Adapting Model-Based Systems Engineering to Production Systems

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Acknowledgements

PhD dissertations on this topic
• Dr. George Thiers, founder ModGeno
• Dr. Tim Sprock, NIST

Major influencers of this work
• Chris Paredis, BMW Chair in Systems Integration, Clemson
• Conrad Bock, NIST
• Sandy Friedenthal, SysML thought leader

Teaching and research software provided by
• NoMagic, Inc

Research supported by
• Lockheed
• Rockwell Collins
• DARPA AVM
• General Electric
• United Technologies
• McKesson
• Boeing
• NIST
My focus for since about 1995 has been on understanding how we could use modeling and computation to support the design, planning and control of DELS.

It’s a hard problem!

Supply chains for airplanes, automobiles, computers, cell phones...

Airplane assembly plants

Semiconductor manufacturing

Health care delivery
About me...

Discrete Event Logistics Systems, DELS

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Production systems for most industrial and consumer products are DELS.
What is Model-Based Systems Engineering?

**MBSE Definition**

**Final Report, Model-Based Engineering Subcommittee, NDIA, Feb. 2011**

“Model-Based Engineering (MBE): An approach to engineering that uses models as an integral part of the technical baseline that includes the requirements, analysis, design, implementation, and verification of a capability, system, and/or product throughout the acquisition life cycle.”

**INCOSE SE Vision 2020 (INCOSE-TP-2004-004-02, Sep 2007)**

“Model-based systems engineering (MBSE) is the formalized application of modeling to support system requirements, design, analysis, verification and validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases.”

INCOSE IW January 30th, 2016 * Fosse
What is Model-Based Systems Engineering?

MBSE Motivation

- Systems Engineering requires structural, behavioral, physics and simulation-based models representing the technical designs which evolve throughout the life-cycle, supporting trade studies, design verification and system V&V.

- Current practice tends to rely on standalone (discipline-specific) models whose characteristics are shared primarily through static documents.

- MBSE moves toward a shared system model with remaining discipline-specific models providing their characteristic information in a mathematically rigorous format. All disciplines “view” a consistent system model.
Why go to the time and expense of MBSE?

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MBSE uses an "analysis agnostic" system model

What makes MBSE possible?

• Almost 50 years of effort to “standardize” the specification of the product—culminating in the ability to exchange designs between CAD systems

• Similar efforts to integrate product analyses with CAD models

• Emergence of SysML, a systems modeling variant of UML

• Recognition of the potential payoff

• Resulting commitment of resources to accomplish integration
Why don’t we apply MBSE methods and principles to DELS?

There are multiple stakeholders, with discipline-specific viewpoints

The systems are large, complicated, expensive, and persistent

The contemporary decision support analyses are independent, stand alone efforts

The consequences of poorly integrated decisions can be catastrophic, especially in terms of time to market
Stakeholders and interactions in DELS design

Points of view and responsibilities
- Product requirements
- Product design
- Production system resources
- Processes instructions to create
- Process time estimates
- Performance prediction
Developing the production system requires sharing a lot of technical information about the product, the intended production processes, the resources that will execute those processes, the instructions for executing those processes, the intended production schedule (or rate or ramp...), and the resulting cycle time and WIP levels.

Today, this information and the way it is shared is still largely *ad hoc*.
Consequences of current practice

• Time to market (time to full scale production) delays while the production system “bugs” are worked out

• Cost targets missed because
  • Resource capacity additions
  • Cycle time and WIP growth
What if?

SysML Models
Product, Process, Resources, Facilities

Product Viewpoint
Bill of Materials

Process Viewpoint
Bill of Process

Resource Viewpoint
Resource Req’ts

Facility Viewpoint
Interface Req’ts

Performance Viewpoint
Cycle Time & WIP

Bill of Process

What if?
Challenge #1  Semantics and Syntax

There is not a common, shared way of using words to describe the elements of a production system.

Contrast to, e.g., electronics or hydraulics, where there are standard vocabularies (semantics) and formal modeling tools (syntax)
Modern integrated circuit design uses a set of formalized concepts that span from high level system specification all the way down to the 3D physical layout of the devices on the silicon wafer. These specifications can be translated into machine instructions for fabrication, can be computationally verified, and drive downstream packaging and testing.
In contemporary production systems analysis, the models tend to be “one-offs” for each system or question of interest. Hand coding these models is time consuming and expensive, so analysis is “conserved”.

Why can’t we (at least partially) automate the creation of analysis models that we already know how to create?
Where are we today?

- Reasonably stable reference models for EBoM and MBoM
- Good progress on reference models for process and resource
- Good understanding of plant-control separation challenges
- Good start on ISA-95 compliant level 3 controller model
- Multiple demonstrations of automated analysis generation, including discrete event simulations
- Multiple industrial engagements, NIST research grant, two NIST SBIRs
https://factory.isye.gatech.edu/
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Production and Logistics Systems Modeling Challenge Team

Purpose

The production and logistics modeling team is advancing the practice and adoption of formal system modeling and model-based systems engineering methodologies in production and logistics systems development and operations. Specific challenges in providing a foundation to production and logistics [systems] engineering are the lack of:

- Standard reference models
- Well-structured engineering design methodologies
- Integrated analysis models and tools available to support design and operational decision-making.

The purpose of this challenge team is to increase the availability of reference models, awareness of these models and methods, and successful use of MBSE in the production, logistics, and industrial engineering communities.


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Your turn
Good sources for more information

• Sysml.org

• Architecting Spacecraft with SysML, Sanford Friedenthal and Christopher Oster, available from Amazon

• https://blog.nomagic.com/comprehensive-overview-of-the-application-of-mbse-at-jpl-nasa/, download the pdf at the end

• https://factory.isye.gatech.edu/

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