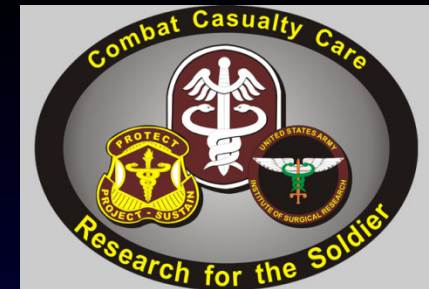




*National Trauma Institute &  
US Army Institute of Surgical Research*  
Symposium on Automation and Decision  
Support Systems  
for the ED, OR and ICU  
June 4-5, 2009



# Trade-Offs in Critical Care Information Systems

Patrick Norris, Ph.D.

Vanderbilt University  
Trauma & Surgical Critical Care  
Nashville, TN



# Motivation

*The need for critical care professionals is becoming dire...*

*The desire and intention to provide every citizen with high-quality healthcare may not be enough...*

*We are balanced on the razor's edge of uncertainty...*

**Mitchell Levy**  
**SCCM '09 Presidential Address**

# Motivation

- **Critical Care Faces Trade Offs**
  - Scare Resources
  - Increasing Demands
- **Increasingly Difficult Decisions**
- **Turning to Decision Support Systems**

# Overview

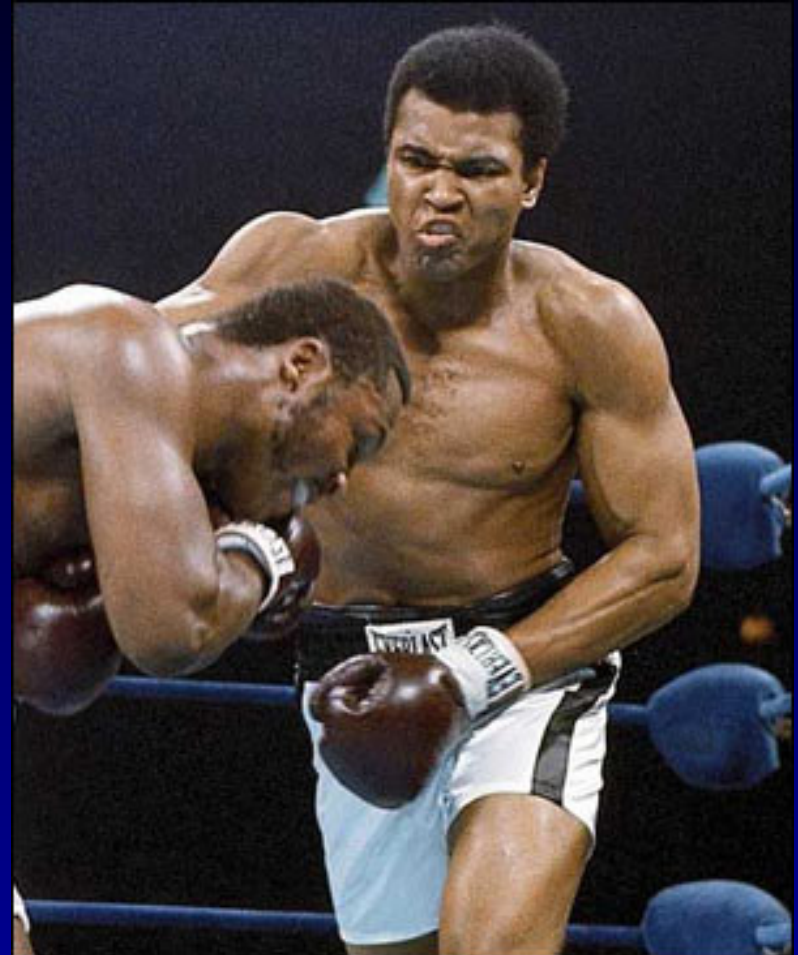
- **A) Defining “Trade-Off”**
  - 1. Competition, 2. Context, 3. Confidence
- **B) Managing Trade-Offs**
  - 1. Explicate, 2. Evaluate, 3. Revisit
- **C) Unique Aspects of Critical Care DSS**

## Survey: Your Top Three Trade-Offs in ED, OR, ICU Automation and Decision Support Systems, i.e.

- Pressure v. Volume
- Speed v. Fuel Economy
- Less Filling v. Great Taste

# A. Trade-Off: Definition

- A Conflict?  
Competition?
- Us Versus Them:  
Trade Offs In  
Designing,  
Implementing, and  
Maintaining Critical  
Care Information  
Systems



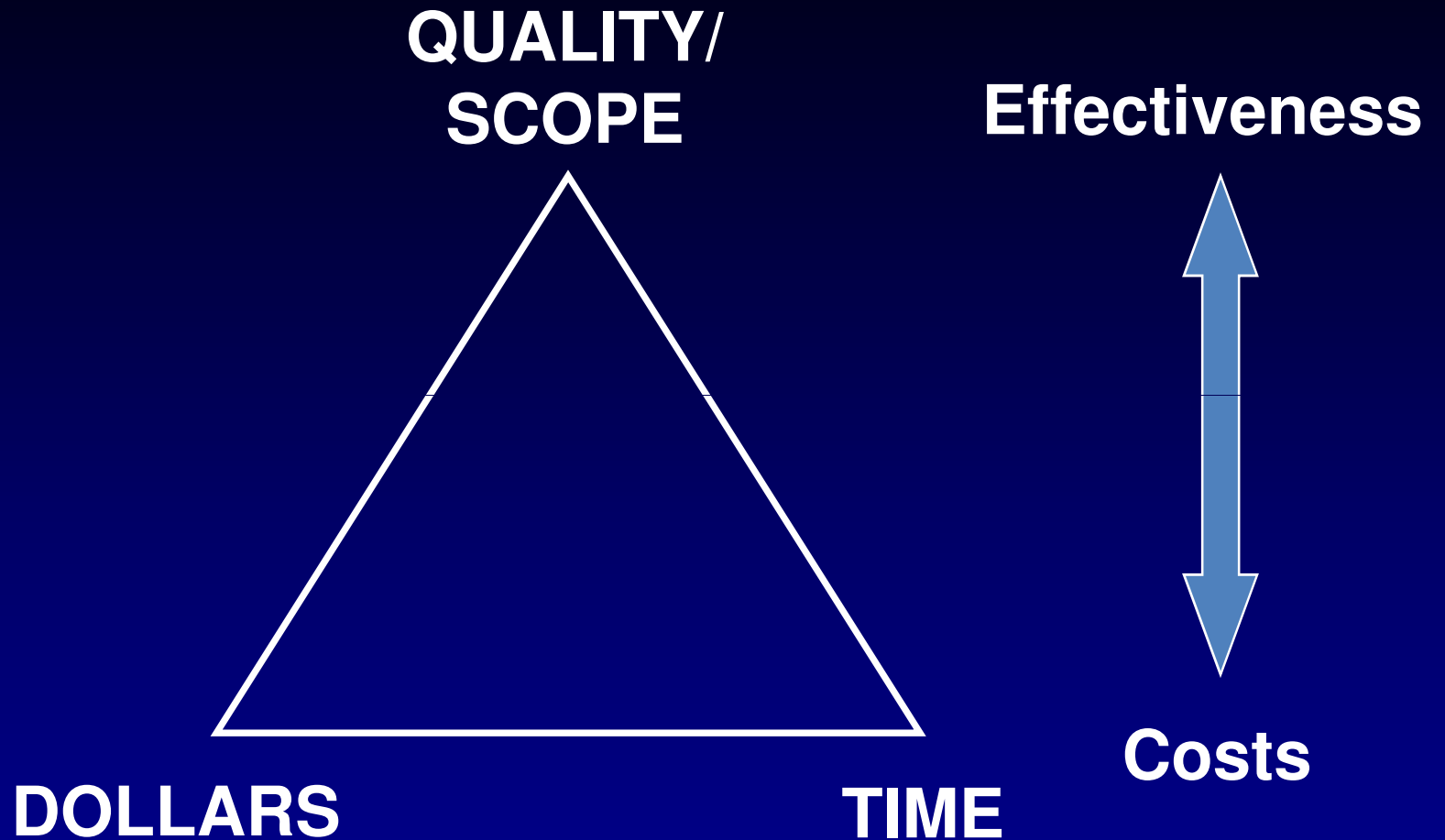
# Trade-Off: Definition

- A Constraint Problem?
- Multi-Dimensional Nonlinear Constraint Optimization  
in the Design, Implementation and Maintenance of Critical Care Information Systems

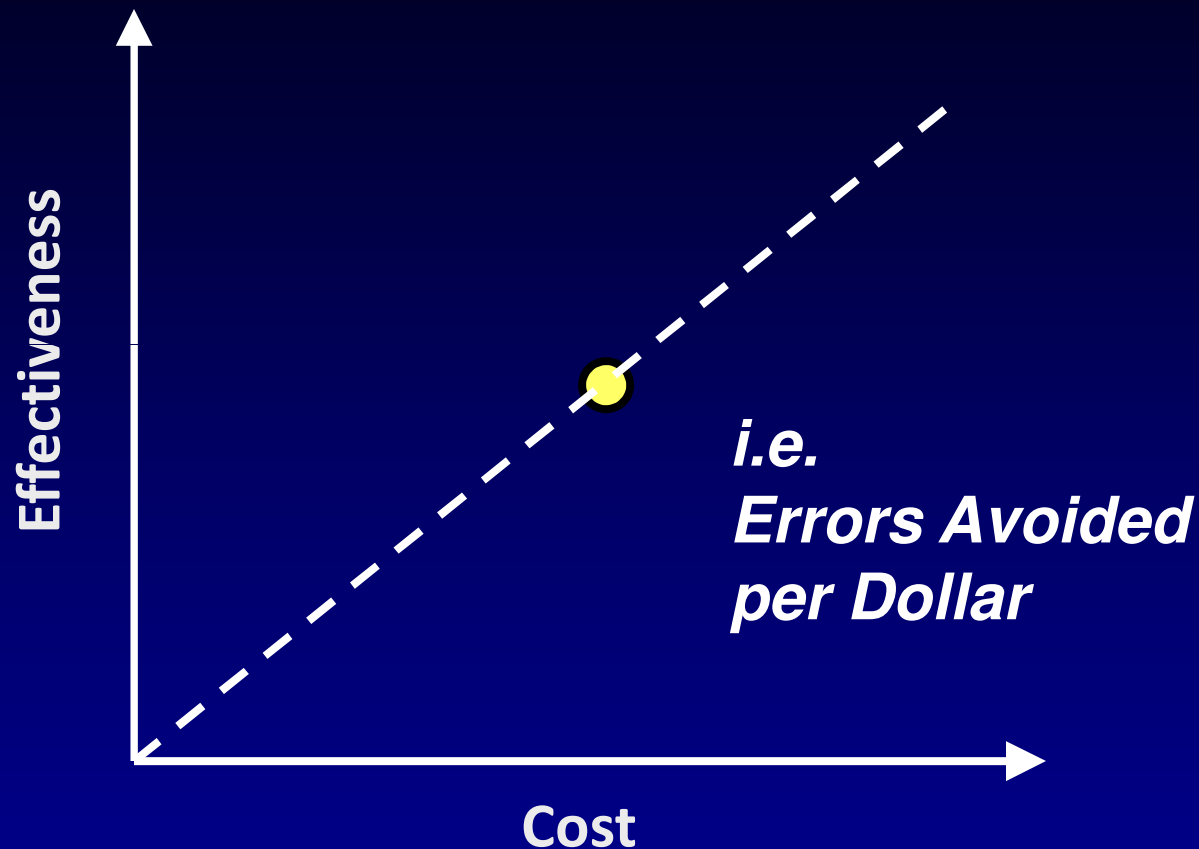
# A. Trade-Off: Definition

- *We Can Do It:*
  - Fast
  - Cheap
  - Right
- *Pick Two...*

# “Iron Triangle”

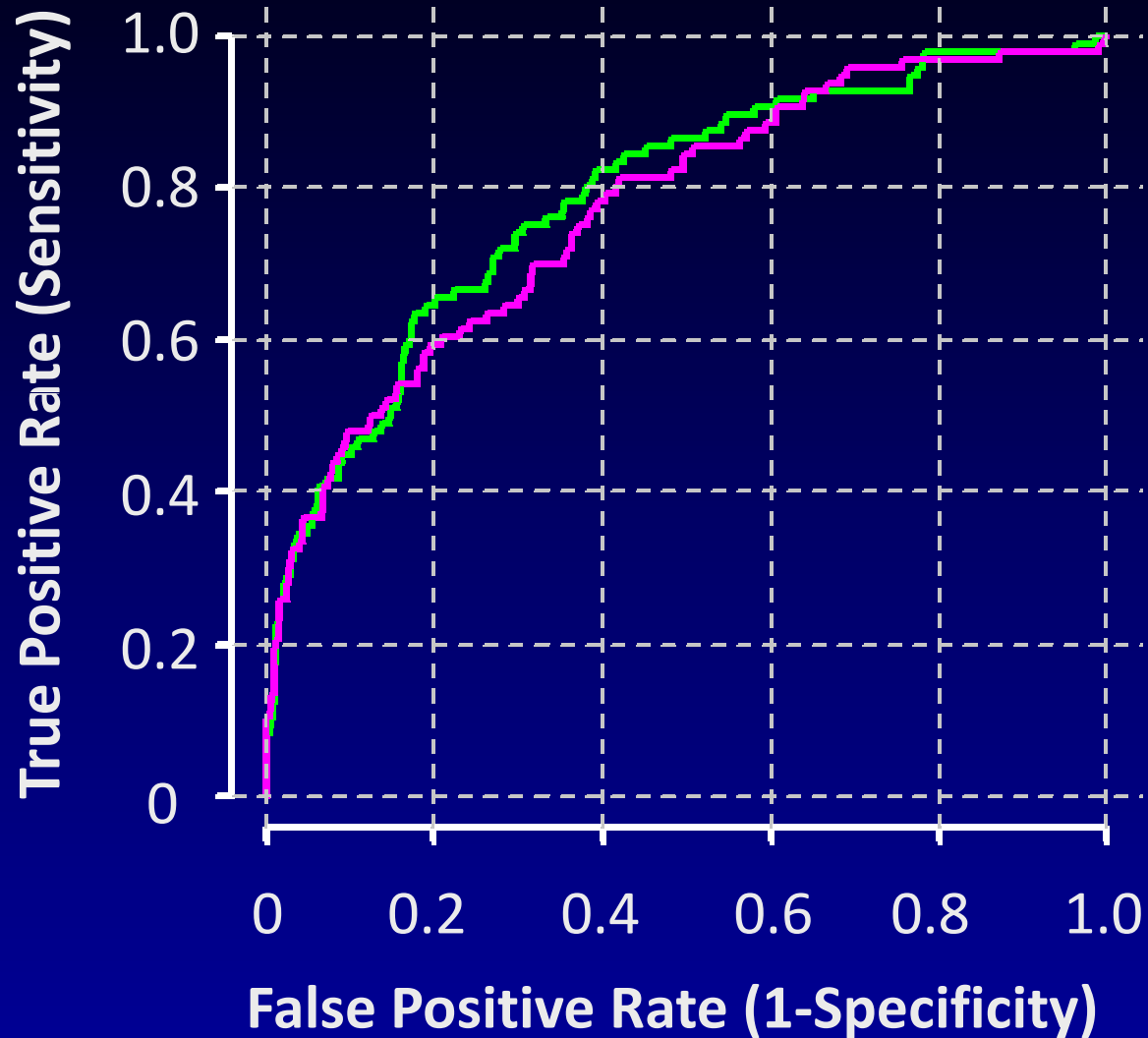


# A1. Competition: Effectiveness v. Cost

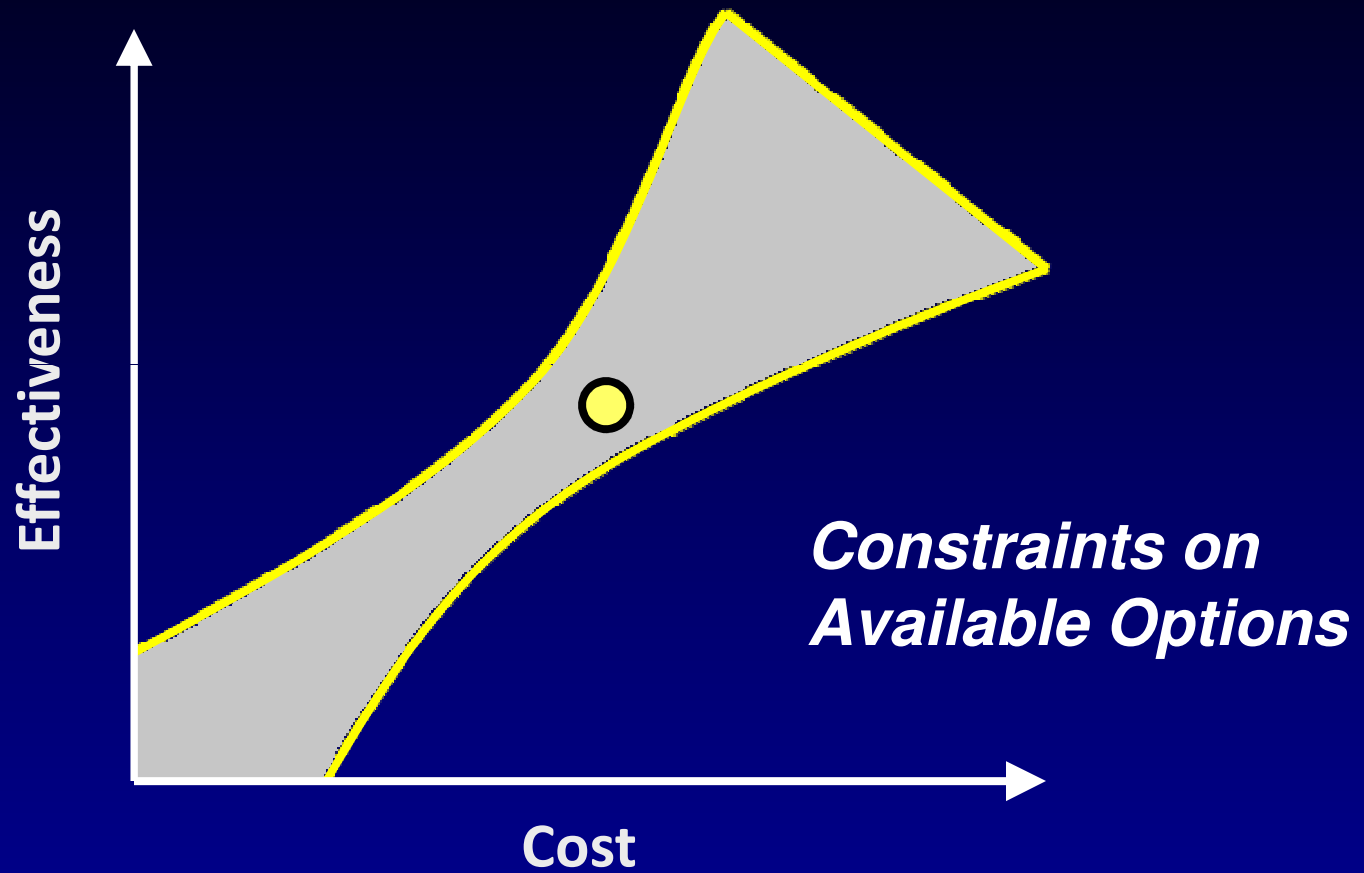


Understanding Costs and Cost-Effectiveness in Critical Care  
Report from the 2<sup>nd</sup> ATS Workshop on Outcomes Research  
*Am J Respir Crit Care Med* 165(4): 540-550, 2002.

# Sensitivity v. Specificity



# A2. Context



# What Defines Context?

- **Environment**
- **Resources**
- **Needs**
- **Culture**
  - **History**
  - **Leadership**

# VUMC: IT System Context

## Bought

- PACS
- Nurse Charting
- ADT
- Billing
- Laboratory
- Pharmacy
- Medication Admin.
- Procurement
- Trauma Registry
- Surgical ICU Registry
- ...

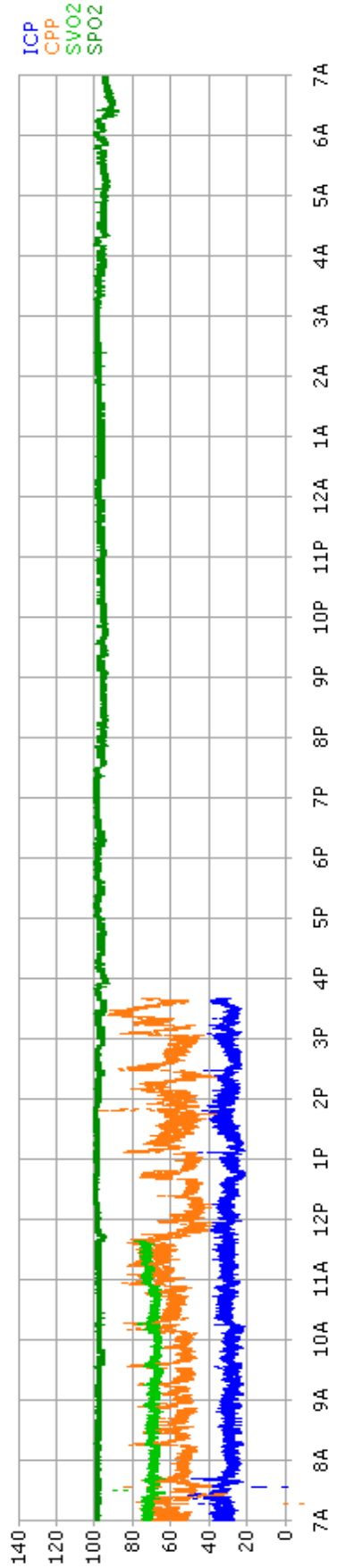
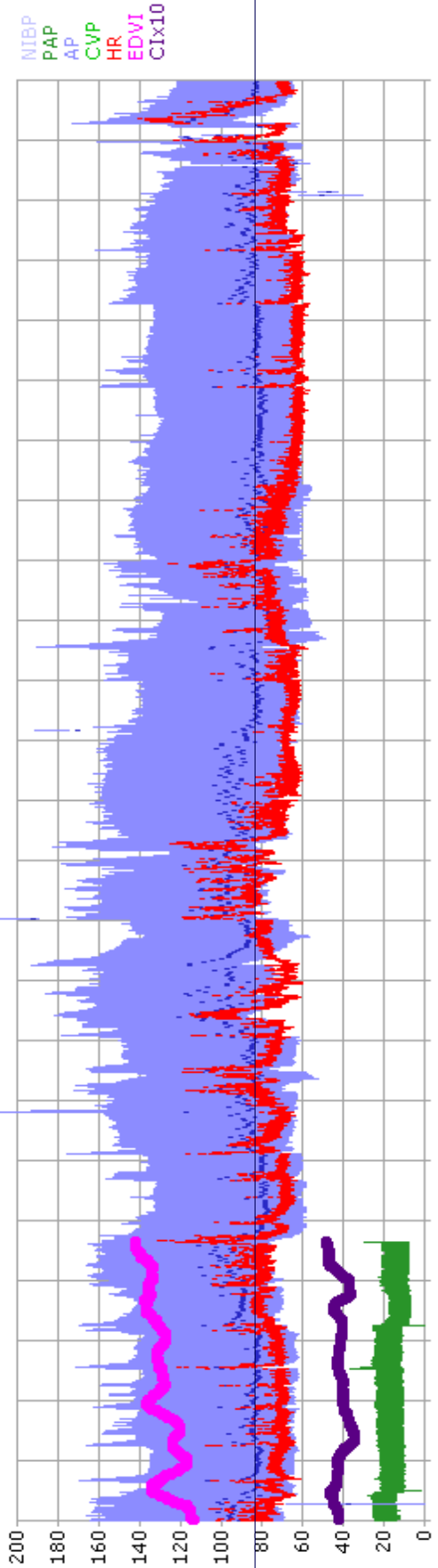
## Built

- Order Entry
- Clinical Info Repository
- Note Entry/Templates
- Dashboard
- Enterprise Data Warehouse
- Perioperative Info Mgmt.
- ICU Database
- ED Whiteboard
- SIMON
- ...

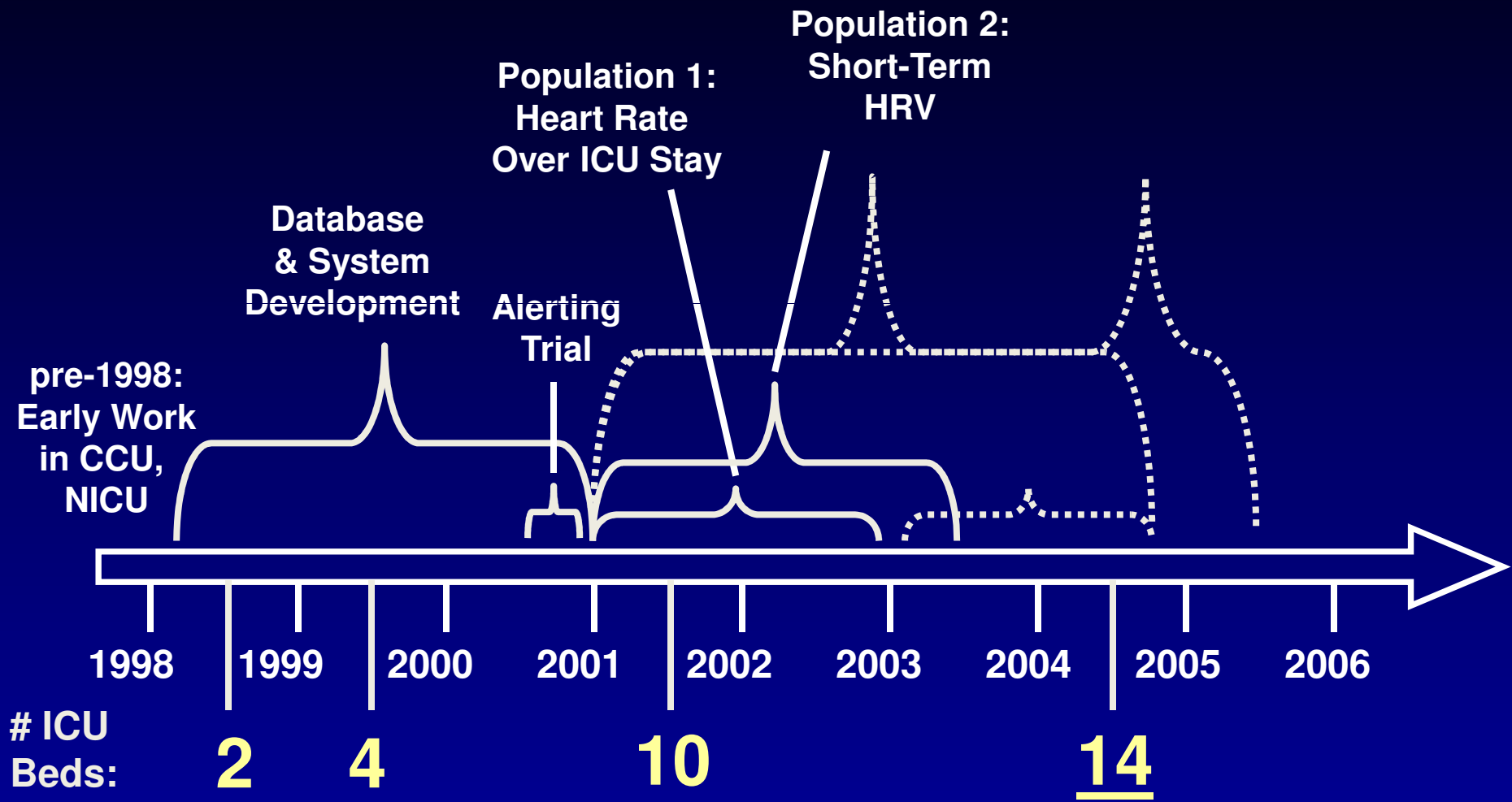
[Previous](#) [Zoom In](#) [Zoom Out](#) [Next](#) [Refresh](#) View:  Time Format:   [Custom Chart](#)

bed #: LASTNAME, Patient (medical rec. #)

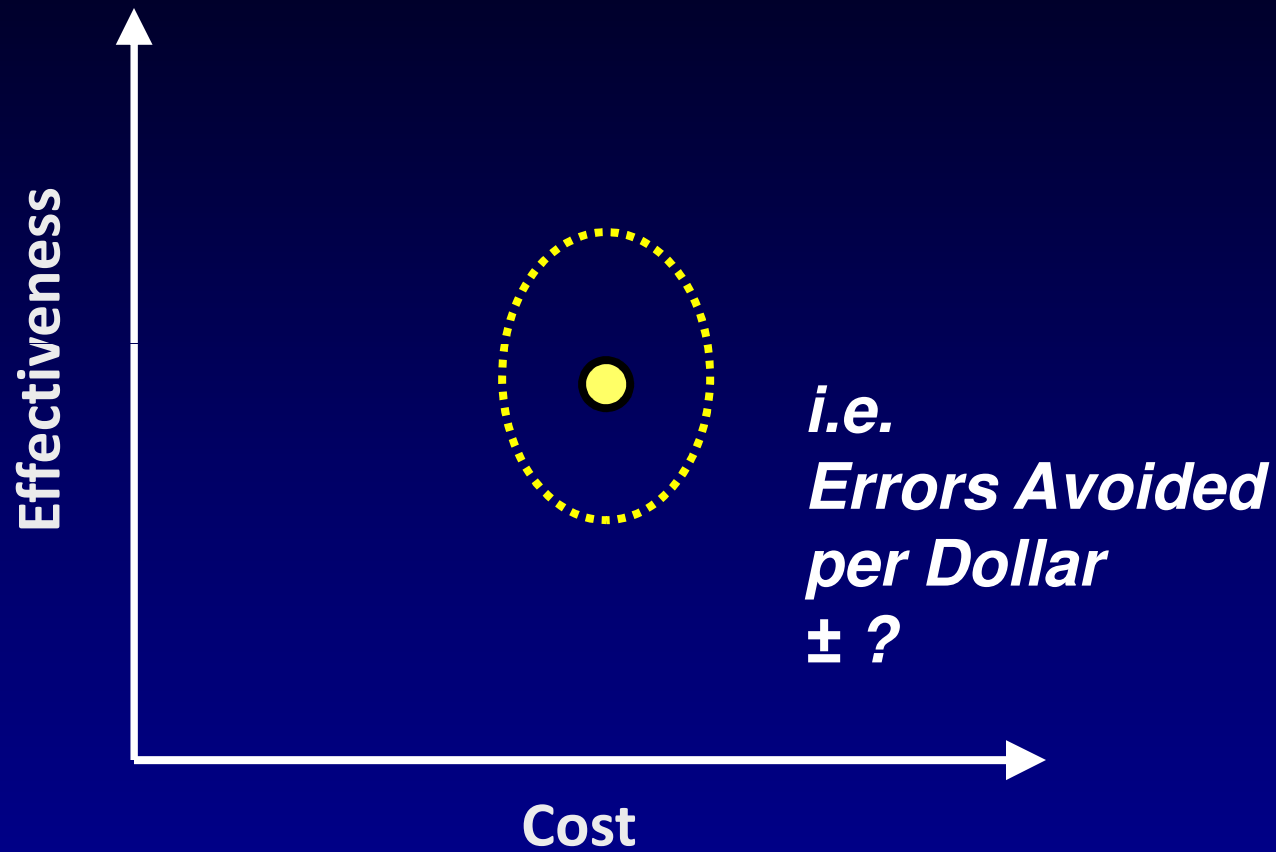
Month 2004, Wed 12, 7:00 AM - Thu 13, 7:00 AM



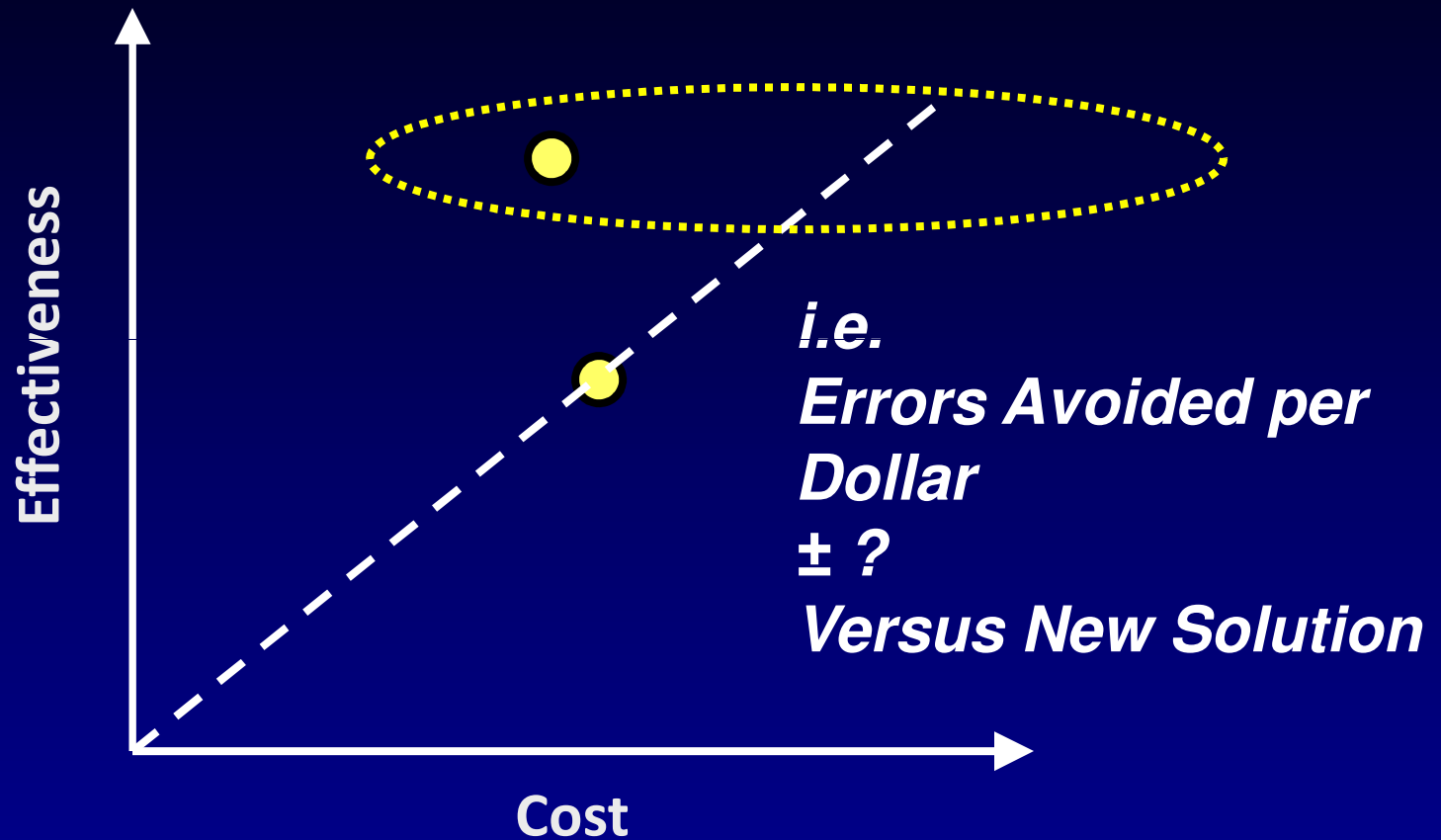
# History: SIMON Timeline



# A3. Confidence



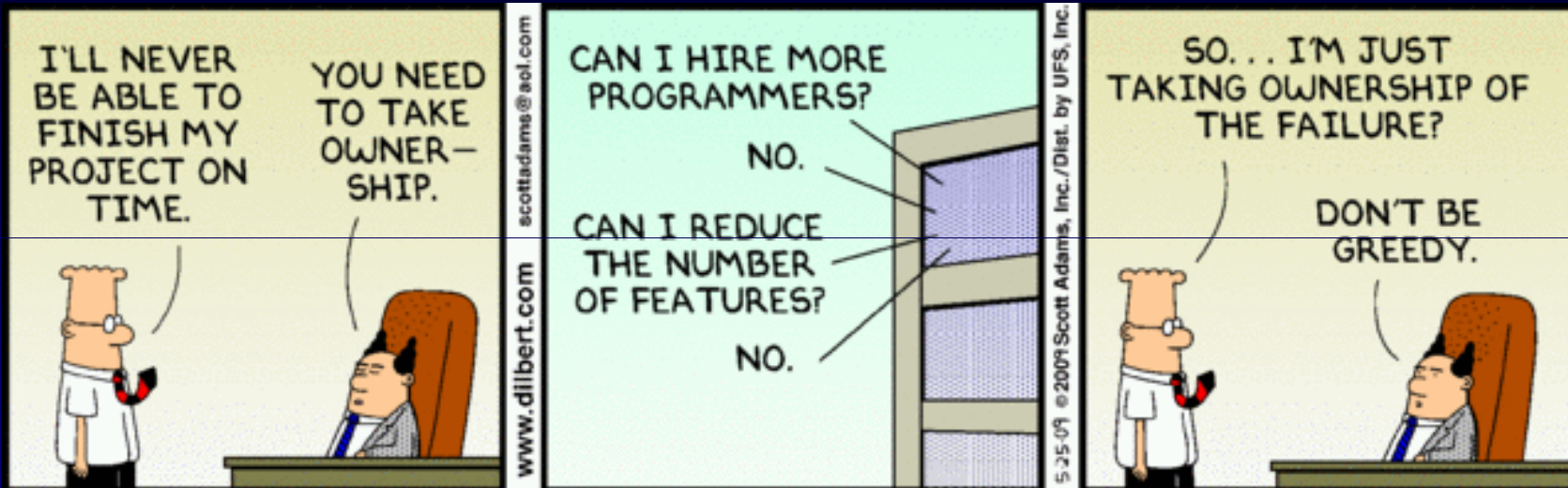
# A3. Confidence



# A. Definition Summary

- **1. “Competition” (w/ Cost Function)**
  - Design, Implementation, Maintenance
- **2. Context**
  - Trade-Offs Occur in the Real World
- **3. Confidence**
  - Can’t Know Everything With Certainty
  - Especially Important During Change

# B. Managing Trade-Offs



*dilbert.com*

# **B1. Explicate**

- **Make Trade Offs Clear, Explicit**
  - Including Uncertainty
- **End Users & Other Stakeholders**
  - Often Reluctant
  - Trade-Offs Can Be Personal

# Example: Alerting Trial

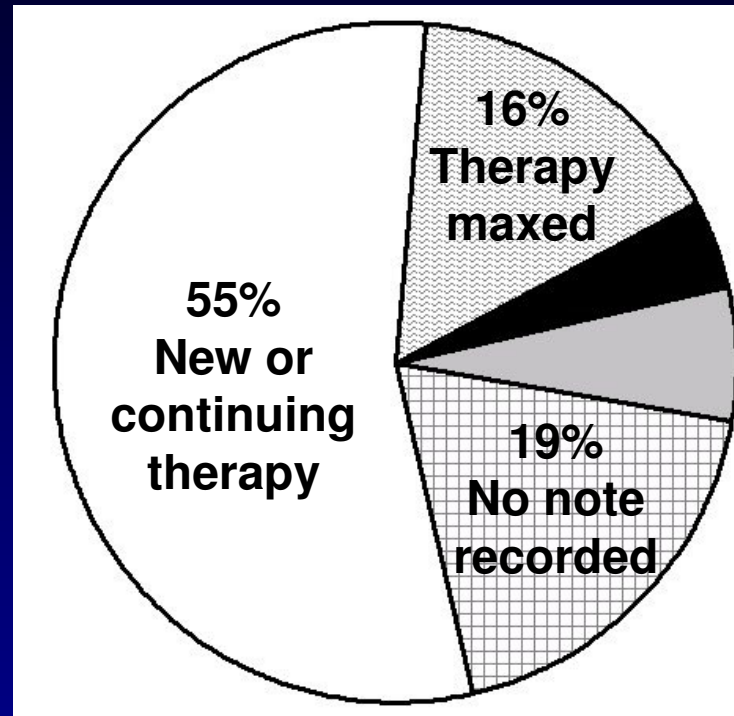
- Nurse Practitioners
  - Document Every Alert
  - Free Text
  - 24/7
- 6 Month Period
  - 530 Alerts
  - 14 Patients
  - 2280 Hours of Data

A green-tinted screenshot of a text message alert. The text reads: "From: Simon bed 05", "Subj: CPP &lt; 60 (and ICP &gt; 25) for 15 min. at 15:31 ."



# Example: Alerting Trial

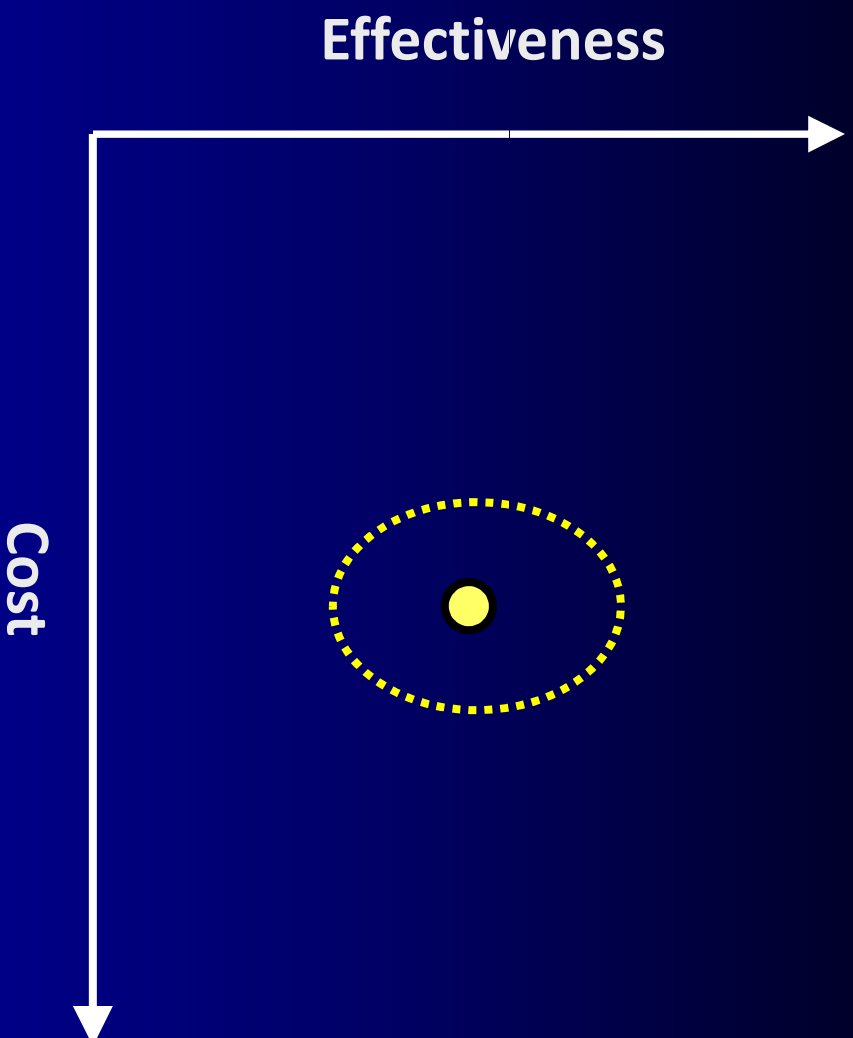
- Most notes referenced therapy
- Many “see previous note”
- Two of disbelief



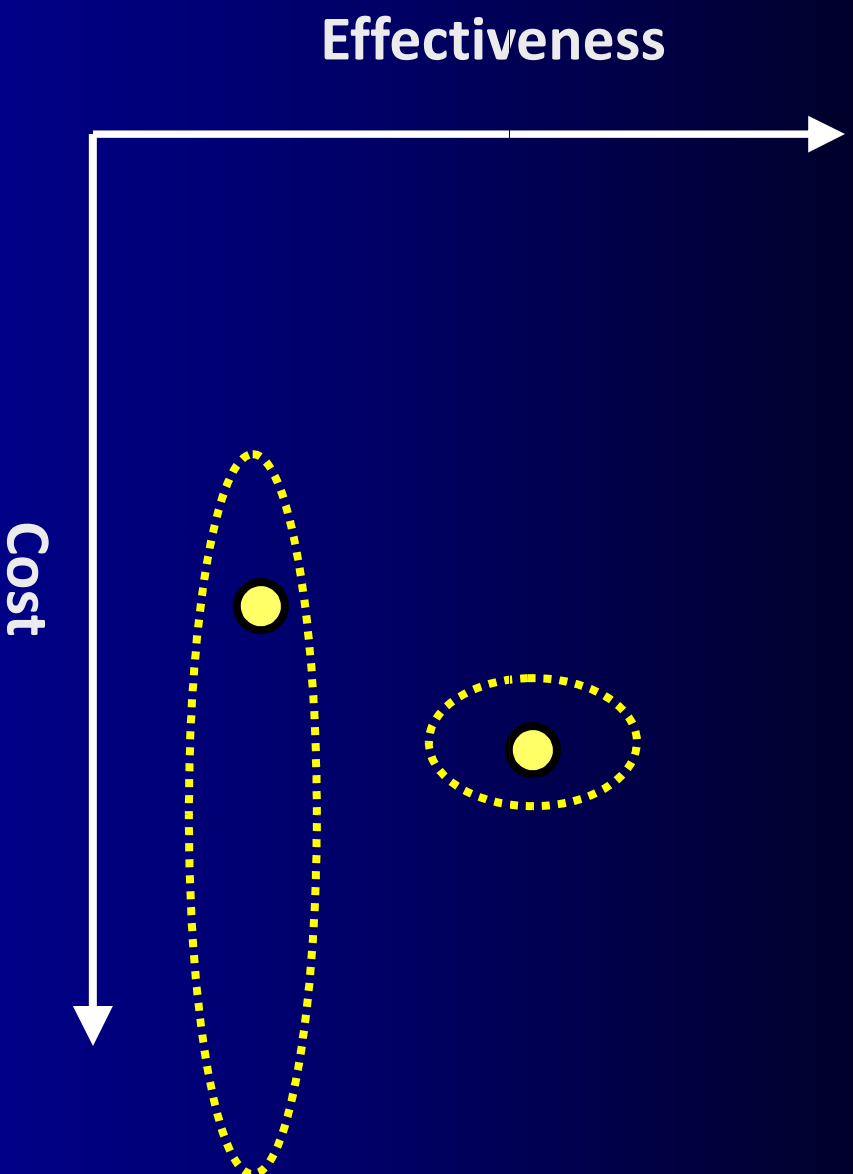
4%  
No therapeutic  
action needed

6%  
Other

# B1. Explicate



# B1. Explicate



# Explicate: What Helps

- **Definite Time Horizon**
  - 6 Months
- **Acknowledge Uncertainty**
  - Both Where We Are
  - And Proposed Solution
- **People Are Worried About Their Own Time**
  - It's Always Personal
  - Allow Flexibility
- **Consider the Confidence Bounds**

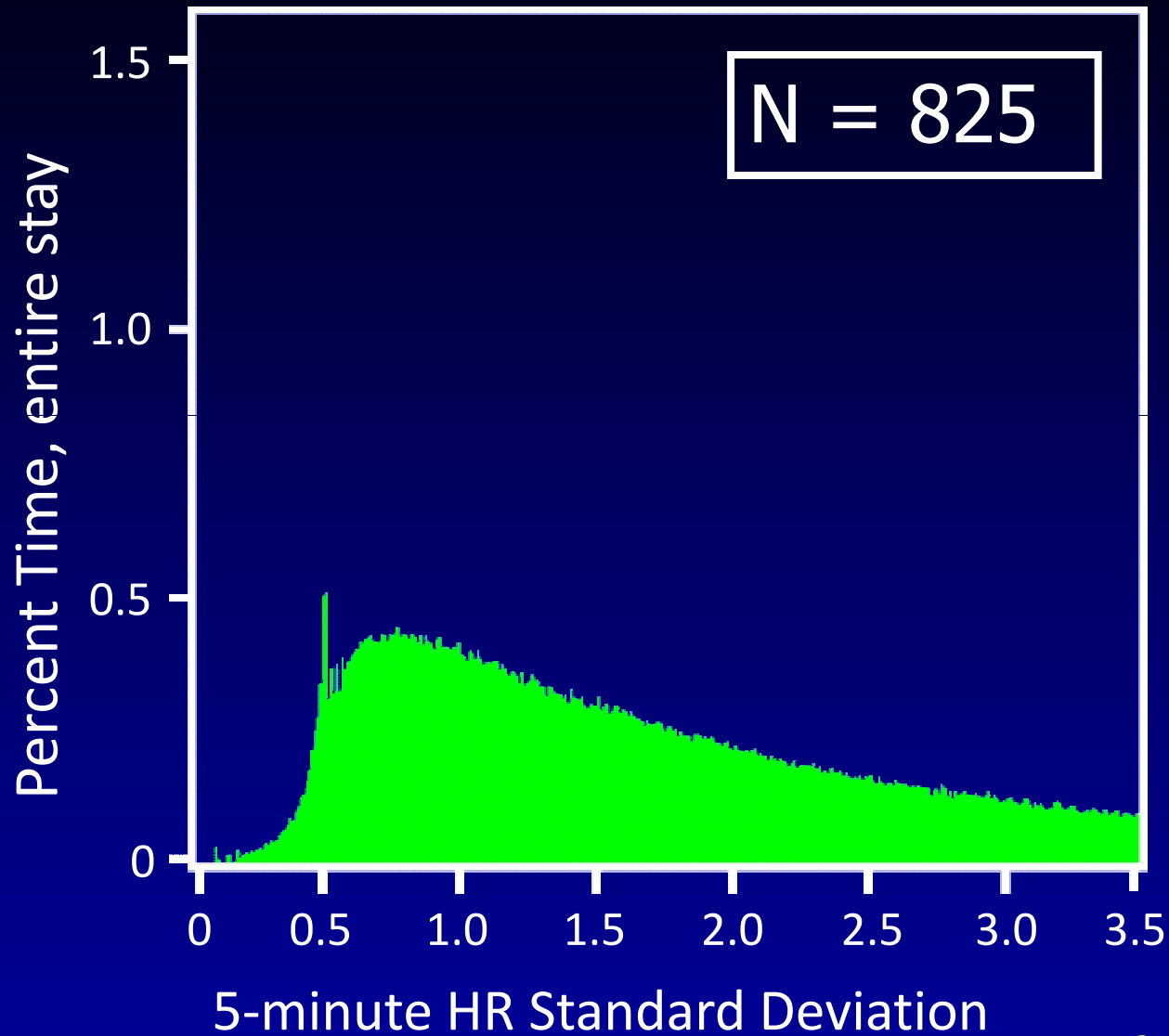
## B2. Evaluate

- **Retrospective Analysis of Trade-Offs**
  - Distinct From Project Outcomes
  - After Realizing Consequences
  - But Before Significant Context Change
- **Evaluate Decision-Making Process**
  - Detect Unintended Consequences
  - Usually Little Incentive to Do So
    - At Best: “I Told You So”
    - At Worst: “Ooops...”

# **SIMON Sampling Rate Trade-Off**

- **Problem**
  - Limited Computational Resources
  - 1Hz Data, Multi-Channel, 14 Beds, *Real-Time*
- **Solution**
  - Down-Sampling (Fixed Rate and/or Adaptive)
  - 0.20 to 1 Hz
- **Trade-Off:**
  - Faster Development, Lower Cost, Real-Time Alert Performance  
vs.
  - Complete Data

# Short-Term HRV - Survival

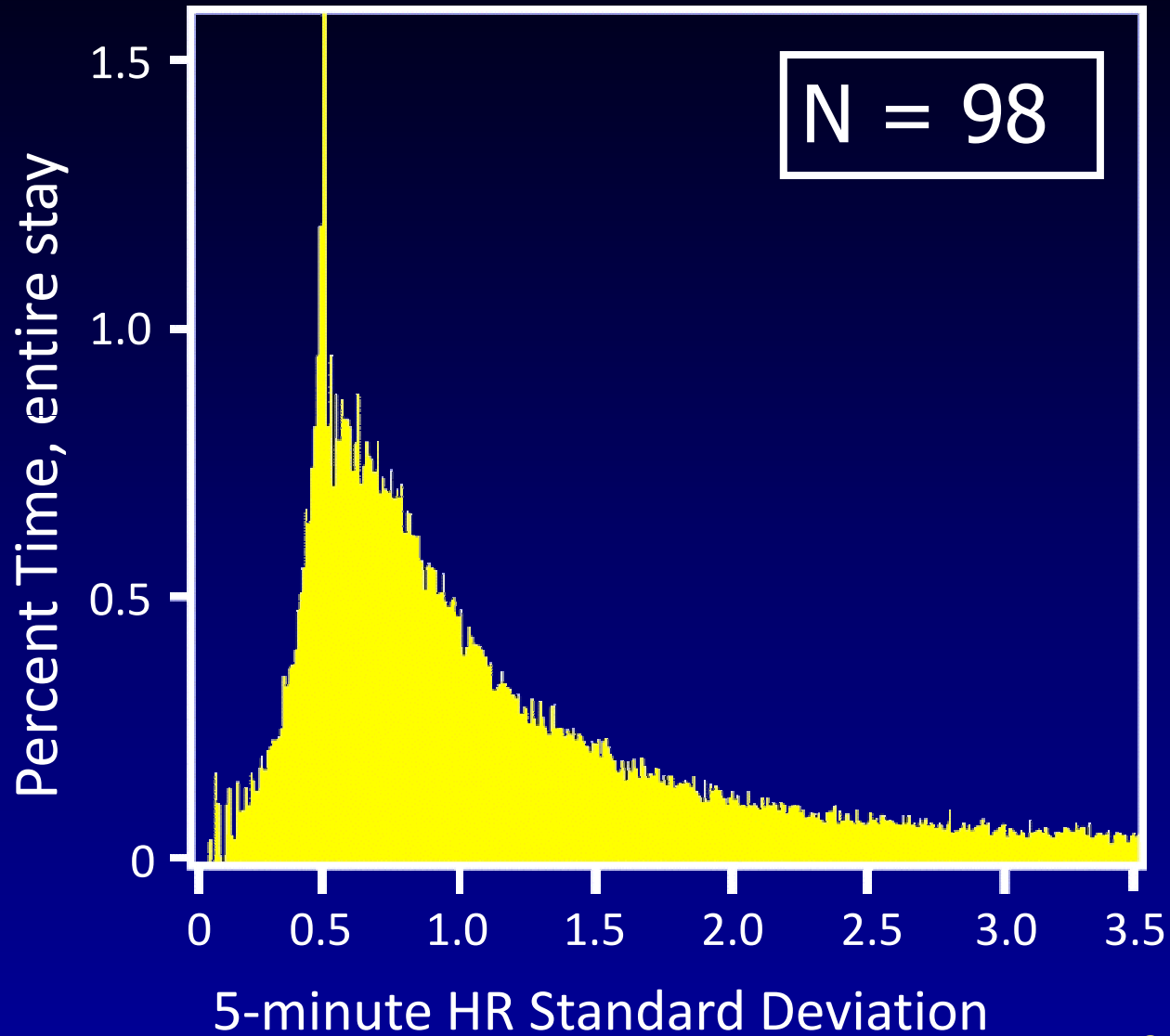


Grogan et. al.

Ann Surg

240(3):547-54, 2004

# Short-Term HRV - Death

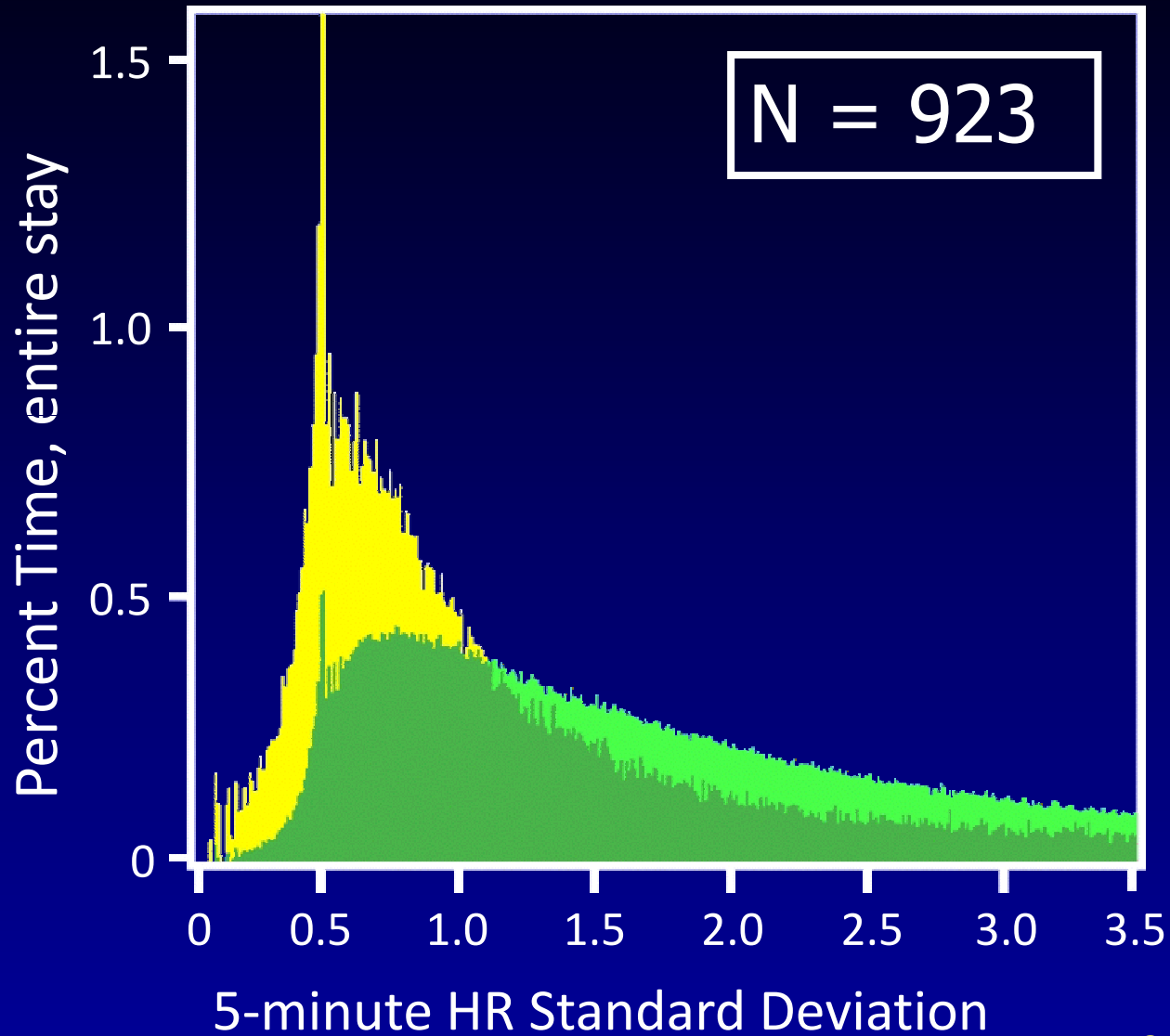


Grogan et. al.

Ann Surg

240(3):547-54, 2004

# Short-Term HRV - Combined



Grogan et. al.

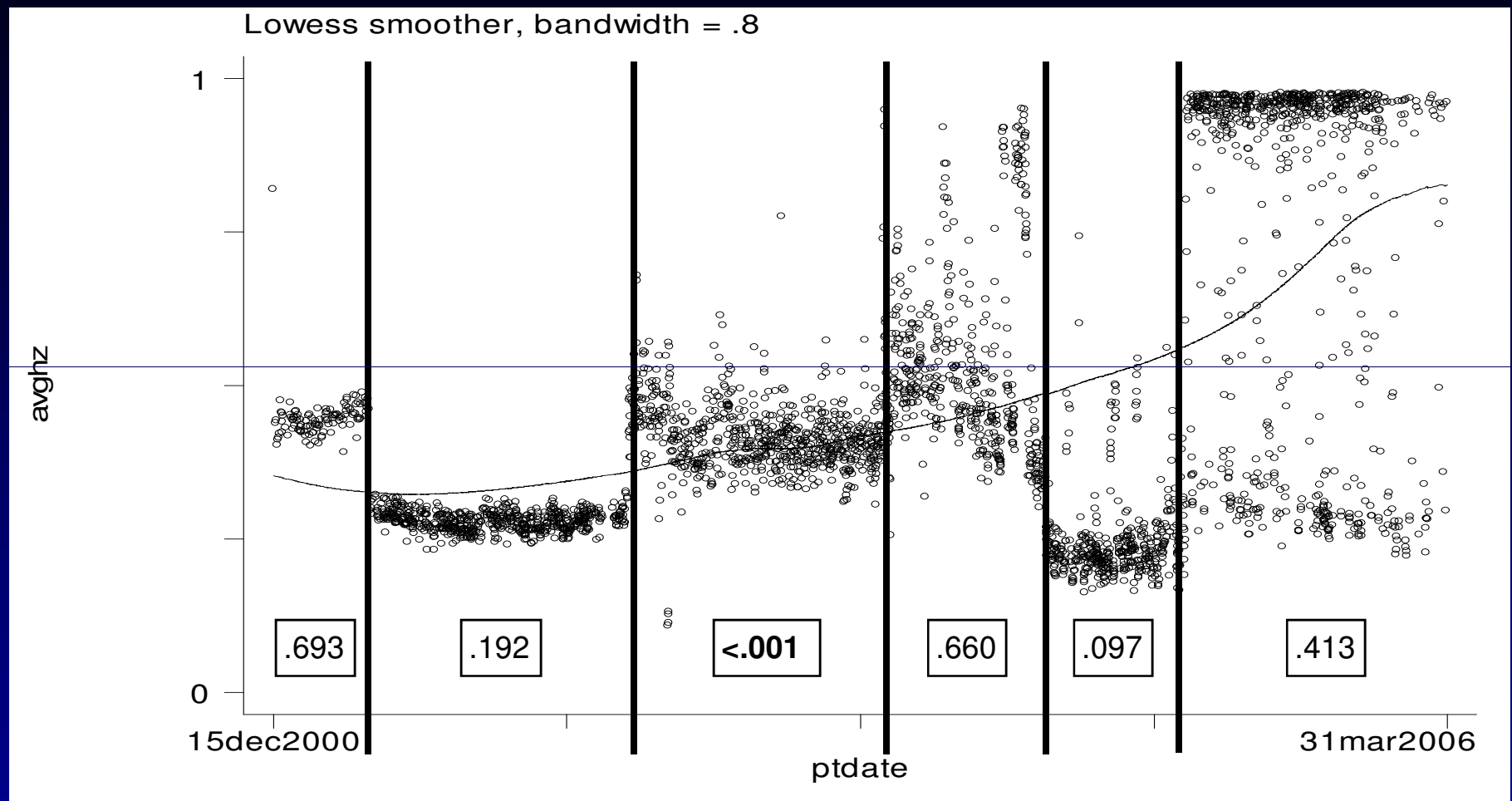
Ann Surg

240(3):547-54, 2004

# **SIMON Sampling Rate Trade-Off**

- **Standard Deviation is Biased Estimate  
(lower frequency → lower SD)**
- **Data Density is Related to Patient Acuity  
(sicker patients → more signals → less data)**
- **To What Extent Does this Impact HRSD5  
Associations with Mortality?**

# Sampling Rate Over Time



**Overall Sampling Rate & Mortality,  $P = .019$**

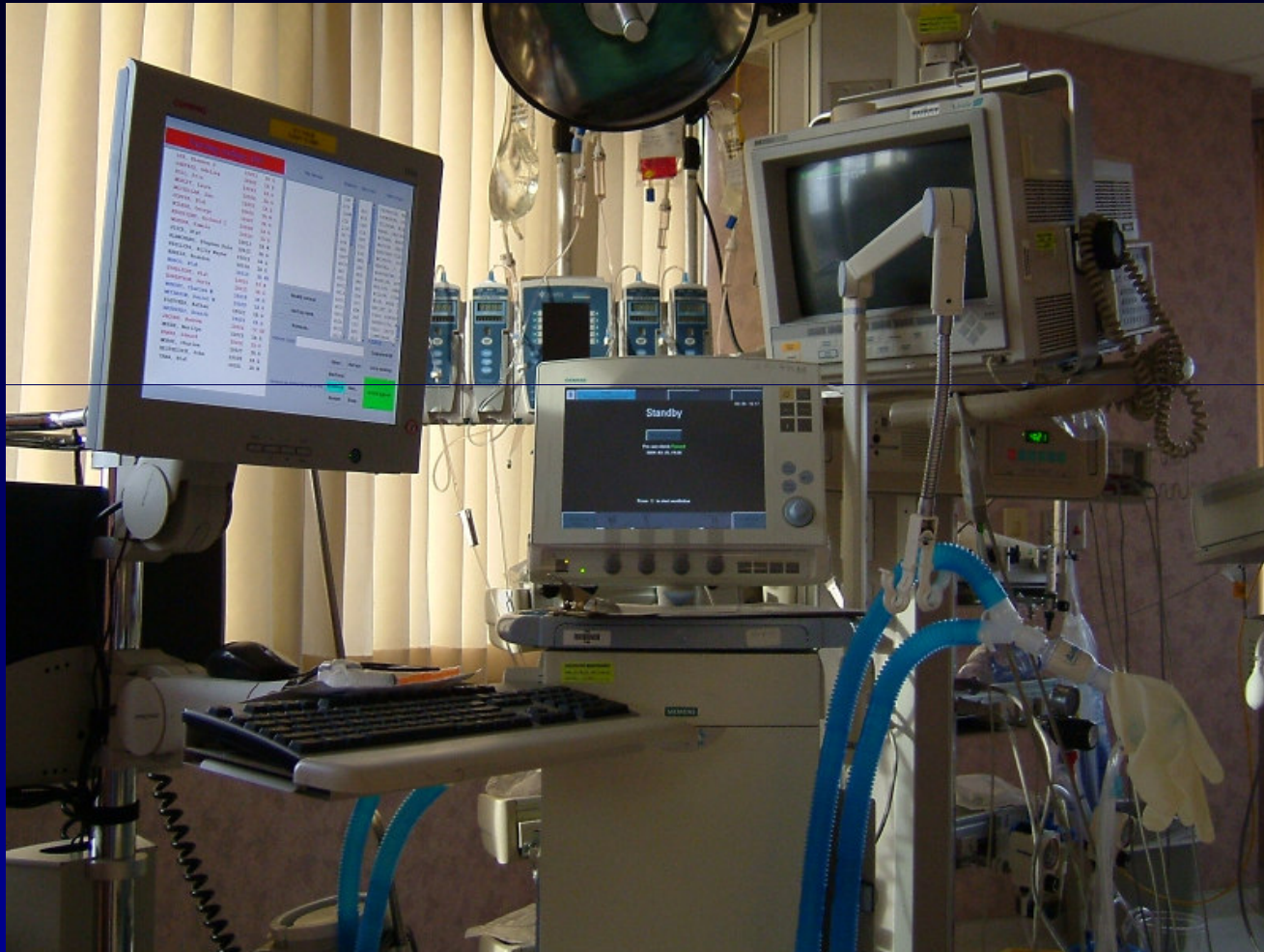
## B3. Revisit

- **When Context Changes**
  - Needs, Resources
- **Usually Pretty Clear**
- **Example: Time Precision**
  - Integer Vital Signs
  - Waveform Data
- **Much Easier w/ *A Record of Trade-Offs***

## B. Management: Summary

- **1. Explicate: Make Trade-Offs Explicit (and Personalized)**
  - Ex: Intracranial Pressure Alerting Trial
  - Time & Time Horizons Are Crucial
- **2. Evaluate: Were You “Right?”**
  - Ex: Sampling Rate
- **3. Revisit: Have Things Changed?**
  - Ex: Temporal Resolution and Precision

# C. Critical Care DSS/Automation



**What  
Makes  
This  
Domain  
Unique?**

# Sensitivity - Specificity

- **Many Tests, Alarm Algorithms**
- **Many Recipients**
- **Huge Range**
  - **~85% False-Positive Monitor Alarms**
  - **<~1% For Most Lab Tests**

# General v. Special-Purpose

- **Should There Be More “Dedicated” Critical Care Info Systems?**
  - VISICU
- **Customizable ≠ Special-Purpose**
- **Issues:**
  - Staff Rotations
  - Profitability
  - Efficiency
  - Top-Down v. Bottom-Up

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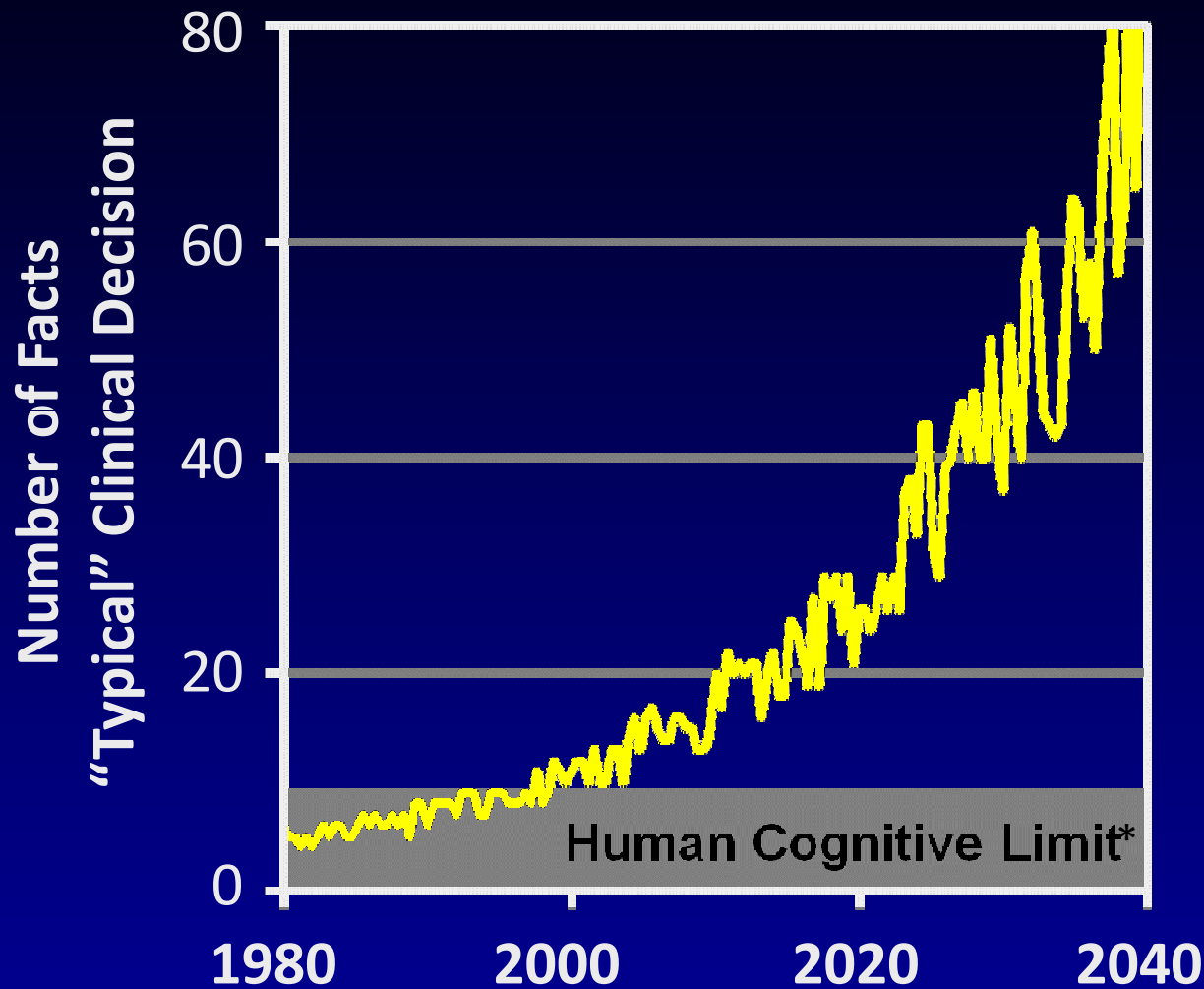
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# Other Examples

- **Domain v. Technical Expertise**
- **Tightly Managed [Regulated] v. Ad Hoc**
  - **Proprietary v. Open**
- **Short v. Long-Term Horizon**
- **Detecting Errors:**
  - Omission v. Commission**
- **Information Trade-Offs**

# Information: Ultimate Trade-Off?



\*Miller G  
*Psychological Review*  
63:81-97. 1956

# Final Thoughts

*Some see the glass as half full.*

*Some see the glass as half empty.*

*I see a glass that's twice as big as it needs to be.*

-George Carlin

- Subjective, Relative Nature of Trade-Offs
- Need to Sometimes Think Differently
- Don't Take a "Big Glass" for Granted

Thank You

