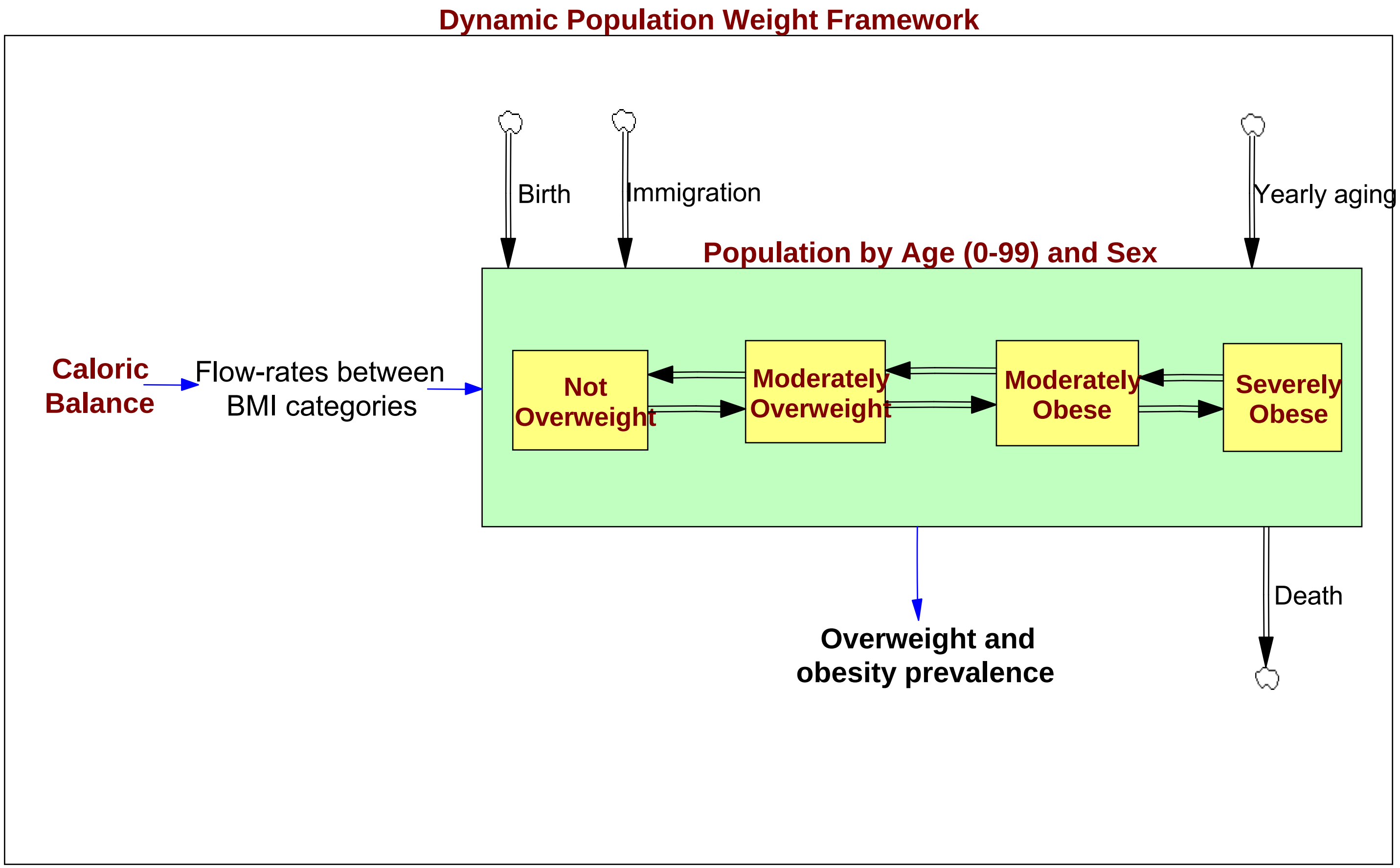
Ages 20-74: BMI>=30

Data source: National Center for Health Statistics, CDC: National Health Examination Survey (NHES) 1960-1970, National Health and Nutrition Examination Survey (NHANES) 1971-2002.

Homer J, Milstein B, Dietz W, et al. Obesity population dynamics: exploring historical growth and plausible futures in the U.S. *Proc. 24th Int'l System Dynamics Conference*; Nijmegen, The Netherlands; July 2006.

Population Weight Dynamics

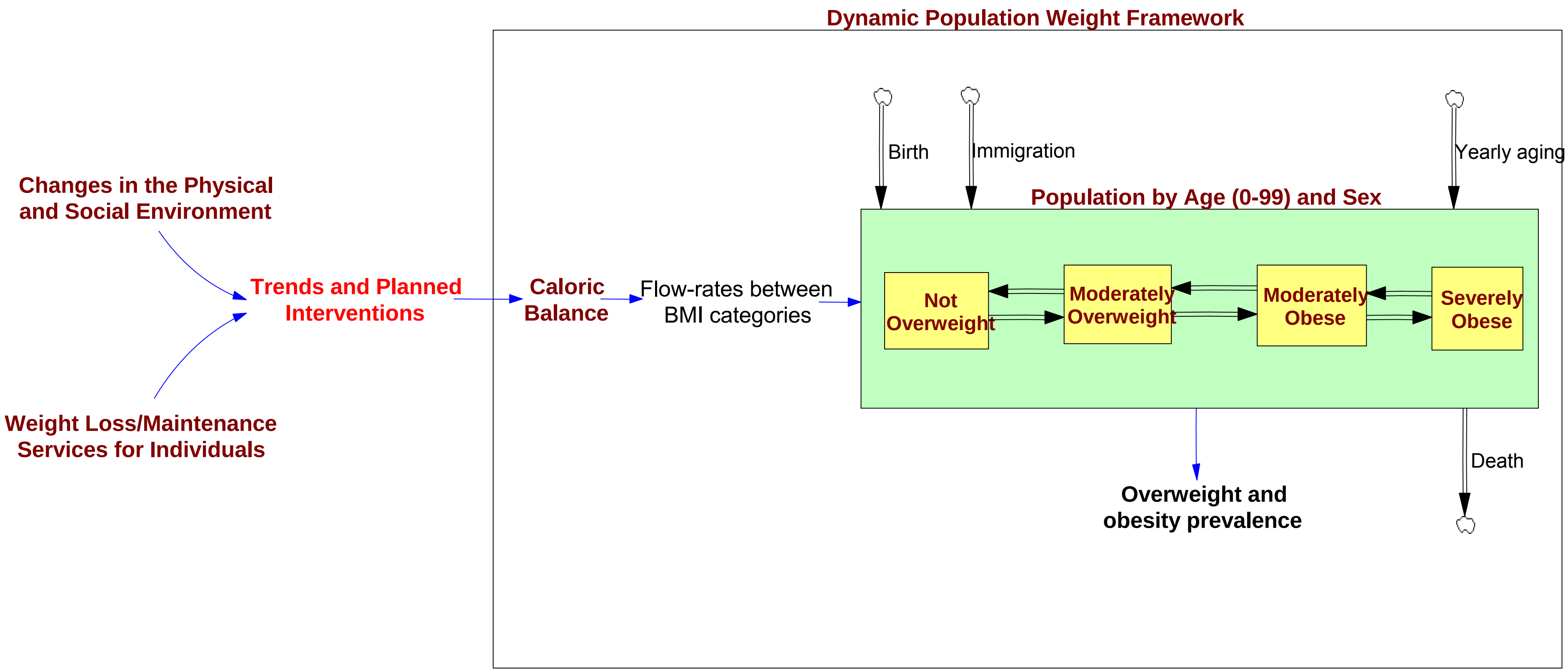
Changes in BMI Category over the Lifecourse



<u>Data sources</u>: NHANES, Arkansas schoolchildren 2-year assessment, Census, Vital statistics, Clinical studies, Attributable-death studies

Population Weight Dynamics

Two Classes of Interventions



<u>Data sources</u>: NHANES, Arkansas schoolchildren 2-year assessment, Census, Vital statistics, Clinical studies, Attributable-death studies

Results of Simulated Interventions

Environmental change approach

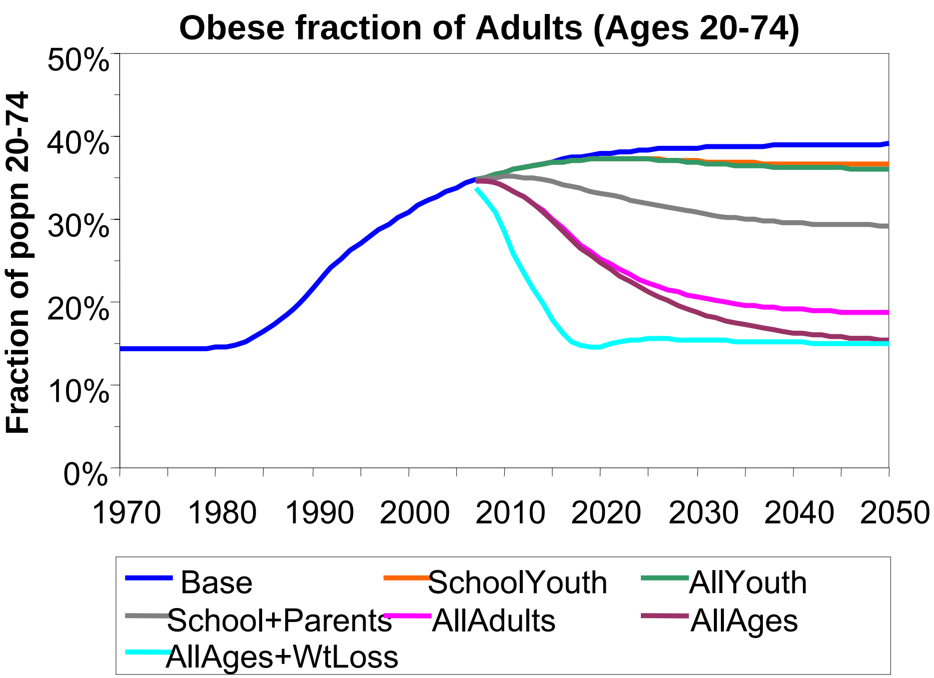
(reduce caloric balances to their 1970 values by 2015 for selected age ranges)

- Youth interventions have only small impact on overall adult obesity *(assuming adult habits determined by adult environment—not by childhood)*
- **Slow decline** in overall adult obesity, even when program covers all ages

Targeted weight loss approach

(obese lose 4 lbs per year, program terminated 2020)

- Such a program could accelerate progress and "buy time" for environmental change *(but first, need to find a cost-effective program with lasting benefits—minimal relapse)*



Need to assure caloric balance throughout all ages, particularly *adulthood*.

Contrast today's narrow national focus on *school-age youth*.

Also need research on extent to which adult habits are determined by childhood.

Hospital Surge Capacity
(with W. Va. Univ., 2003-04)

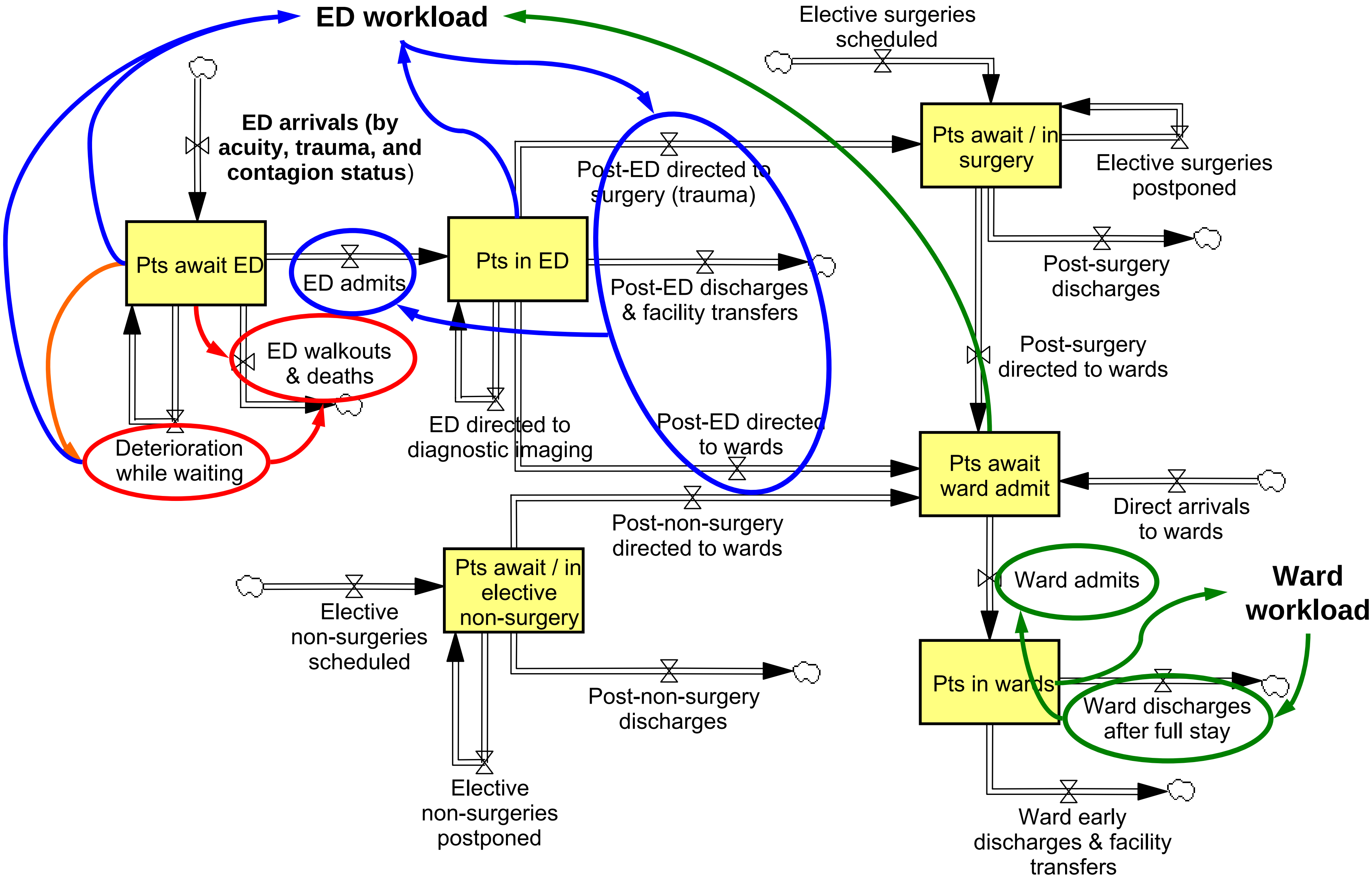
- **Overcrowding due to patient surges in Emergency Dept. creates risk**
  - Deterioration of patients while awaiting ED admission
  - Walking-out of patients who should be treated or isolated
- **Hospital disaster plans are required to address surge capacity**
  - Flow-control methods, e.g. triage, transfer, early discharge
  - Reserve resources—nurses, beds, supplies—are limited, esp. for rural hospitals
  - **How best to deploy limited resources?**

St. Joseph's Hospital, Buckhannon, W.Va.

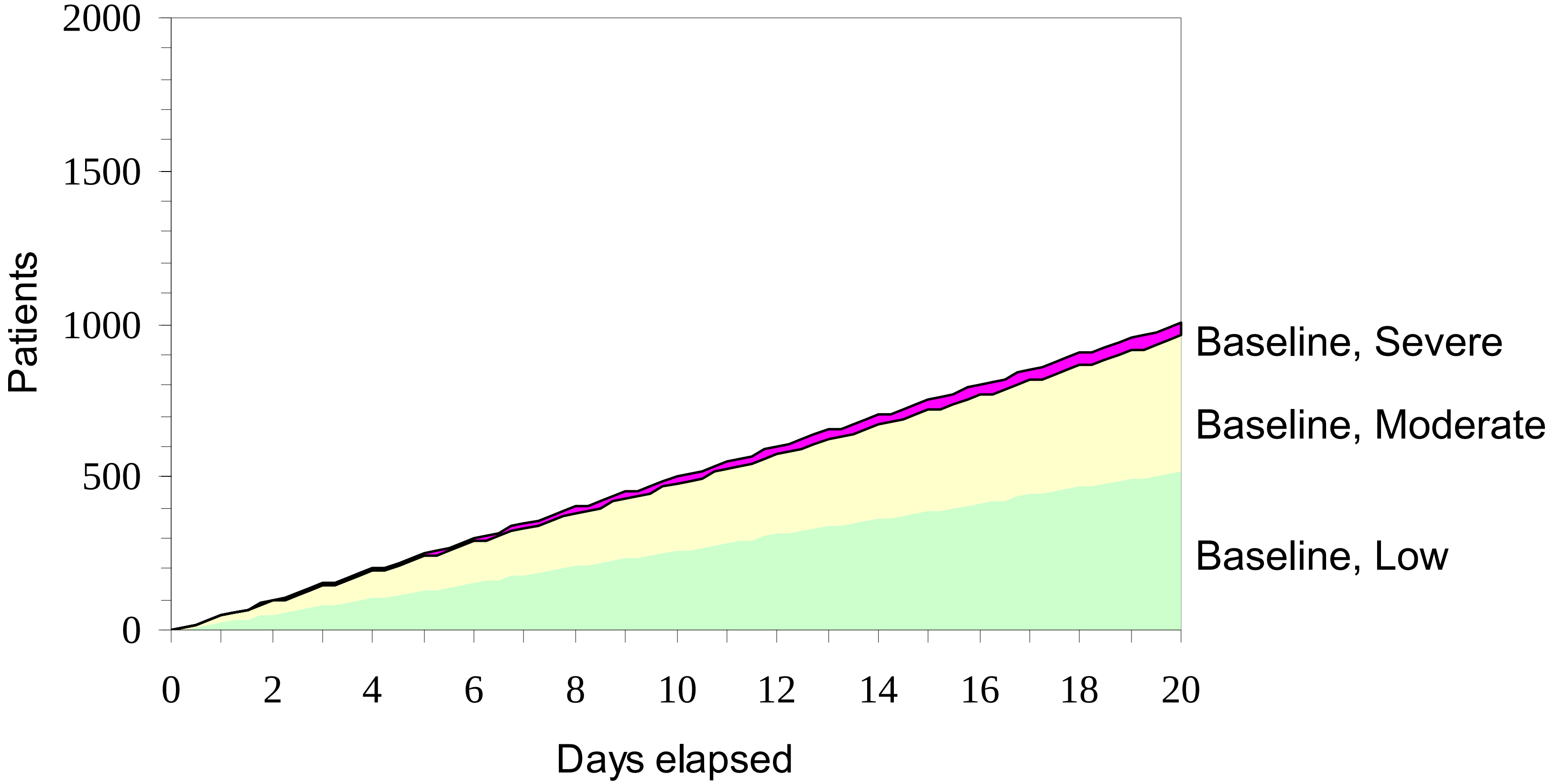
Hoard M, Homer J, Manley W, et al. Systems modeling in support of evidence-based disaster planning for rural areas. *Intl J of Hygiene and Envir Health* 2005; 208:117-125.

Manley W, Homer J, et al. A dynamic model to support surge capacity planning in a rural hospital. 23rd Int'l SD Conference, Boston, MA; July 2005. <http://cgi.albany.edu/~sdsweb/sds2005.cgi?P333>

Patient Flows and Feedback Loops



Cumulative ED Arrivals by Acuity:
Baseline Scenario

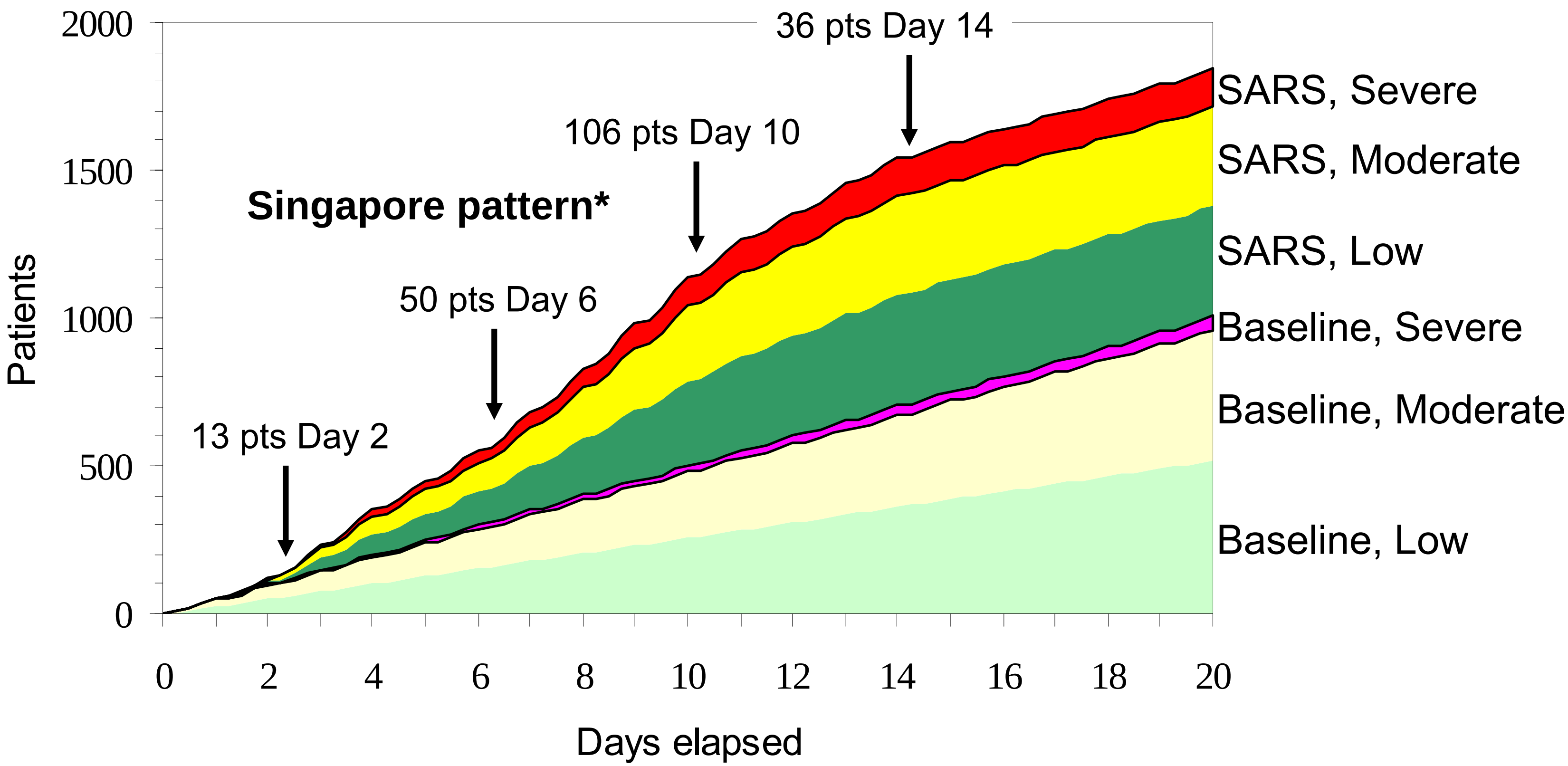


Baseline (no surge) scenario

50 ED arrivals per day for 20 days.

Result: Volume well handled, no avoidable deaths from deterioration

Cumulative ED Arrivals by Acuity:
SARS Scenario



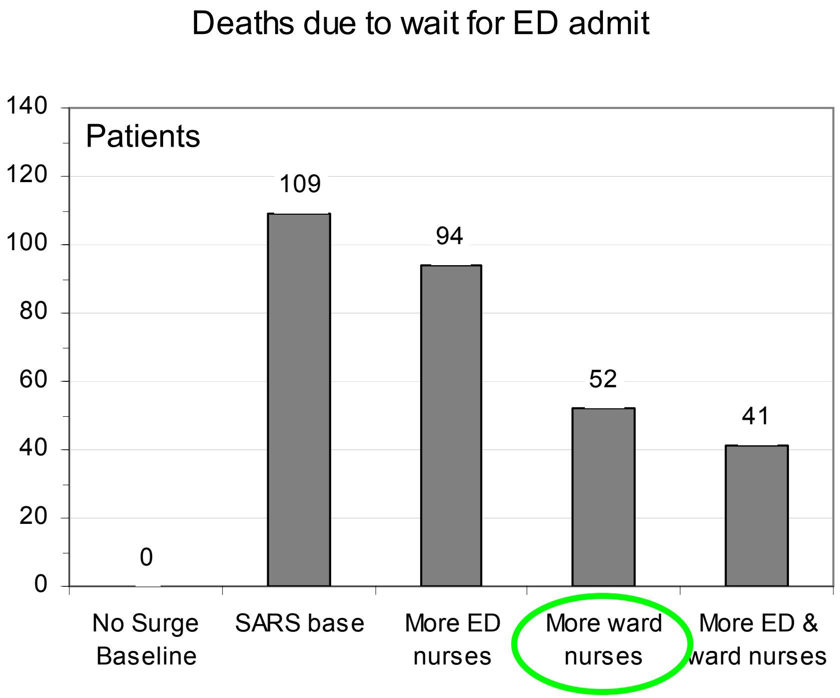
SARS outbreak scenario

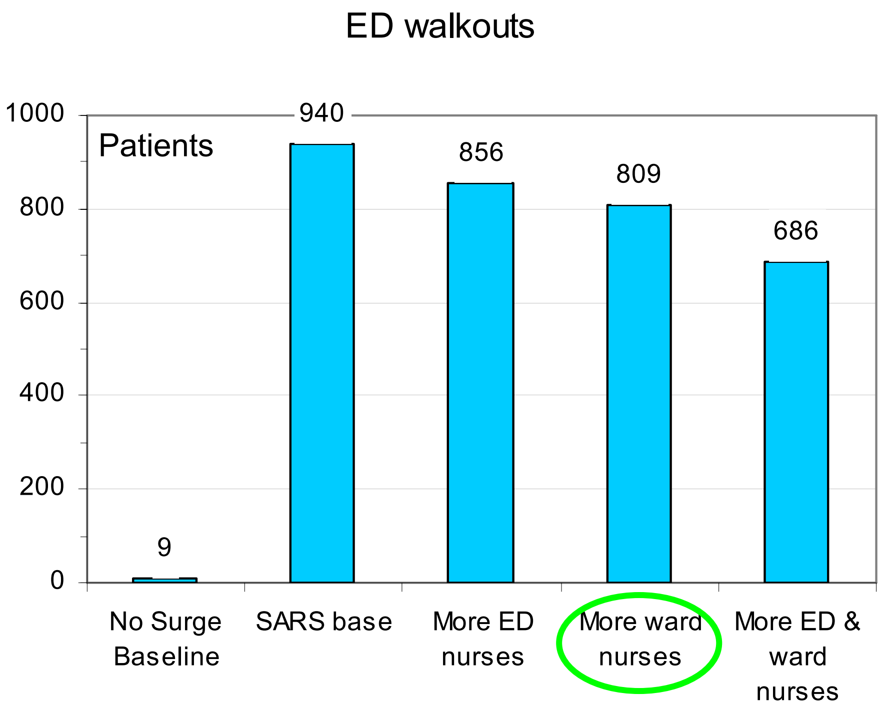
Over the course of 13 days, 837 cumulative SARS ED arrivals, all requiring isolation, in addition to baseline arrivals.

Result: Severe bottlenecks and many avoidable deaths

* CDC. *Preparedness and Response in Healthcare Facilities: Public Health Guidance for Community-Level Preparedness and Response to SARS* (Supplement C). January 8, 2004.

SARS Policy Testing (20 Days Cumulative):
Deaths & Walkouts Due to ED Admit Wait





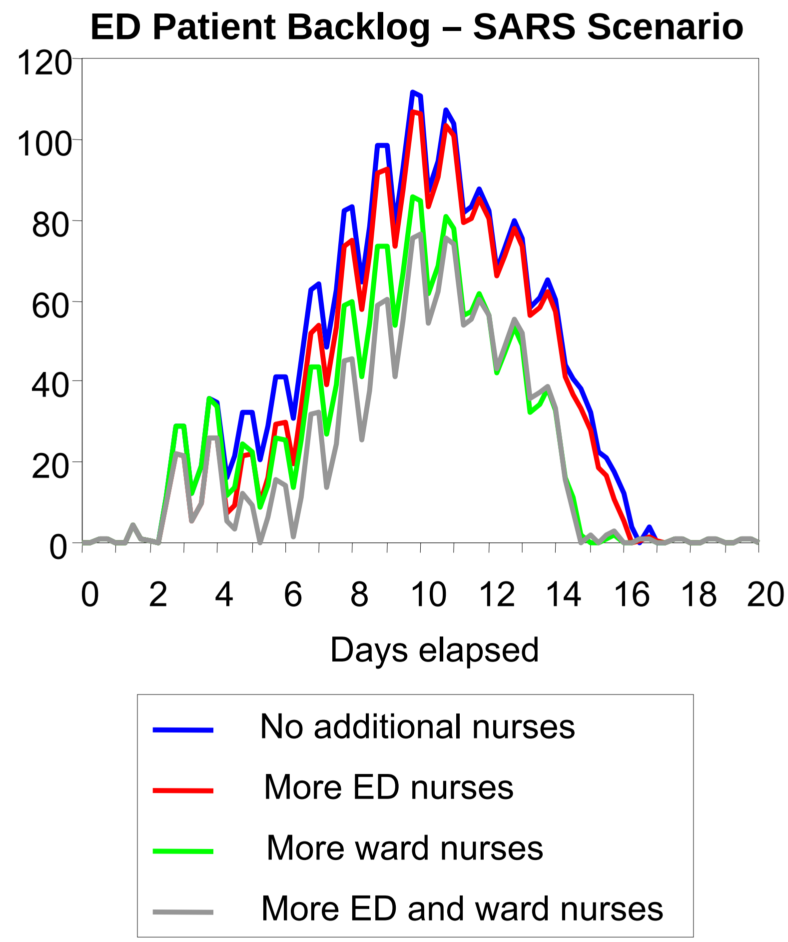
Reserve nurses recruited from RNs off-duty, part-time, in offices, retired

Why is the ward nurse policy so much more effective?

You can't push the car forward until the hand brake is released.

Hospital Model Findings

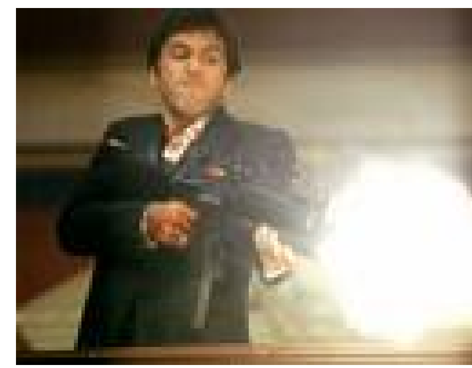
- **Recommendations affected by particulars of the hospital and the type of surge**
  - **St. Joseph's** → need nurses, not beds
  - **SARS** → need ward nurses the most *(the surge creates significant need for inpatient stays, not just ED care)*
- **But model is broadly applicable**
  - Could develop optimal strategies—**best practices**—customized to type of hospital and type of surge
  - Allows for systematic "all hazards" planning



Cocaine Prevalence Dynamics

(with UCLA and National Inst. of Justice 1988-1991)

- **Planners want better estimates and projections**
  - Self-report surveys under-report—to an extent that may change over time
  - Need to synthesize **multiple indicators**—"triangulate"
- **Theory evolved with new data**
  - Initial focus on economics, but needed social theory, and modeling of crack cocaine
  - Can project **underreporting** by knowing how it varies by type of user and social climate

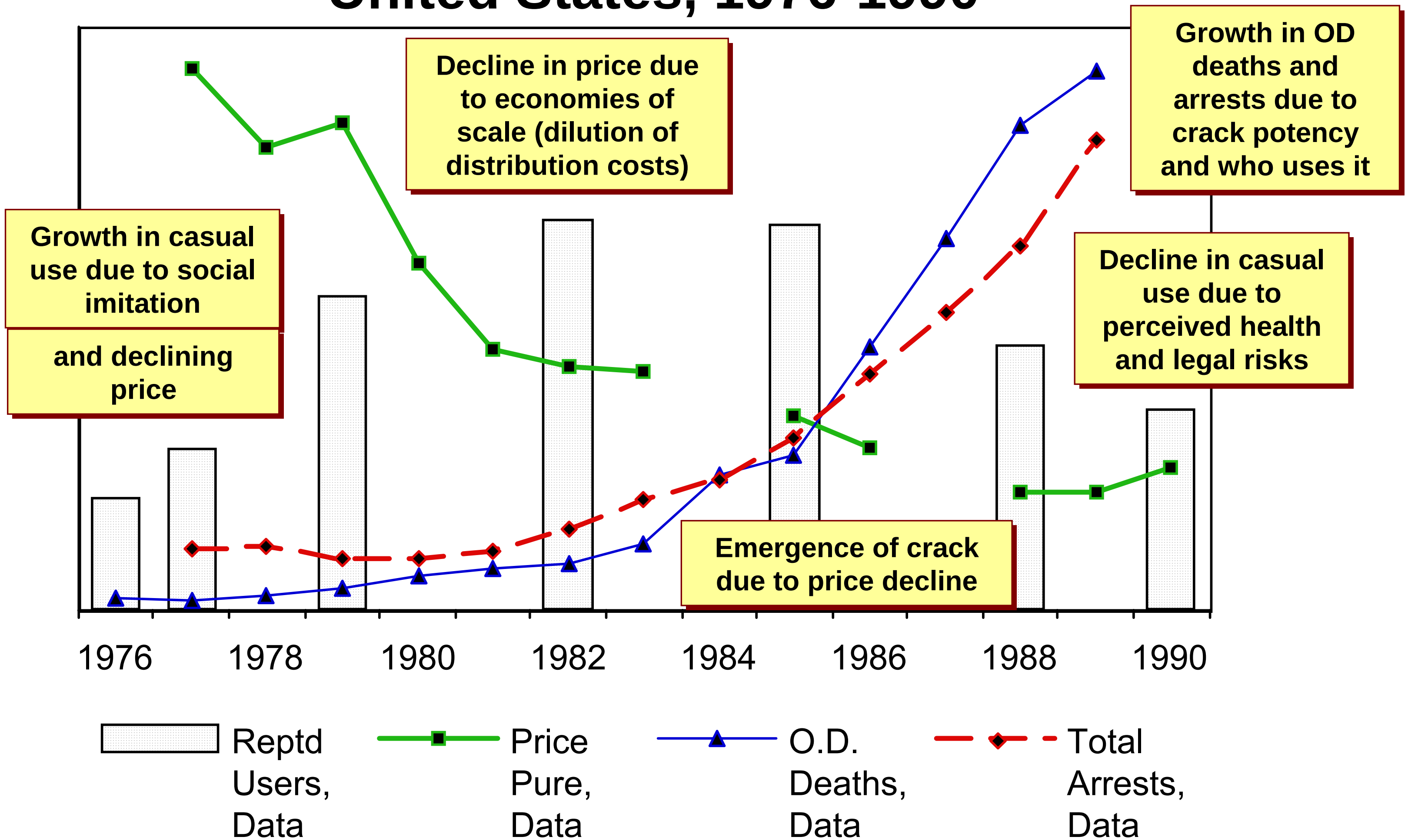


Homer J. A system dynamics model for cocaine prevalence estimation and trend projection. *Journal of Drug Issues* 1993; 23(2):251-279.

Hser YI, Anglin MD, Wickens TD, Brecht ML, Homer JB. Techniques for the estimation of illicit drug use prevalence. Research report NCJ 133786, National Institute of Justice, May 1992.

Homer J. Why we iterate: Scientific modeling in theory and practice. *System Dynamics Review* 1996; 12(1):1-19.

Trends in Reported Cocaine Use, Price, Death, and Arrest, United States, 1976-1990

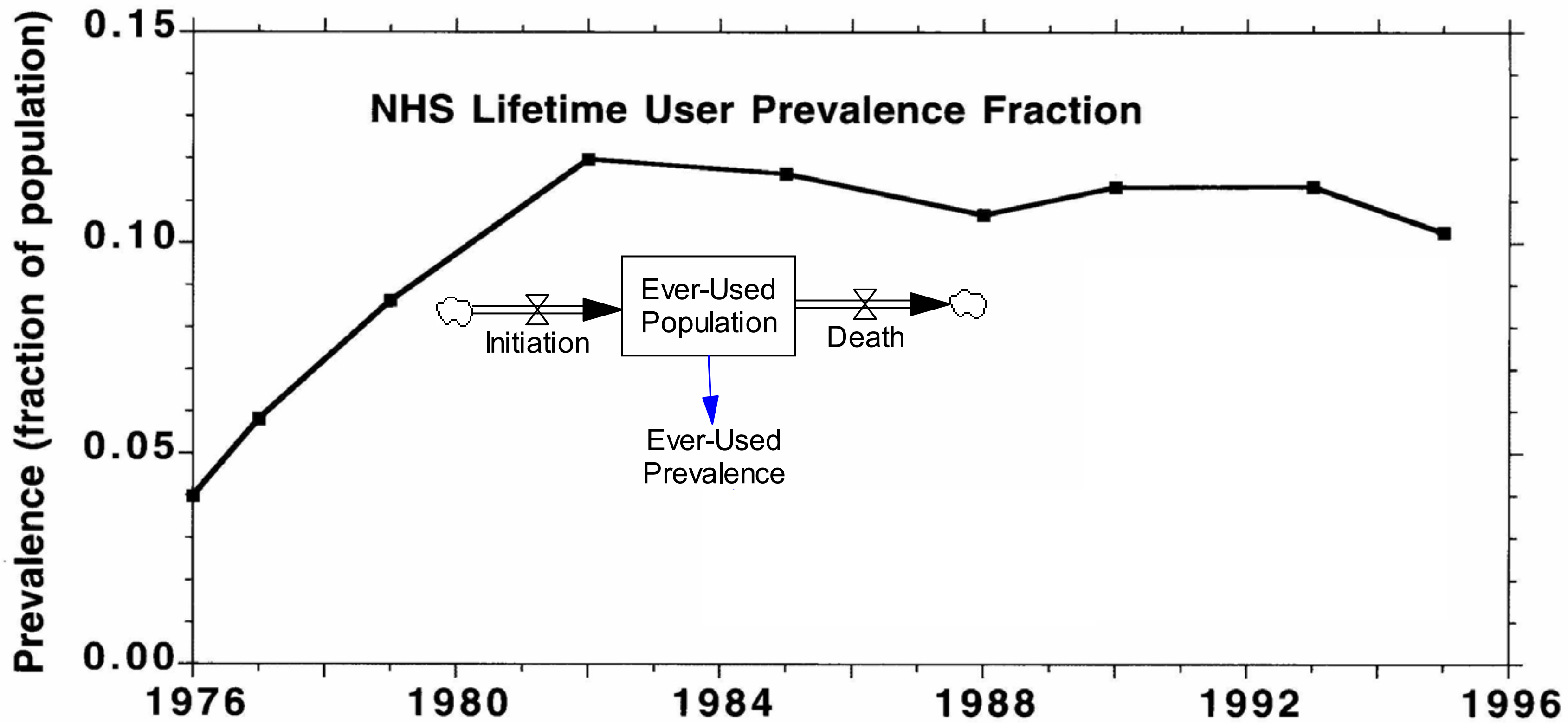


Sources: Users—National Household Survey (NIDA), Price—STRIDE drug deals database (DEA), OD Deaths—DAWN Medical Examiner Mentions (NIDA), Arrests—UCR (FBI)

Other data: HS Sr. Survey usage and attitudes (NIDA), DUF usage (NIJ), OBTS incarcerations (BJS), NNICC seizure volume (DEA), DAWN E.R. mentions (NIDA)

Reported Cocaine "Ever-Used" Fraction

National Household Survey on Drug Abuse, 1976-1995

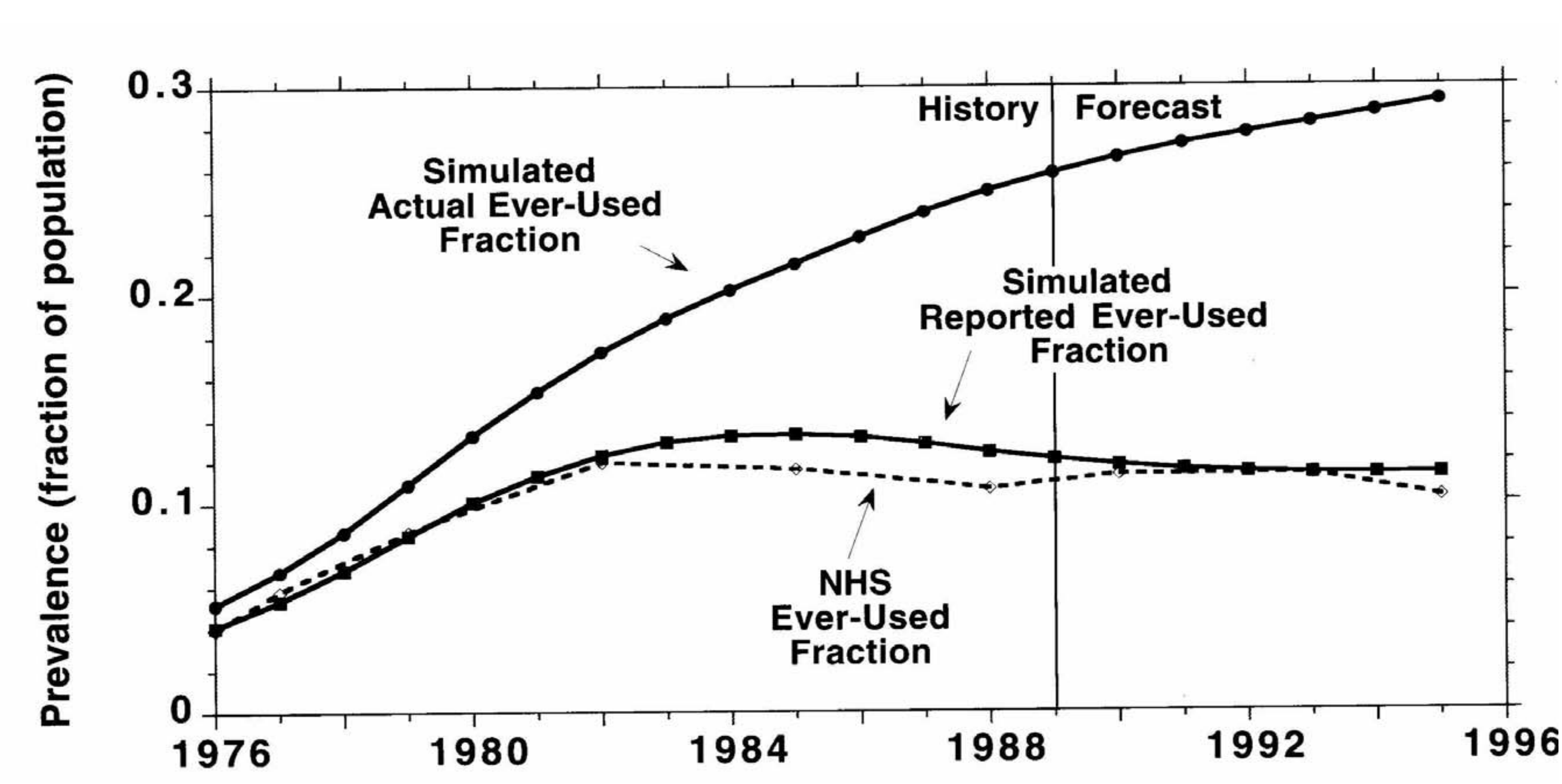


Source: National Household Survey, Homer (1993, 1997).

Homer J. A system dynamics model for cocaine prevalence estimation and trend projection. *Journal of Drug Issues* 1993; 23(2):251-279.

Homer JB. Structure, data and compelling conclusions: Notes from the field (Jay Wright Forrester Prize Lecture.) *System Dynamics Review* 1997; 13(4):293-309.

Inferred Underreporting of Cocaine "Ever-Used" Fraction



By 1995, only about 40% of actual lifetime use was accurately reported, down from about 70% in 1980.

System Dynamics:
Looking Further for the Key

The world is complex, and many important things are not well-measured.

(The key is not always under the light.)

SD allows for broader causal structures and types of data.

Such models often lead to novel conclusions—and firm ones despite the uncertainties.

This is why SD is a powerful approach to support planning and policymaking.