Model-Based Systems Engineering Applied to a Hospital Department

An "illustration" of the concepts in a reference architecture for an emergency department

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Background

- **From healthcare track at IW 2015 …**
  - Healthcare industry has many systems thinkers, but few systems engineers
    - Recommendation: INCOSE HWG outreach to non-SE partners
  - Systems engineers need demonstrations of the systems engineering value proposition in a healthcare context
    - Recommendation: SE for Healthcare Value Proposition briefing
    - Recommendation: MBSE Challenge Team example of a systems engineering model for hospital operations
  - Systems engineers must show MBSE adds value beyond that of on-going non-SE systems modeling and analysis
    - Recommendation: INCOSE HWG members create white paper
    - Recommendation: INCOSE HWG outreach to Society for Simulation in Healthcare

This presentation is part of the on-going process to address approaches to tailor systems engineering for healthcare operations

Today's Discussion

- **Goals**
  - Provide an *illustration* of how model-based systems engineering techniques can be used for healthcare operations
  - Provide concepts that can be discussed this morning
  - Provide material that can be used in this afternoon's discussion

- **Outline**
  - Explore the MBSE model
  - Discuss candidate value propositions

> This is not a complete reference architecture. But hopefully it's enough to stimulate further thinking and work.

Contributors

- **INCOSE Biomedical-Healthcare MBSE Challenge Team and collaborators**
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- **INCOSE Healthcare Working Group and collaborators**
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Many people made valuable contributions – but any errors you find are mine.
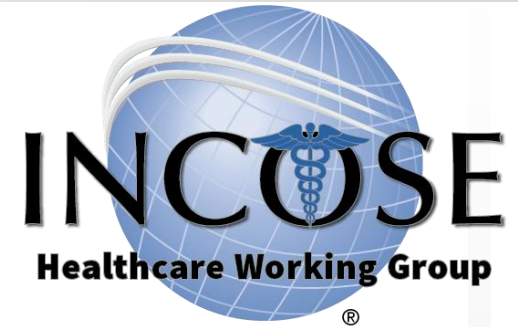
Exploring the Model

This is an initial attempt building a systems engineering model of the emergency department.

It only has limited information incorporated. It needs much more input.

Hopefully it is enough to set the stage for us to brainstorming the potential value.

- **Classes of "models"**
  - Computational models
    - Computer-interpretable algorithms to perform quantitative analysis on some aspect of the system
    - Examples: physics models (thermal, structural, etc.), process models (DES, statistical dynamics, etc.), probability models
  - Emulators (physical simulators)
    - Equipment that emulates real world activities in order to support training and experimentation
    - Examples: flight simulators, part-task trainers, surgical mannequins, etc.
  - Descriptive models
    - Human-interpretable model describing the system and its design characteristics
    - Examples: CAD models, circuit diagrams, software design models (e.g., UML), systems engineering models (e.g., SysML)

SE models describe but do not compute

Limitations to This Draft MBSE Model

- **Follows a "reverse engineering" approach**
  - Tailors the process of applying systems engineering principles to address an existing (functioning) enterprise

- **Patient is represented as "system" that the ED acts upon during treatment**
  - May not be the best way to address the patient

- **There is only one use case in the model**
  - Simple use case for treating hypoglycemia
  - If there were more use cases in the model, the queries to the model would be more insightful

- **Probably many, many others**

This is just a start – everyone will need to use their imaginations to provide feedback on where it could go.

- **One simple use case: hypoglycemia**

ED – Typical Presentation for Hypoglycemia
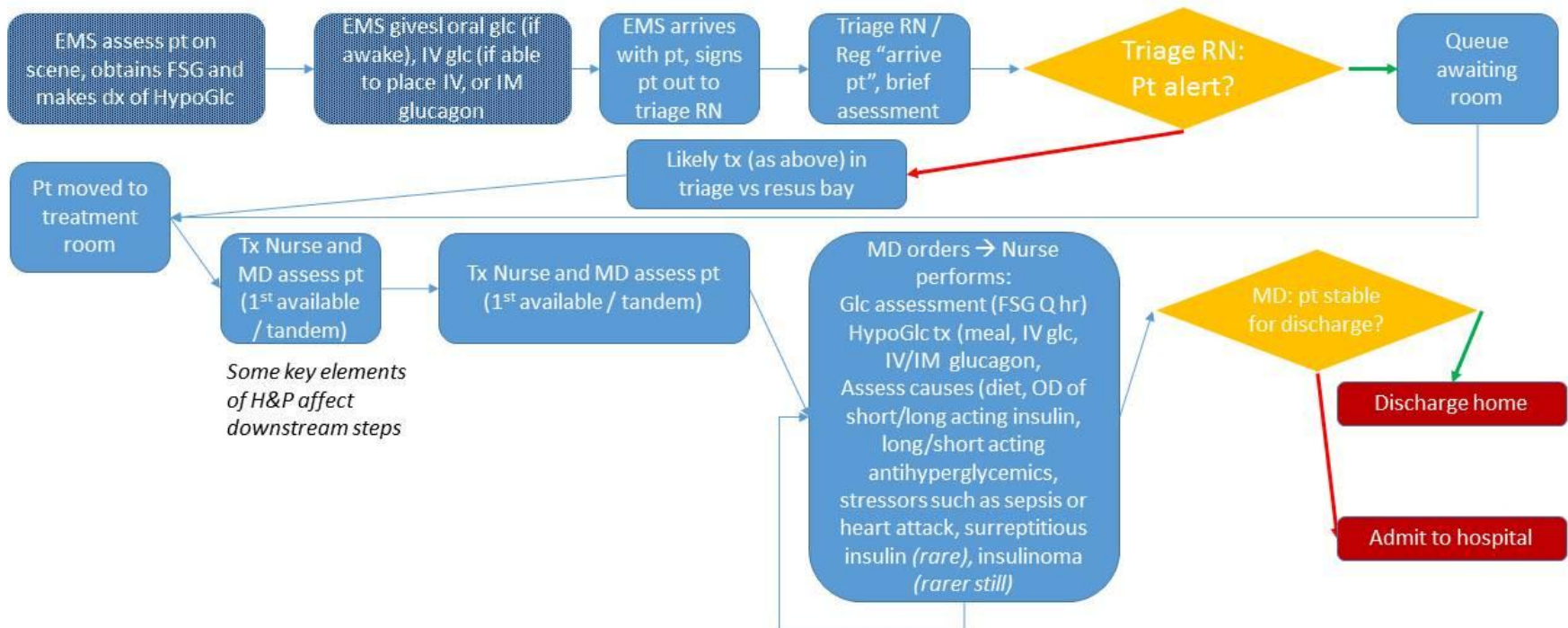
FSG = fingerstick glucose; Glc = glucose, HypoGlc = hypoglycemia, H&P = Hx & PEx = History and Physical, Q___ = repeat each ___ D50QW= 50% dextrose (glc) in water; D5-0.45NS = 5% dextrose in "half-normal" saline (normal = 0.9% NaCL in water)

Process illustration and much other good information graciously provided by Eric Goldlust, MD

>>>>>>MBSE Model <<<<<

MBSE Model Elements Reviewed

- **MBSE model of hypoglycemia treatment in the ED**
  - Review the overall activity diagram
  - Examine the record behind the activity "Monitor Physiological Status"
    - Link to measures and measure attributes
    - Link to location and activities in that location
    - Link to equipment used in the activity and in the location
  - Examine the record behind the performer "ED Doctor Jones"
    - Link to the class of performer "ED Physician"
      - Role in the organizational class "ED Dept."
      - Link to "required competencies"
    - Analysis of activity model: activities performed, locations used, information items owned
    - Link to ED capabilities

These relationships were explored using the actual model to show how the MBSE modeling process creates an integrated framework
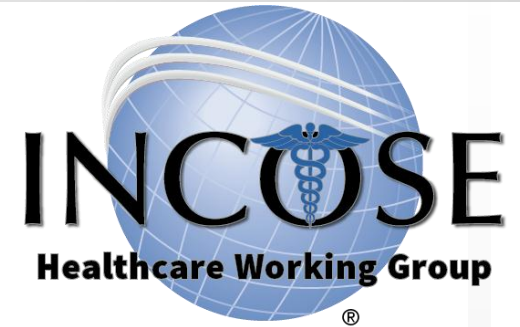
Candidate Value Propositions

- **Proposition: Systems engineering models can support …**
  - Analyzing and improving clinical workflows, business processes, and the interactions between the two
  - Incorporating new equipment and systems (and thereby new technology)
  - Modifying infrastructure or creating new infrastructure

Let's look at the MBSE model again and see what it can do to support these three candidate value propositions

Clinical and Business Workflows

- **MBSE models can *support* Lean studies …**
  - Capture results of individual studies for future re-use
  - Link multiple lean studies into an enterprise framework
  - Provide framework to assess enterprise implications of process change recommendations

- **MBSE models can *support* computer simulations**
  - Provide the descriptive information to initiate simulations
  - Capture simulation descriptive and quantitative results
  - Provide an enterprise framework for linking process improvement recommendations to system designs

- **MBSE models can *support* physical simulations**
  - Provide context and environment descriptions
  - Capture process actions for creating SOPs, training materials

The MBSE model provides the enterprise framework for integrating many different kinds of process improvement studies

>>>>>>MBSE Model <<<<<

MBSE Model Elements Reviewed

- **Clinical and business workflows value proposition**
  - Support to Lean studies
    - MBSE model as the workflow characterization
    - MBSE activity measures to accumulate data
    - MBSE information flows to show links between workflows
  - Support to simulation studies
    - MBSE model as an authoritative representation of workflow
    - MBSE model to capture Lean observations as input data and/or parametric data used in the simulations
  - Support to physical simulations for training
    - MBSE activity model as basis of SOP
      - Once "validated" via Lean studies
    - MBSE characterization of activity in terms of people, location, equipment, before/after activities to define simulation req'ts

These relationships were explored using the actual model to show how the MBSE modeling process creates an integrated framework

Computer Simulation Modeling

Fig 3. Part of the Current Model Showing Variables Influencing Flows Inside the ED
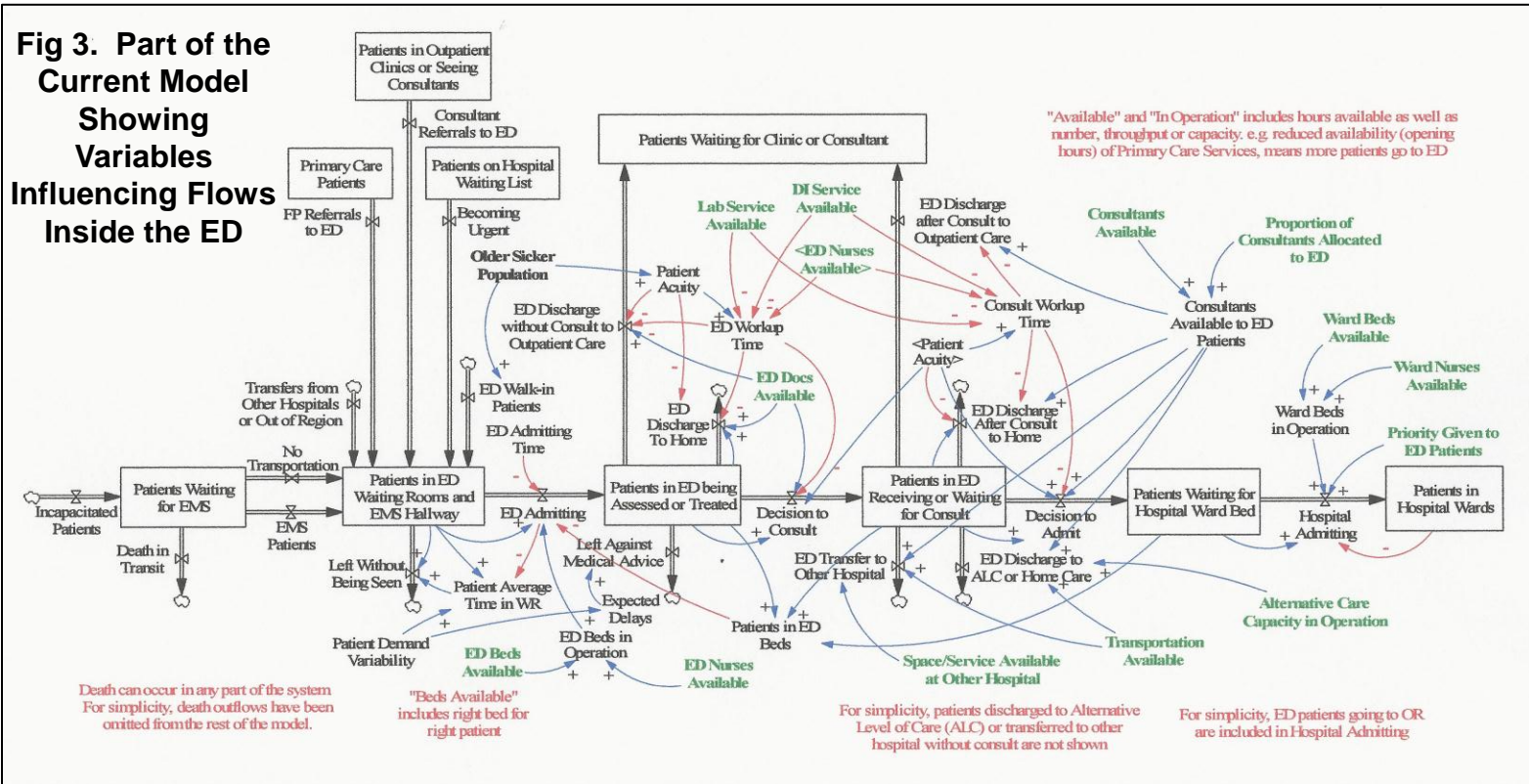
A highly flexible array of methods for examining performance issues and their sensitivities to resources and clinical environment issues.

Incorporating New Systems-Technology

- **MBSE models can support medical device developers …**
  - Describe the intended use environment
    - Who will use the equipment; what are they doing
    - What happens before and after
  - Support assessment of risks that originate from the intended use environment

- **MBSE models can support hospital planners and care providers …**
  - Understand support requirements/plan technology insertion
    - Example: if new patient tracking system installed
    - Example: where is IT support required to provide information
  - Support process oriented risk assessment

MBSE can describe the clinical environment and processes in order to support device and process analyses

>>>>>MBSE Model <<<<<

MBSE Model Elements Reviewed

- **Incorporating new systems-tech value proposition**
  - Support to device developers
    - Analyze equipment item records and equipment summary to show intended use environment
      - Where is it used, who uses it, when do they use it, what else is going on
    - Activity model to analyze risks arising from use environment using process FMEA methods
  - Support to hospital planners
    - Analyze location records and location summary showing equipment and activities in each location
      - Analysis of connectivity needs related to EMR and patient tracking system
      - Activity model to analyze risks using process FMEA methods

These relationships were explored using the actual model to show how the MBSE modeling process creates an integrated framework

Understanding-Designing Infrastructure

- **MBSE models can support hospital infrastructure planning …**
  - Infrastructure modifications
    - Understand what processes are impacted
    - Assessing infrastructure bottleneck
  - New infrastructure designs
    - Capturing requirements from existing operations
    - Packaging requirements by location
  - Revisions or refinements to organizations
    - Capture understanding of current organization
    - Linking new requirements to staff positions

MBSE models capture knowledge in a data system that enables querying and tracing relationships

>>>>>MBSE Model <<<<<

MBSE Model Elements Reviewed

- **Infrastructure planning support value proposition**
  - Support to designing-analyzing infrastructure
    - Return to summary of activities by location
      - Discuss impact of including more use cases on ability to characterize needs by location
    - Return to summary of equipment by location
      - Discuss impact of including more use cases on ability to characterize needs by location
    - Discuss long-term goal of creating a reference architecture that any hospital can use as a "template" for evaluating operations
  - Support to organizational design
    - Return to organizational design summary
      - Discuss analysis of staff required competencies
      - Discuss use in responding to new regulations or accreditation requirements

These relationships were explored using the actual model to show how the MBSE modeling process creates an integrated framework

- **MBSE models can capture knowledge from existing enterprises from a system perspective**
  - Knowledge about the system
    - Who, what, when, where, using what equipment
  - Relationships and dependencies within the system
    - Performers-activities-locations-equipment-external departments

- **The knowledge captured by the MBSE model can complement and/or support multiple applications**
  - Lean studies/simulations ⇔ MBSE models
  - Physical simulations, training, SOPs ⇔ MBSE models
  - Intended use environment ⇔ MBSE models
  - Technology plans/designs ⇔ MBSE models
  - Infrastructure plans/designs ⇔ MBSE models