USING SOFTWARE ENGINEERING TO HELP REDUCE MEDICAL ERRORS

Lori A. Clarke

College of Information and Computer Sciences

University of Massachusetts Amherst

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How did I get here?

- BA, mathematics, University of Rochester
- Programmer, U of R Medical School
- PhD, CS, University of Colorado Boulder
- Faculty, University of Massachusetts Amherst

Research Focus

- Most of my career has focused on Software Engineering Research
  - How to make software systems more reliable
    - Automated testing techniques
    - Automated reasoning techniques
    - Better approaches for representing requirements
  - How to better support developers
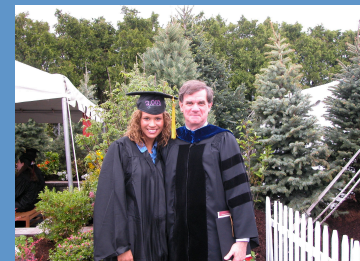   - Object management
    - Software architecture

Software Engineering

- A wonderful, rich area for research

- Systems are always getting more complex
  - Sequential to distributed
  - Internet-based to cloud-based, client-server

- Safety and security concerns are increasing

- But one day...

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Medical Errors

A crisis in healthcare!

Could techniques developed for analyzing software systems be effectively applied to medical procedures to reduce errors and improve outcomes?

Nurse Beth Henneman

Question

- Leading causes of death in the US?
  - Heart disease   ~611,000
  - Cancer   ~584,000
  - Medical Errors   ~440,000
  - Accidents   ~130,000

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What this means?

If 3 B747 airplanes crashed everyday, for an entire year, it would be equivalent to the number of deaths due to medical errors a year

Medical Procedures

- 2009 National Research Council Report
  - *"persistent problems do not reflect incompetence on the part of health care professionals - rather, they are a consequence of the **inherent intellectual complexity** of health care taken as a whole and*
  - ***a medical care environment that has not been adequately structured to help clinicians avoid mistakes or to systematically improve their decision making and practice.***"
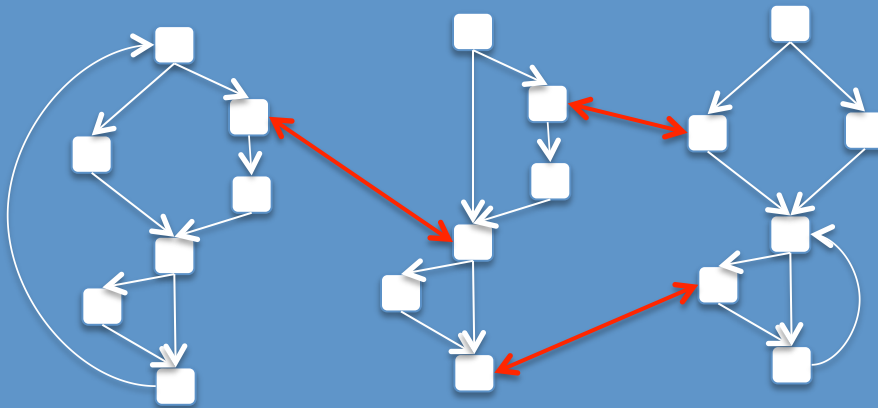
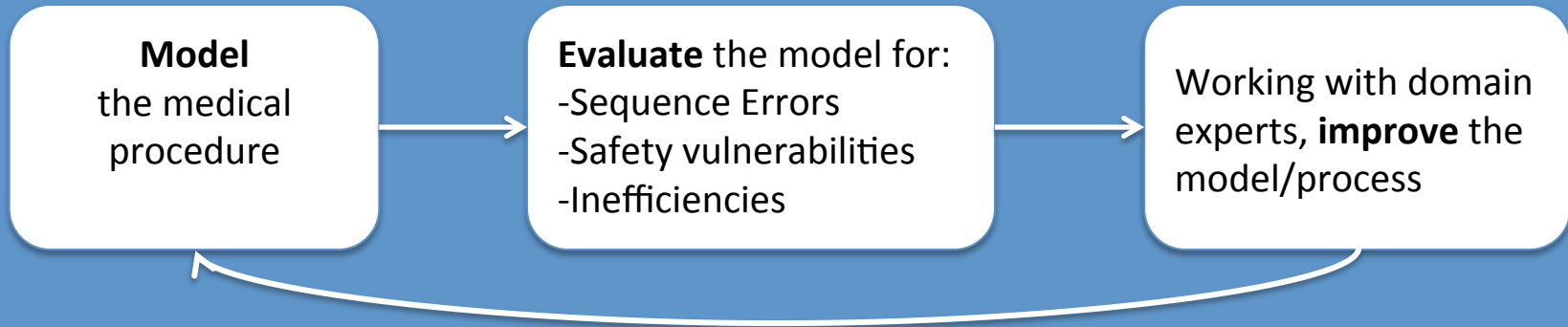# Medical Procedures Are Complex, Distributed Systems

- ***Human- Intensive Systems*** that involve coordination among software applications, hardware devices, and human performers
  - Humans are central decision makers, but
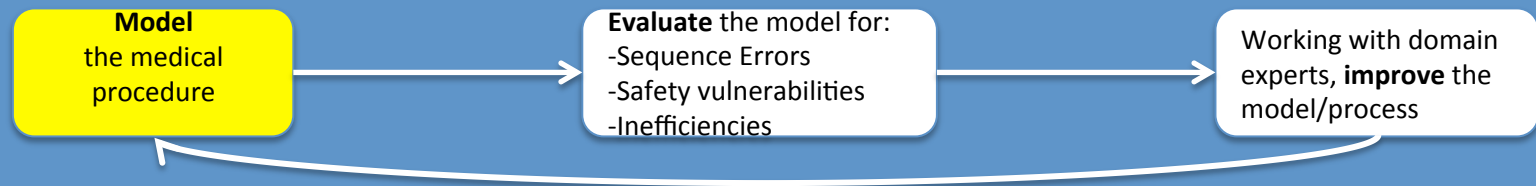 - Humans may be exhausted or distracted and may make mistakes

Our approach

Model
the medical procedure

→

Evaluate the model for:
-Sequence Errors
-Safety vulnerabilities
-Inefficiencies

→

Working with domain experts, **improve** the model/process

Model
the medical procedure

Evaluate the model for:
-Sequence Errors
-Safety vulnerabilities
-Inefficiencies

Working with domain experts, **improve** the model/process

Little-JIL graphical view

Single-Unit Transfusion Process

Suspected Transfusion Reaction

BedsideChecks

Prepare for Infusion

VerifyPatient ID

ProductVerification

AdministerUnit Blood Product

Stop Transfusion

Handle Adverse Reaction

Begin Transfusion

Assess Patient

Post Transfusion Work

***Exception:
Adverse Reaction**

Discard Transfusion Materials

Record Infusion Info

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Model	Evaluate the model for:	Working with domain
the medical	-Sequence Errors	experts, **improve** the
procedure	-Safety vulnerabilities	model/process
	-Inefficiencies	

Textual hyperlinked view

Perform Blood Specimen Obtaining Process
The following agent may be involved in this (sub)process: *nurse*

 The following may be utilized in this step: *specimen-container, label, agent: ma/nurse, specimen-collection-equipment*.

 To "perform Blood Specimen Obtaining process", the following need to be done in the listed order:

        determine the need for blood test
        order test(s)
        recognize some tests have been ordered
        collect labels
        gather equipment for specimen collection
        walk to patient
        verify the correct patient to get specimen
        obtain and label specimen
        send blood specimen to lab

E If *Info Not Match*, report this error.
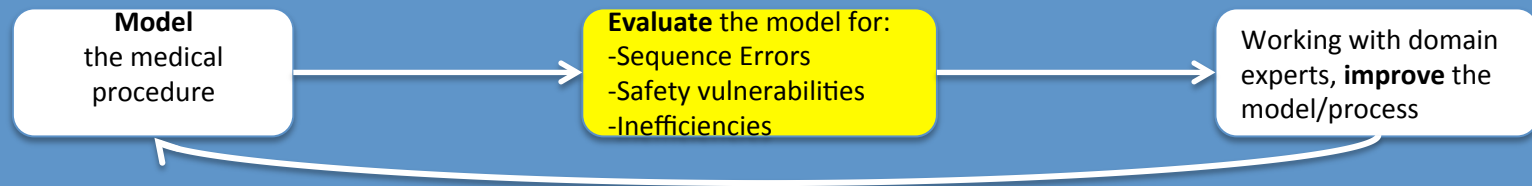**E** If *Patient Has Multiple ID Bands*, report this error.
E If *Info Not Found*, report this error.
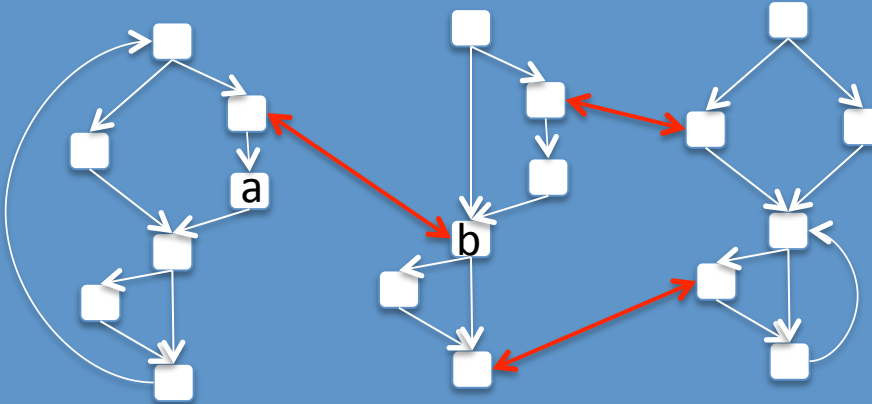**E** If *Patient Has No ID Band*, report this error.

Model
the medical procedure

Evaluate the model for:
-Sequence Errors
-Safety vulnerabilities
-Inefficiencies

Working with domain experts, **improve** the model/process
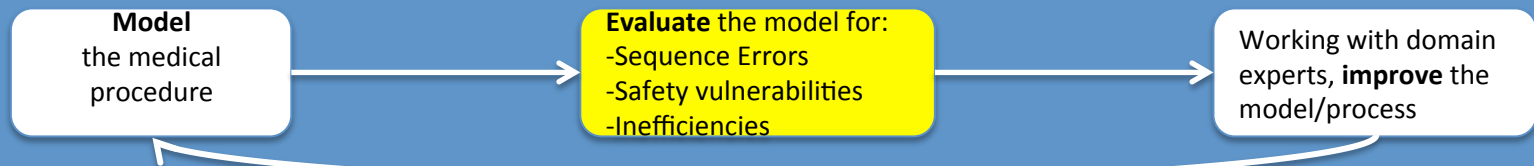
Sequence errors
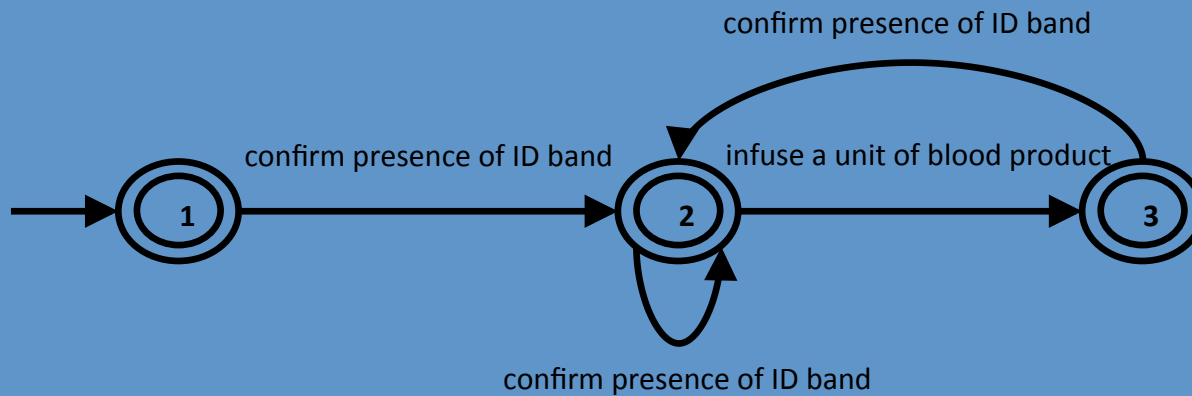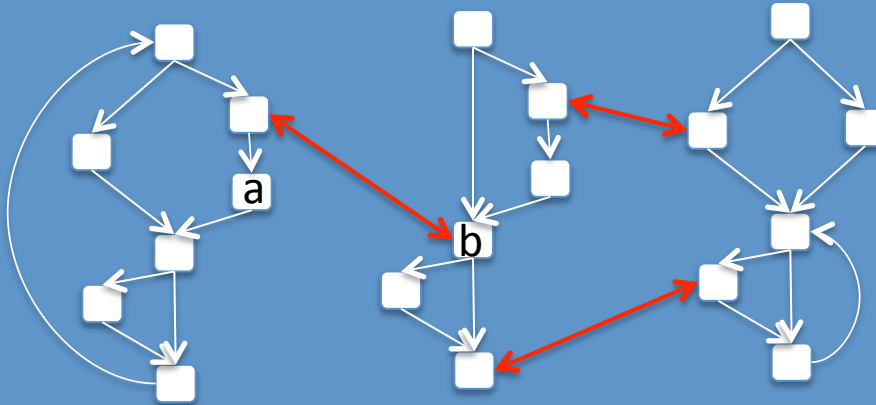

Can event a happen before event b?

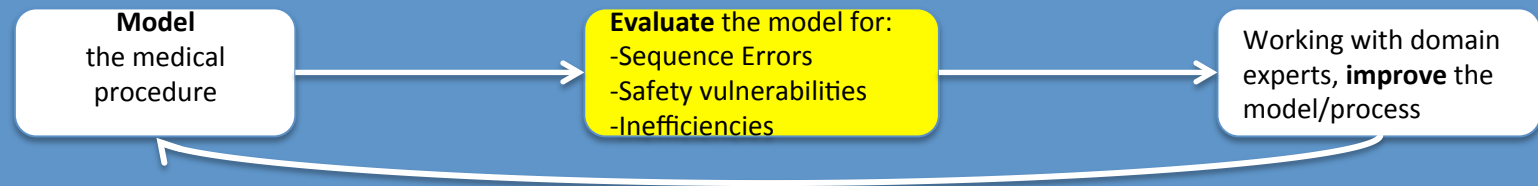Use model checking techniques to verify if the property holds or provide counter example traces

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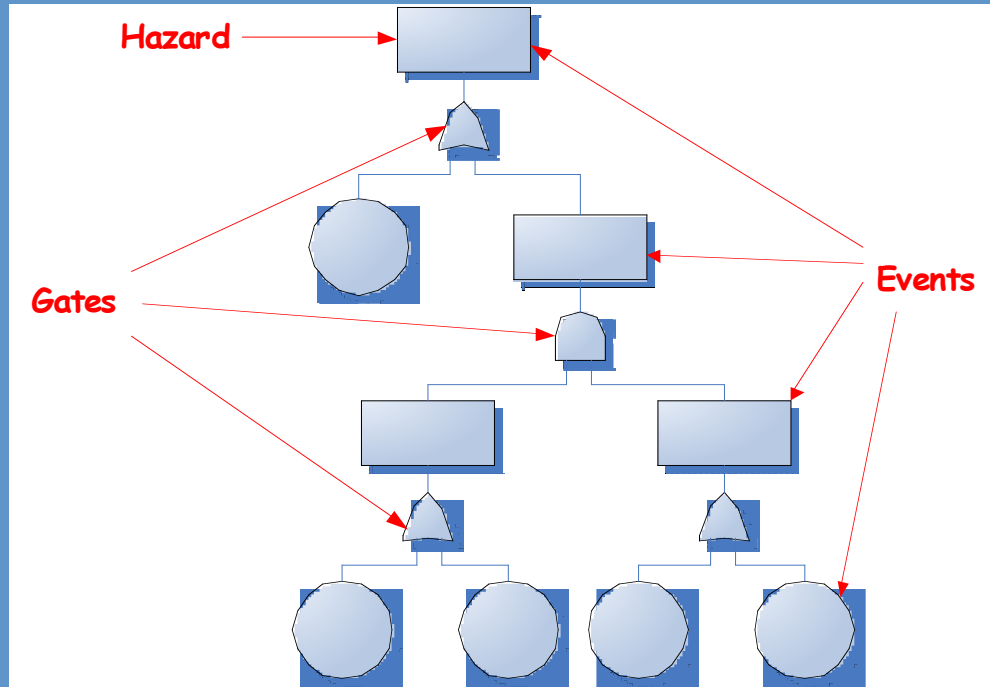Women

Sequence errors: representing properties

a

b

confirm presence of ID band

confirm presence of ID band

infuse a unit of blood product

1 → 2 → 3

confirm presence of ID band

Model
the medical procedure

Evaluate the model for:
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Working with domain experts, **improve** the model/process

Safety Vulnerabilities: Fault Tree Analysis

Hazard

Gates

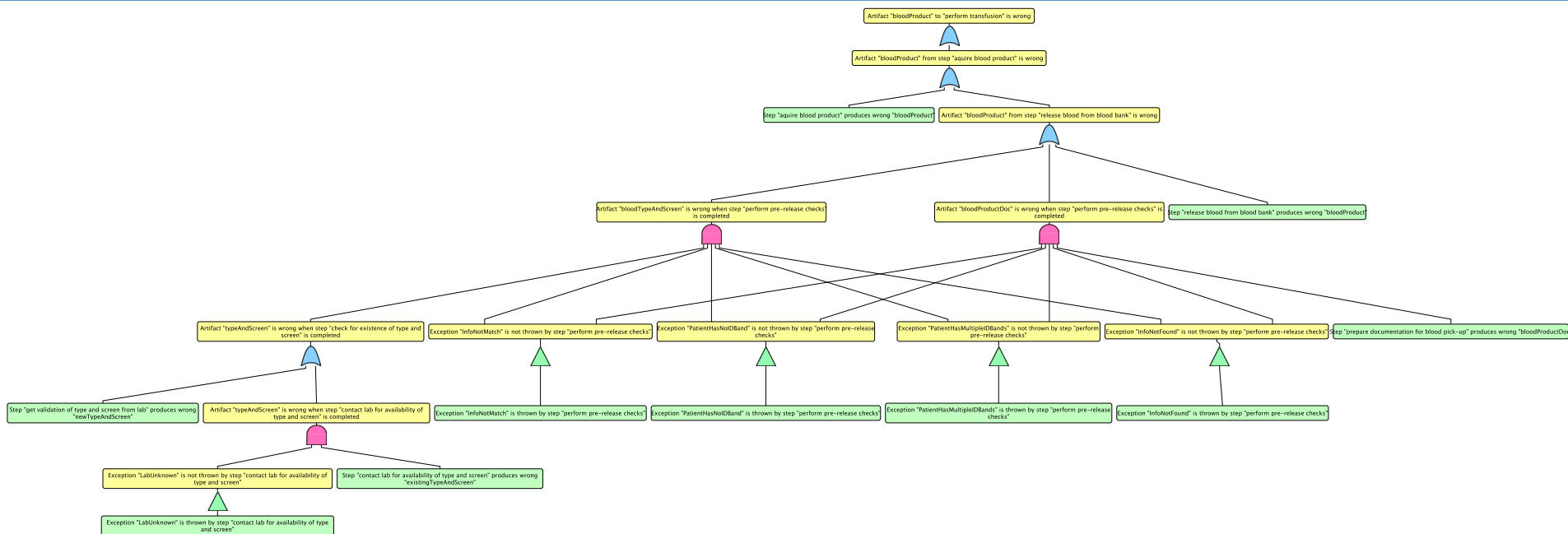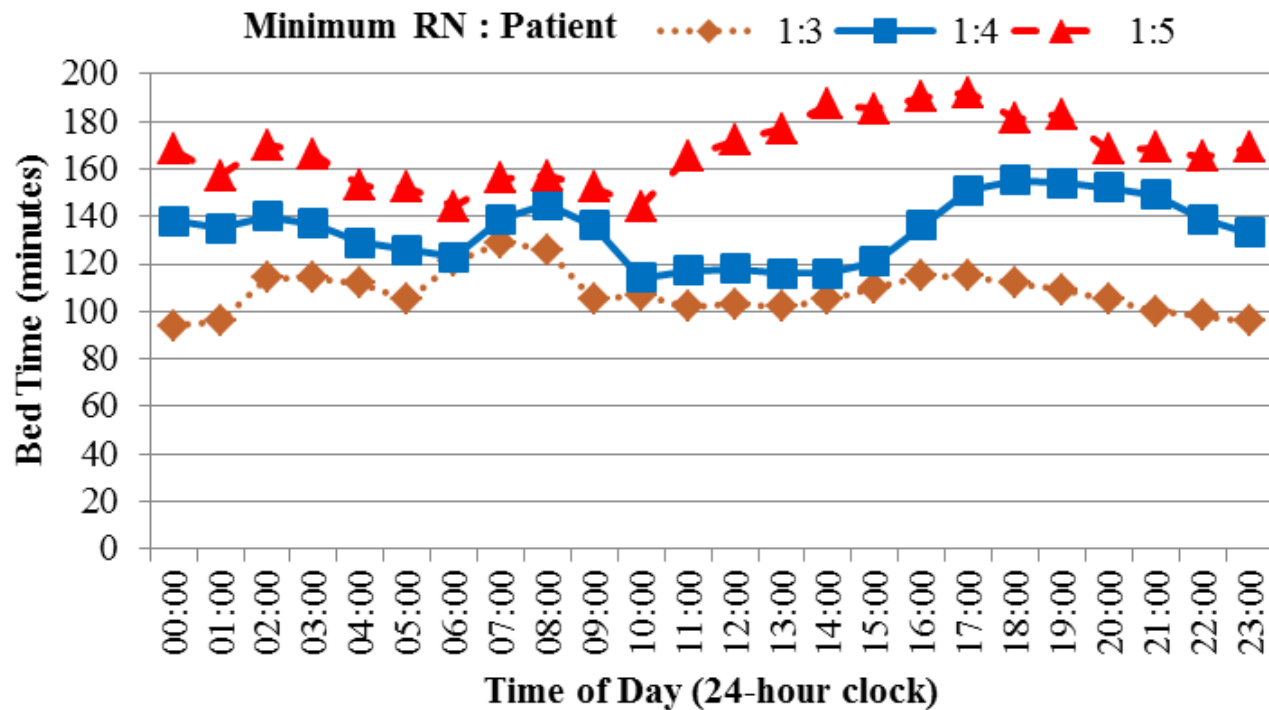Events

Safety Vulnerabilities: Fault Tree Analysis

Model
the medical procedure

Evaluate the model for:
-Sequence Errors
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Working with domain experts, **improve** the model/process

Efficiencies: Discrete Event Simulation

Results

- Mostly found problems in our models and properties

- BUT, after those problems are removed, found important errors in the processes

  - Single points of failure

  - Deadlocks

  - Use of stale data

  - Etc.

- Case studies: Blood transfusion, Emergency room flow, Cardiac surgery, Chemotherapy (saw a 70% reduction in errors that reached patients)
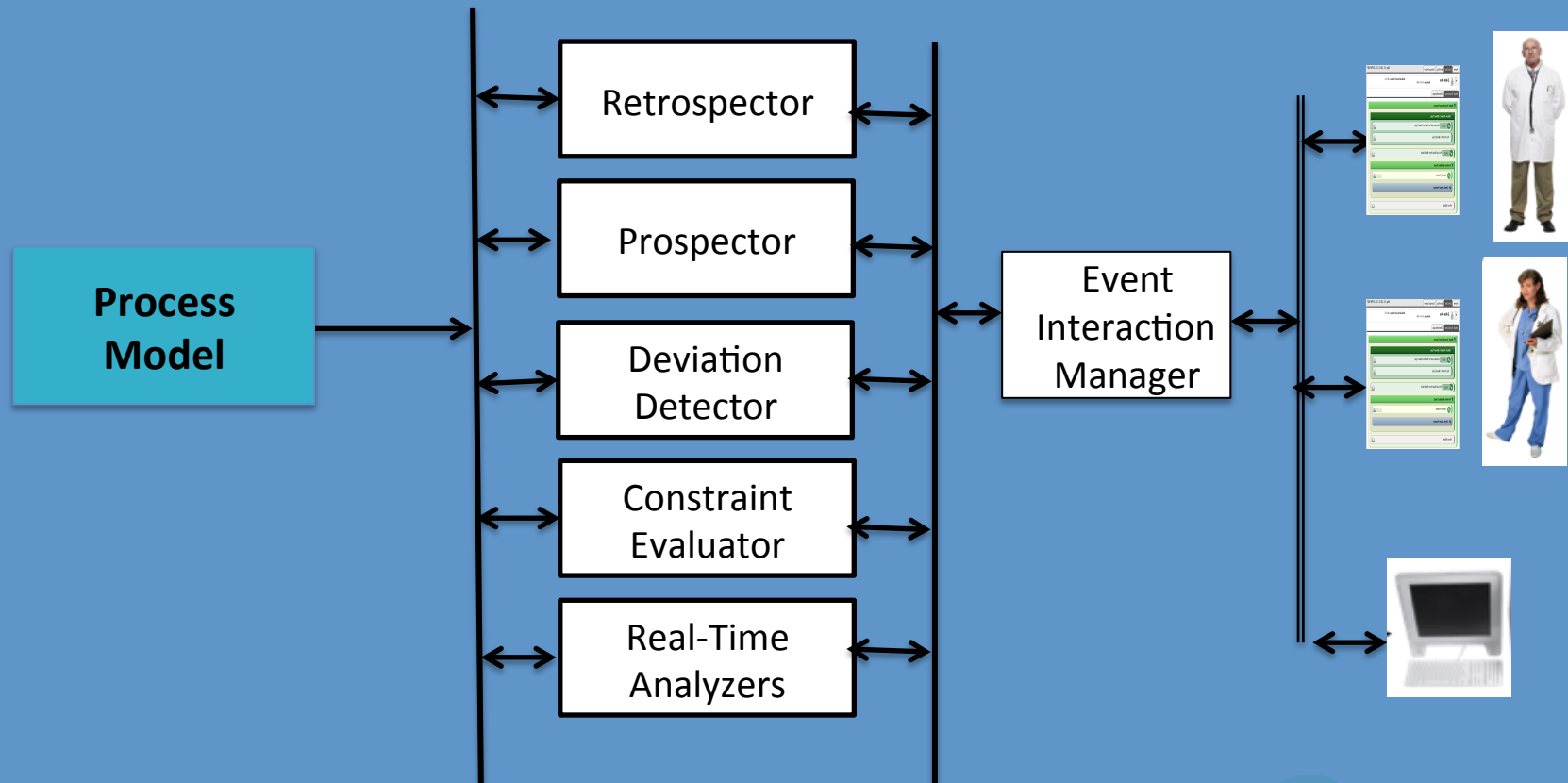
Dynamic Guidance and Analysis

- Using the validated models to provide context sensitive, dynamic guidance and feedback

Nurse: Jane Doe

Geary, Margaret

Gender: female

Birthdate: 07-03-1926

Age: 89

MRN: 12345678

Room: 204

HR 78

TEMP 37.0 **C**

SYS / DIAS 116 / 80

SpO2% 95

ADMINISTER A SINGLE UNIT OF BLOOD PRODUCT *In progress*

General Notes

▼ **administer a single unit of blood product**

  ▼ **perform pre-infusion work**

    ▼ **assess patient**

review patient history	✔ 13:55

    ▼ **evaluate patient clinically:**
    Perform all of the following in any order

perform clinical evaluation	✔ 13:56

      ▼ **check vital signs**

obtain vital signs	✔ 13:55
document vital signs	✔ 13:56

confirm presence of IV catheter ✔

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Geary, Margaret

Gender: female

Birthdate: 07-03-1926

Age: 89

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HR 78

TEMP 37.2 **C**

SYS / DIAS 121 / 80

SpO2% 95

ADMINISTER A SINGLE UNIT OF BLOOD PRODUCT *Successfully completed*

✔ 13:57 General Notes

- ▶ **perform pre-infusion work**
- ▶ **infuse unit of blood product**
- ▼ **perform post-infusion work**
  - ▼ **evaluate patient clinically:**
    Perform all of the following in any order
    - **perform clinical evaluation** ✔ 13:57
    - ▼ **check vital signs**
      - **obtain vital signs** ✔ 13:57
      - **document vital signs** ✔ 13:57
  - **record infusion info** ✔ 13:57
  - **discard infusion materials** ✔ 13:57

Administer A Single Unit Of Blood Product

Last updated: Mon Mar 21 13:57:59 EDT 2016; Created: Mon Mar 21 13:54:38 EDT 2016

Client Name: John Doe			MRN#: 12345678	
Activity	**Date**	**Time**	**Clinician**	**Comments**
review patient history	Mon Mar 21, 2016	13:55:29	Jane Smith	
obtain vital signs	Mon Mar 21, 2016	13:55:53	Jane Smith	
document vital signs	Mon Mar 21, 2016	13:56:21	Jane Smith	
perform clinical evaluation	Mon Mar 21, 2016	13:56:23	Jane Smith	
confirm presence of IV catheter	Mon Mar 21, 2016	13:57:02	Jane Smith	
gather infusion materials	Mon Mar 21, 2016	13:57:05	Jane Smith	
verify patient ID to ID band	Mon Mar 21, 2016	13:57:20	Jane Smith	
verify blood product information	Mon Mar 21, 2016	13:57:23	Jane Smith	
begin infusion of blood product	Mon Mar 21, 2016	13:57:30	Jane Smith	
perform clinical evaluation	Mon Mar 21, 2016	13:57:33	Jane Smith	
obtain vital signs	Mon Mar 21, 2016	13:57:34	Jane Smith	
document vital signs	Mon Mar 21, 2016	13:57:35	Jane Smith	
perform clinical evaluation	Mon Mar 21, 2016	13:57:39	Jane Smith	
obtain vital signs	Mon Mar 21, 2016	13:57:40	Jane Smith	
document vital signs	Mon Mar 21, 2016	13:57:43	Jane Smith	
perform clinical evaluation	Mon Mar 21, 2016	13:57:50	Jane Smith	
obtain vital signs	Mon Mar 21, 2016	13:57:51	Jane Smith	

Many Contributors

George Avrunin
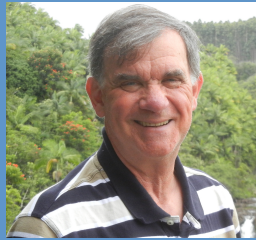
Leon Osterweil

Beth Henneman

Jenna Marquard

Phil Henneman

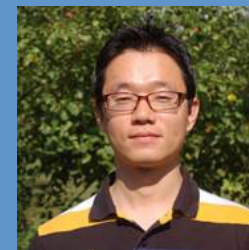Hari Balasubramanian

Bin Chen

Stefan Christov

Rachel Cobleigh

Heather Conboy

Huong Phan

Seung Yoeb Shin

M.S. Raunak

MENTORS: WHY DO WE NEED THEM AND HOW DO WE FIND THEM?

CRA-W Virtual Undergraduate Town Hall

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A MENTOR?

Homer: "wise and trusted counselor"

A Mentor = someone who takes a special interest in helping another person develop into a successful professional.

Mentoring = professional + personal relationship

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Research on Mentoring

Research shows that *those who are mentored achieve greater career advancement and higher work satisfaction than those who are not mentored.*

Why do I need mentors? Benefits of being Mentored

+ **Knowledge of your discipline's expectations**

+ **Solid foundation of skills and knowledge in your discipline**

+ **Self confidence**

+ **Independent problem solving skills**

+ **A good start on a professional reputation**

+ **Access to a professional network**

A Good mentor provides:

- advice on courses, career, personal challenges
- Contacts/connections for networking,
- information
- letters of reference,
- Encouragement
- Opportunities (advocates)
- Coaching
- Help: how to use your strengths;
-           overcome your weaknesses
- A role model
- A listening ear
- Powerful/probing questions
- **ALL possibilities, w/o judgment**

How to Find Mentors Look Everywhere

-In your department at your institution

-Outside your department at your institution

-In your field outside your institution (e.g., at an internship)

- Outside your field outside your institution

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You, the Mentee, have responsibilities too

Attention: SHOW UP with an open mind and respect

Advice: LISTEN + FOLLOW as appropriate

Information: LISTEN, LEARN, and USE

Encouragement: LISTEN + SAVOR

Opportunities: EXPLOIT

You too can be a Mentor…
Benefits of being a Mentor

+ Facilitate another's accomplishments: parenthood

+ Increase confidence

+ Strengthen your own network

+ Give back