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

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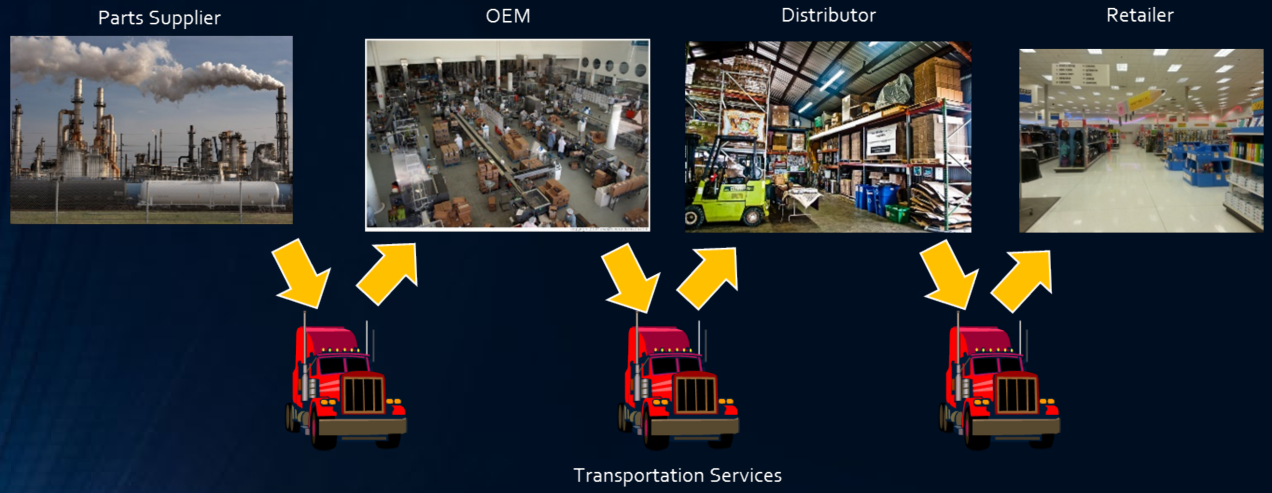
- General Electric
- United Technologies
- McKesson
- Boeing
- NIST

About me…

Discrete Event Logistics Systems, DELS



Units of flow move through a network of resources, which execute processes that transform the units of flow in some way—location, age, configuration, information, etc. These are **"discrete event logistics systems" or DELS**.

Transformations can be adequately described by their start and end events, and by the summary description of the state change accomplished.

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

Production systems for most industrial and consumer products are DELS

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What is Model-Based Systems Engineering?

MBSE Definition

Final Report, Model-Based Engineering Subcommittee, NDIA, Feb. 2011	INCOSE SE Vision 2020 (INCOSE-TP-2004-004-02, Sep 2007)
“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.”	“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

http://www.omgwiki.org/MBSE/lib/exe/fetch.php?media=mbse:2016_iw-mbse_101.pdf

What is Model-Based Systems Engineering?

MBSE

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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

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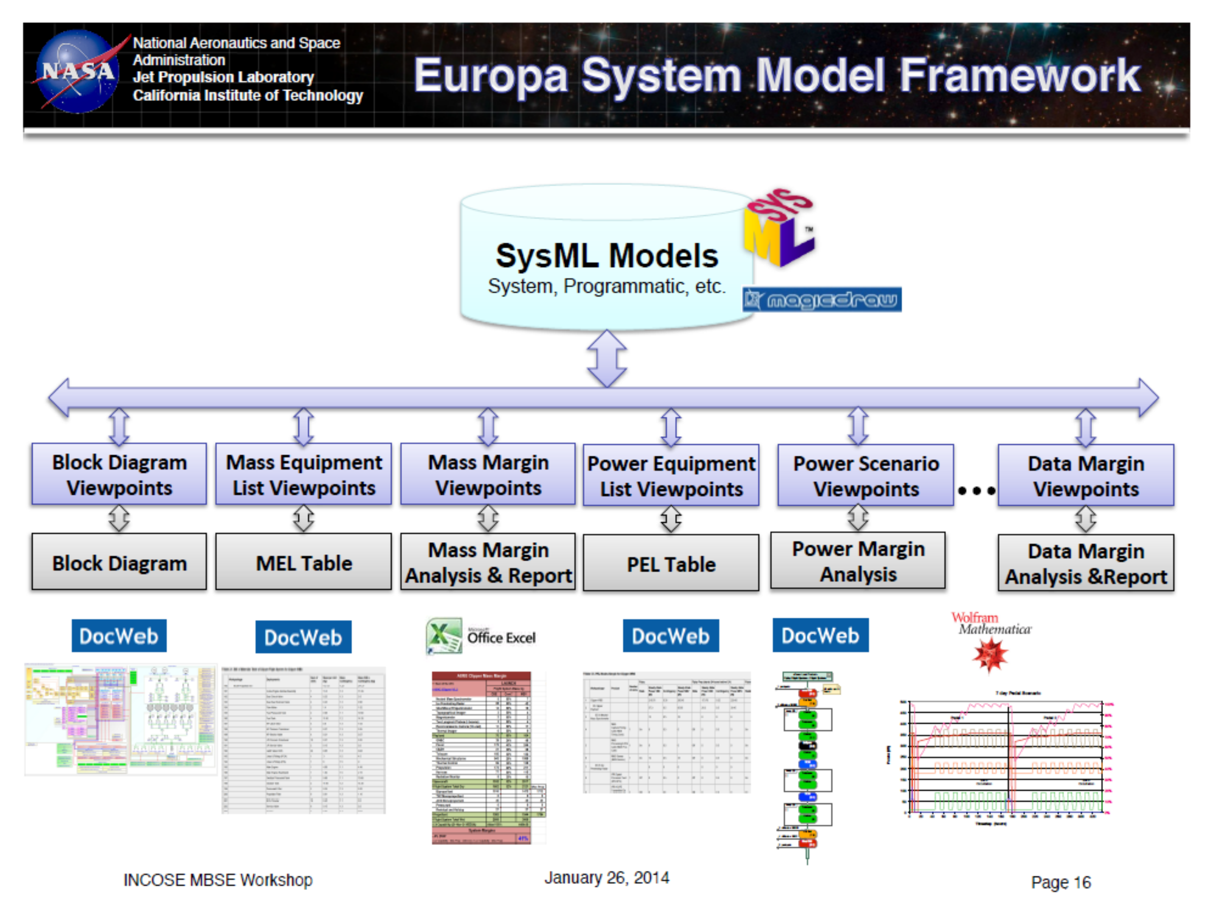
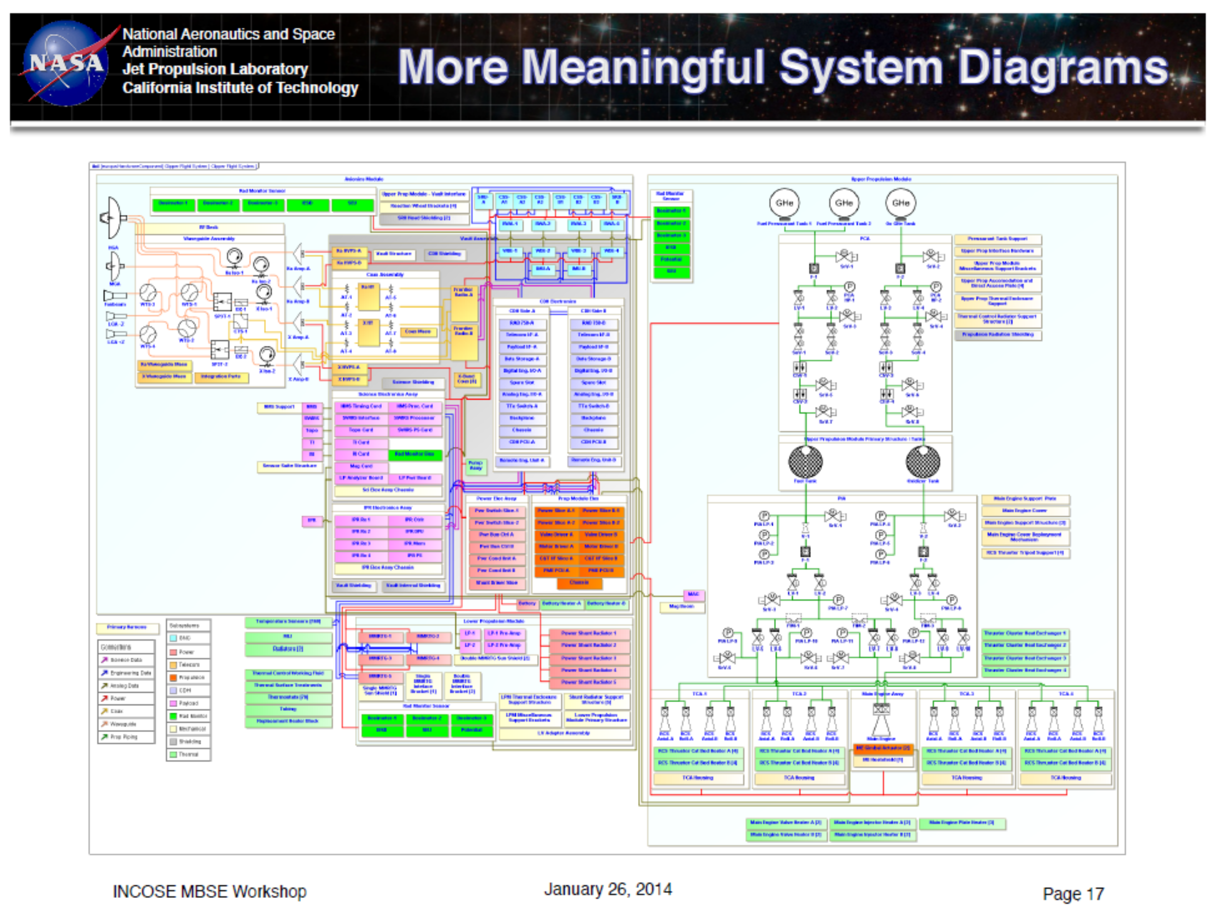
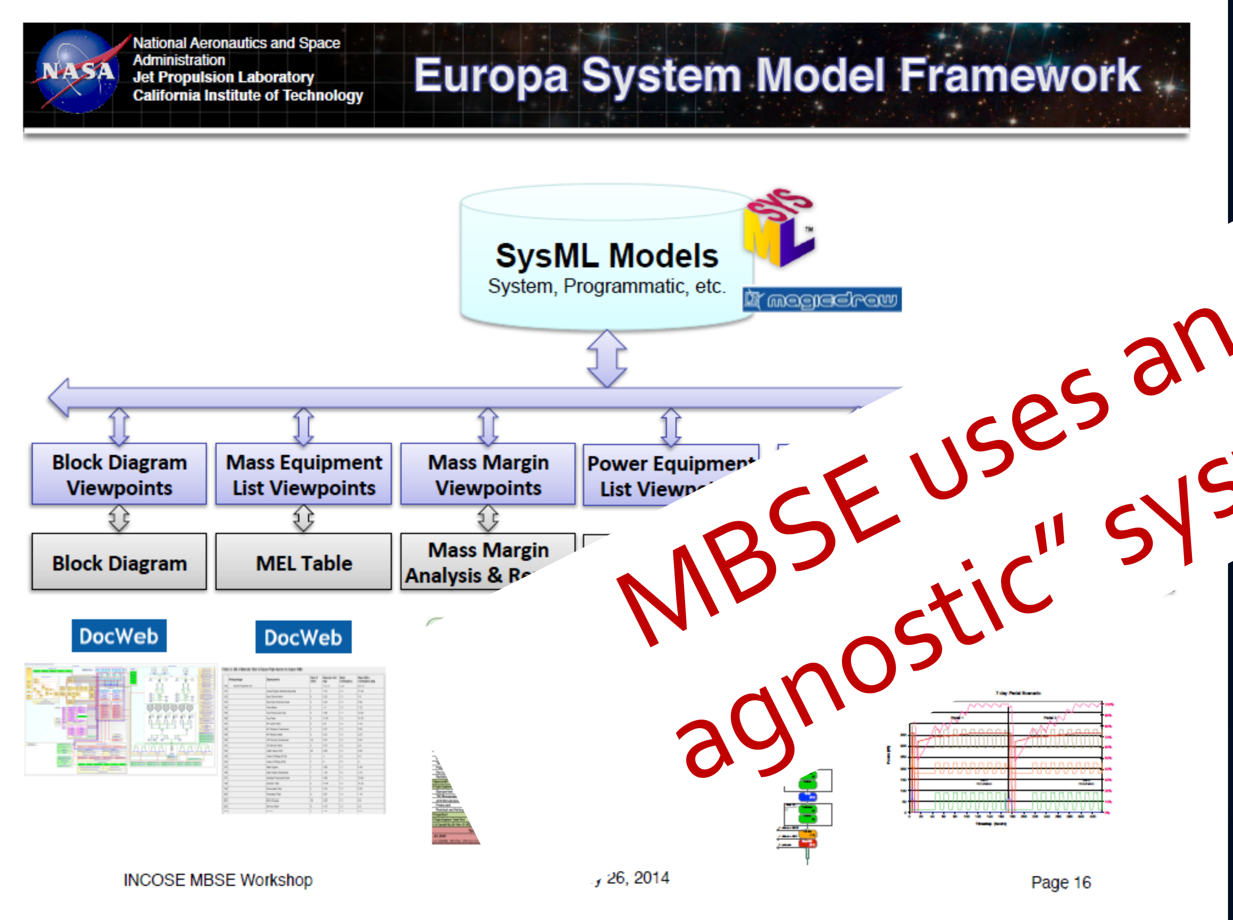
Why go to the time and expense of MBSE?

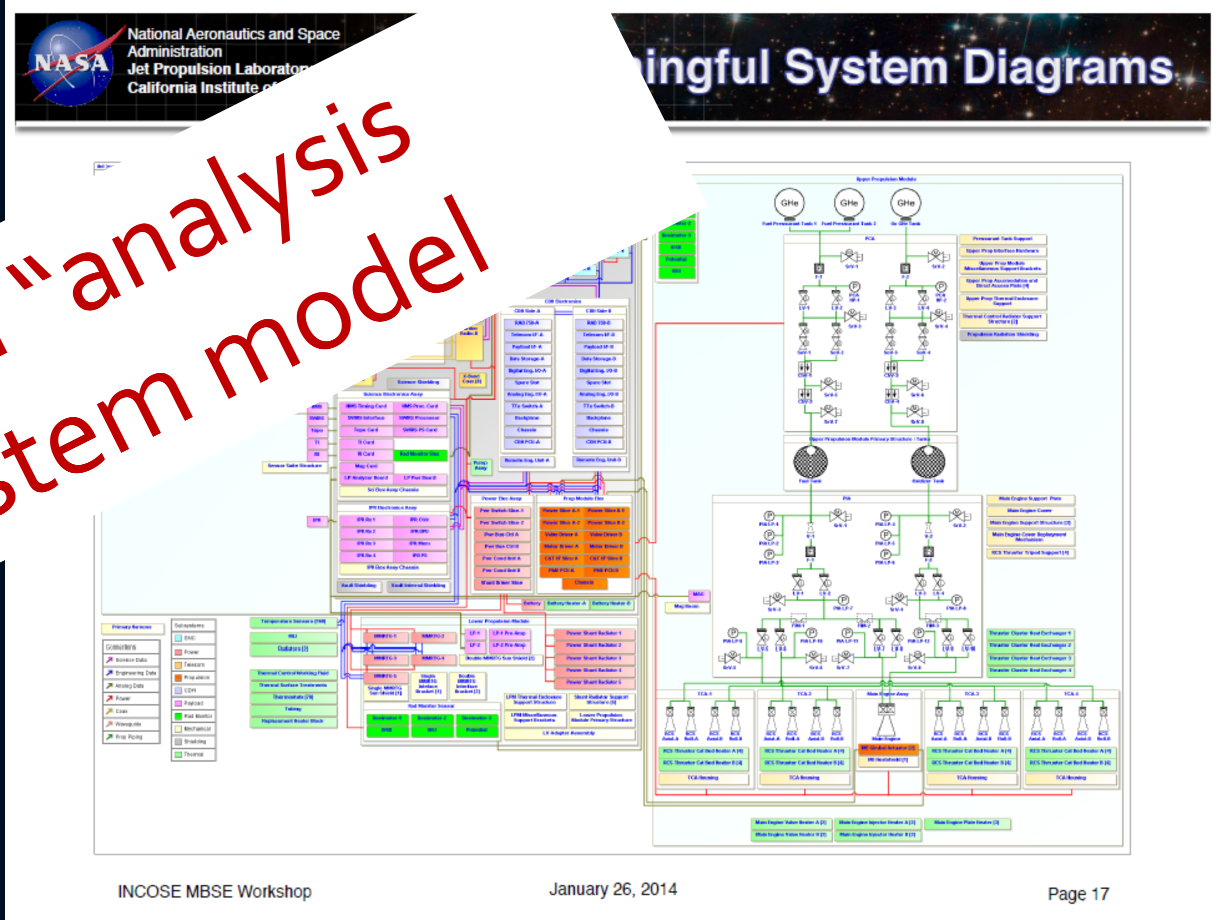




Dave Nichols & Chi Lin, "Integrated Model-Centric Engineering: The Application of MBSE at JPL Through the Life Cycle," INCOSE IW 2014

Why go to the time and expense of MBSE?





MBSE uses an "analysis agnostic" system model

Dave Nichols & Chi Lin, "Integrated Model-Centric Engineering: The Application of MBSE at JPL Through the Life Cycle," INCOSE IW 2014

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

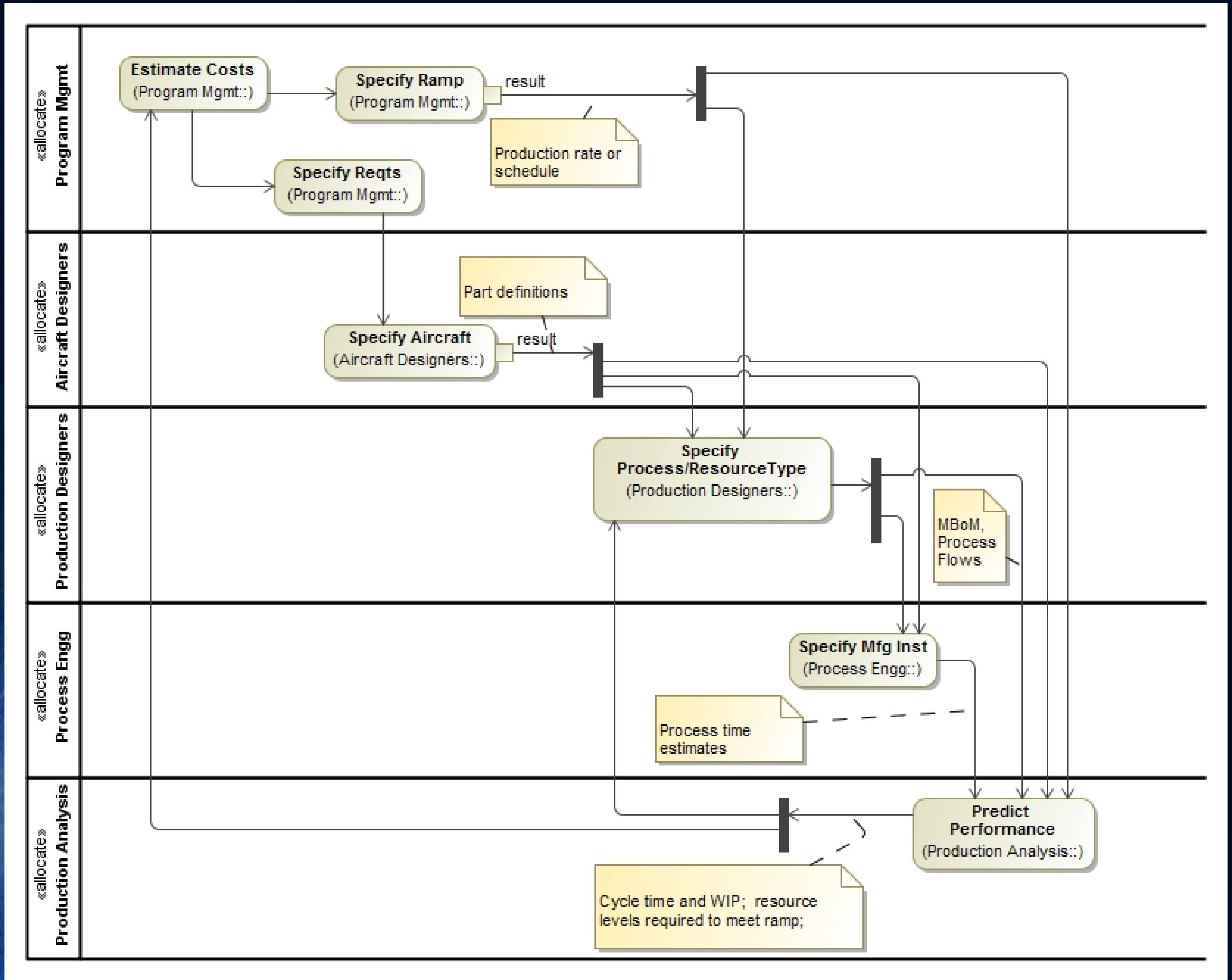
There are multiple stakeholders, with discipline-specific viewpoints

The systems are large, complicated, expensive, and persistent

The contemporary decision support analyses are independent, stand alone efforts

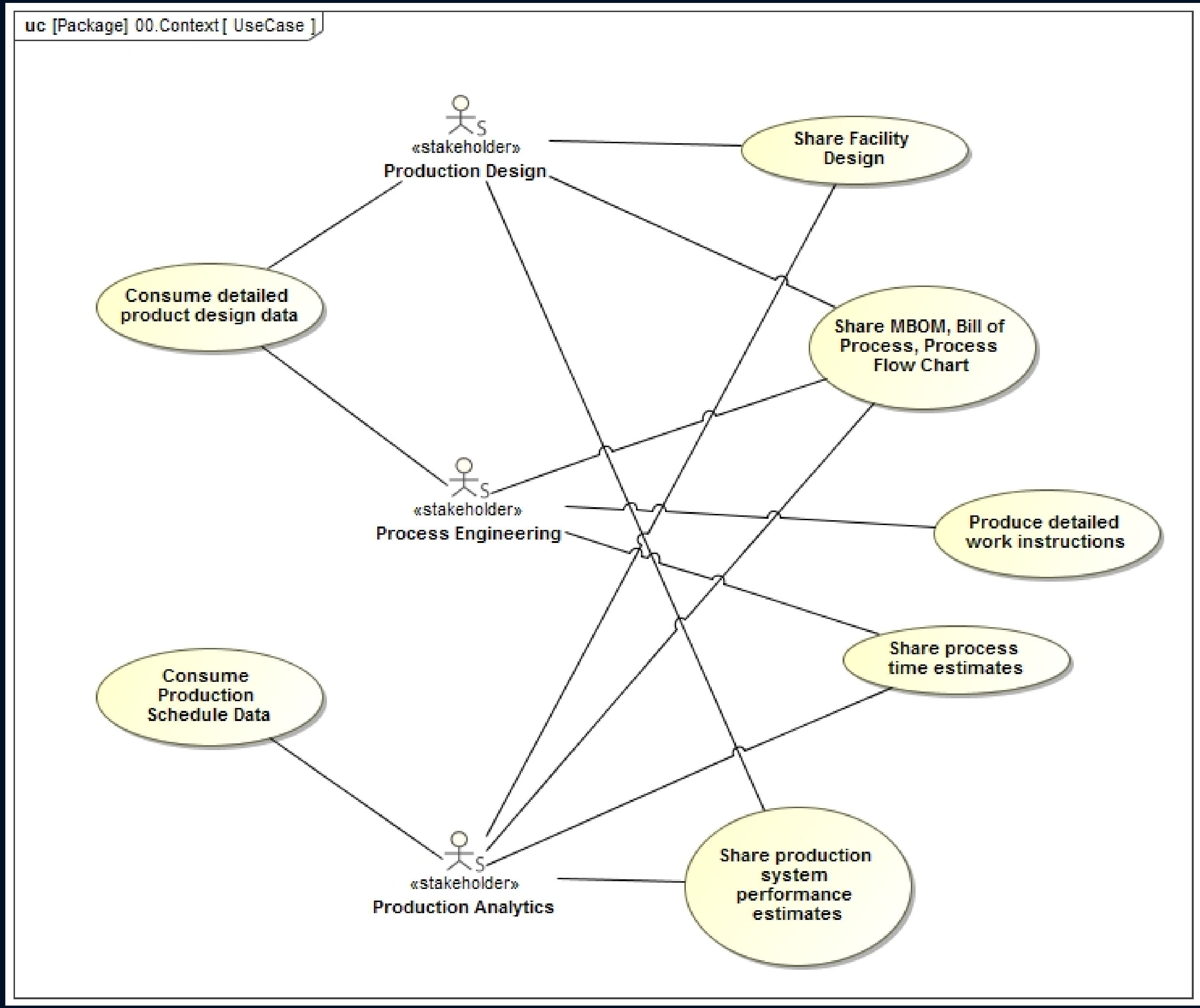
The consequences of poorly integrated decisions can be catastrophic, especially in terms of time to market

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



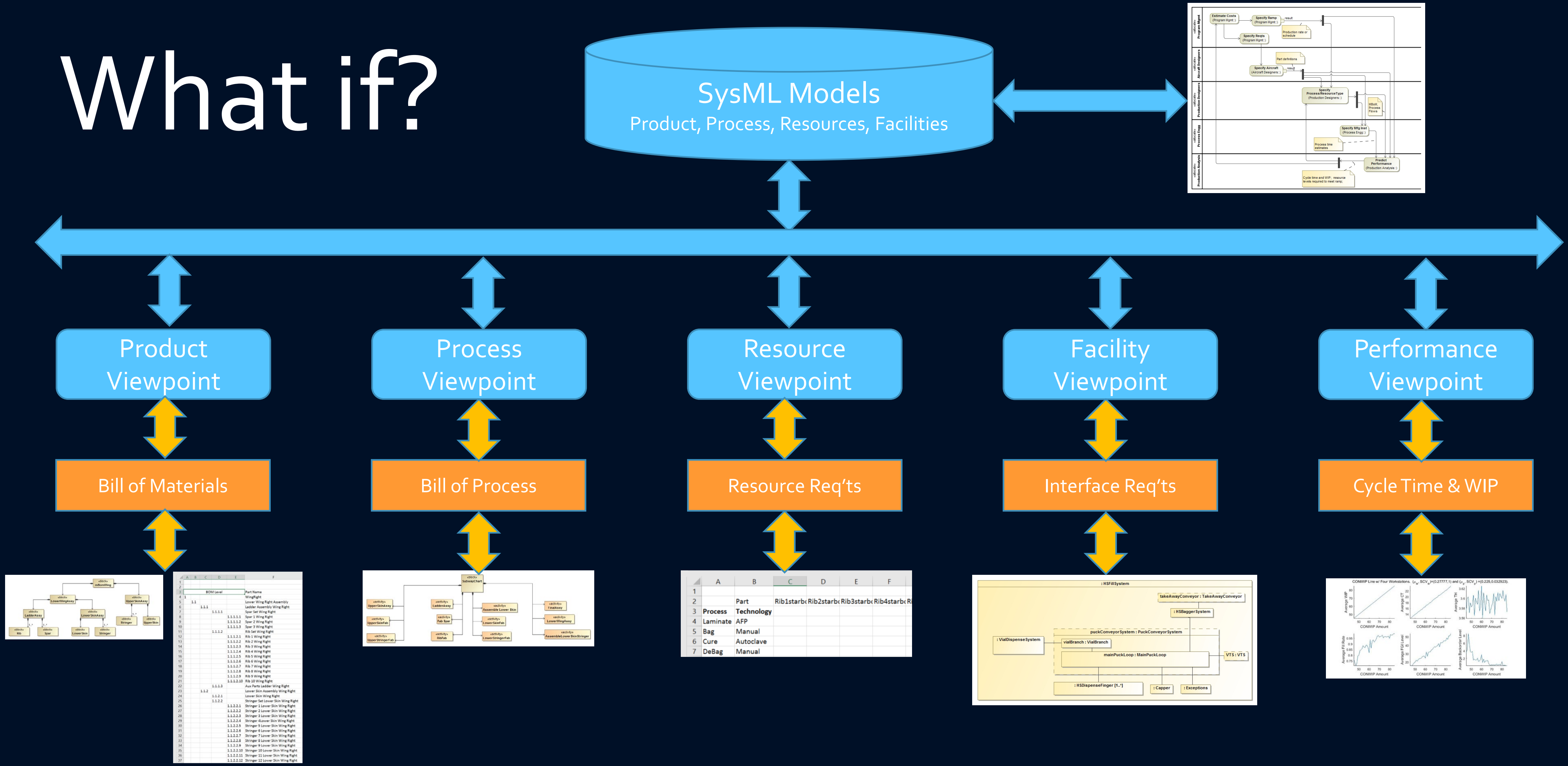
Developing the production system requires sharing a lot of technical information about the product, the intended production processes, the resources that will execute those processes, the instructions for executing those processes, the intended production schedule (or rate or ramp…), and the resulting cycle time and WIP levels.

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

Consequences of current practice

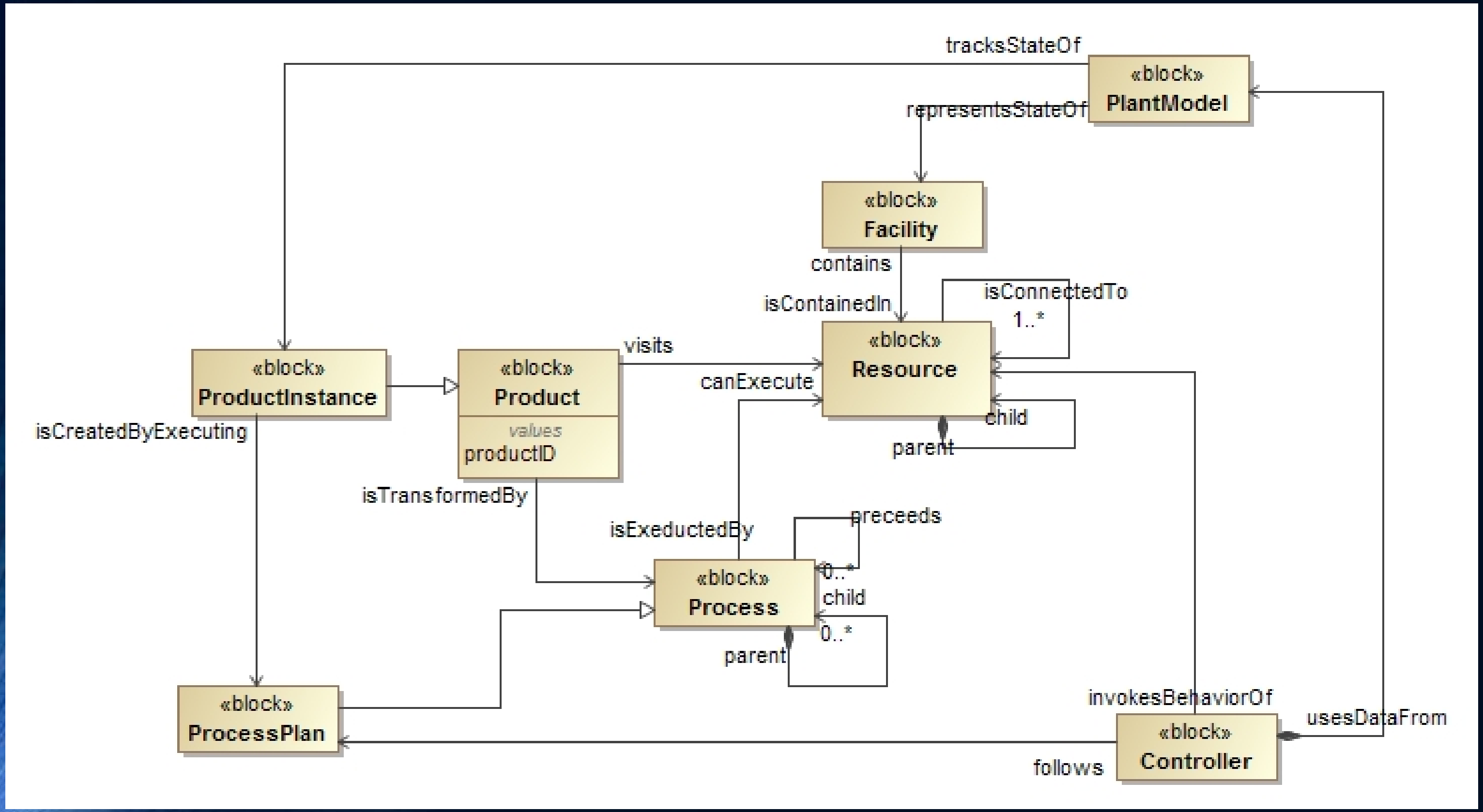
- Time to market (time to full scale production) delays while the production system "bugs" are worked out
- Cost targets missed because
  - Resource capacity additions
  - Cycle time and WIP growth

What if?



SysML Models
Product, Process, Resources, Facilities
Product Viewpoint
Process Viewpoint
Resource Viewpoint
Facility Viewpoint
Performance Viewpoint
Bill of Materials
Bill of Process
Resource Req'ts
Interface Req'ts
Cycle Time & WIP
Part
Process
Technology
Laminate
AFP
Bag
Manual
Cure
Autoclave
DeBag
Manual

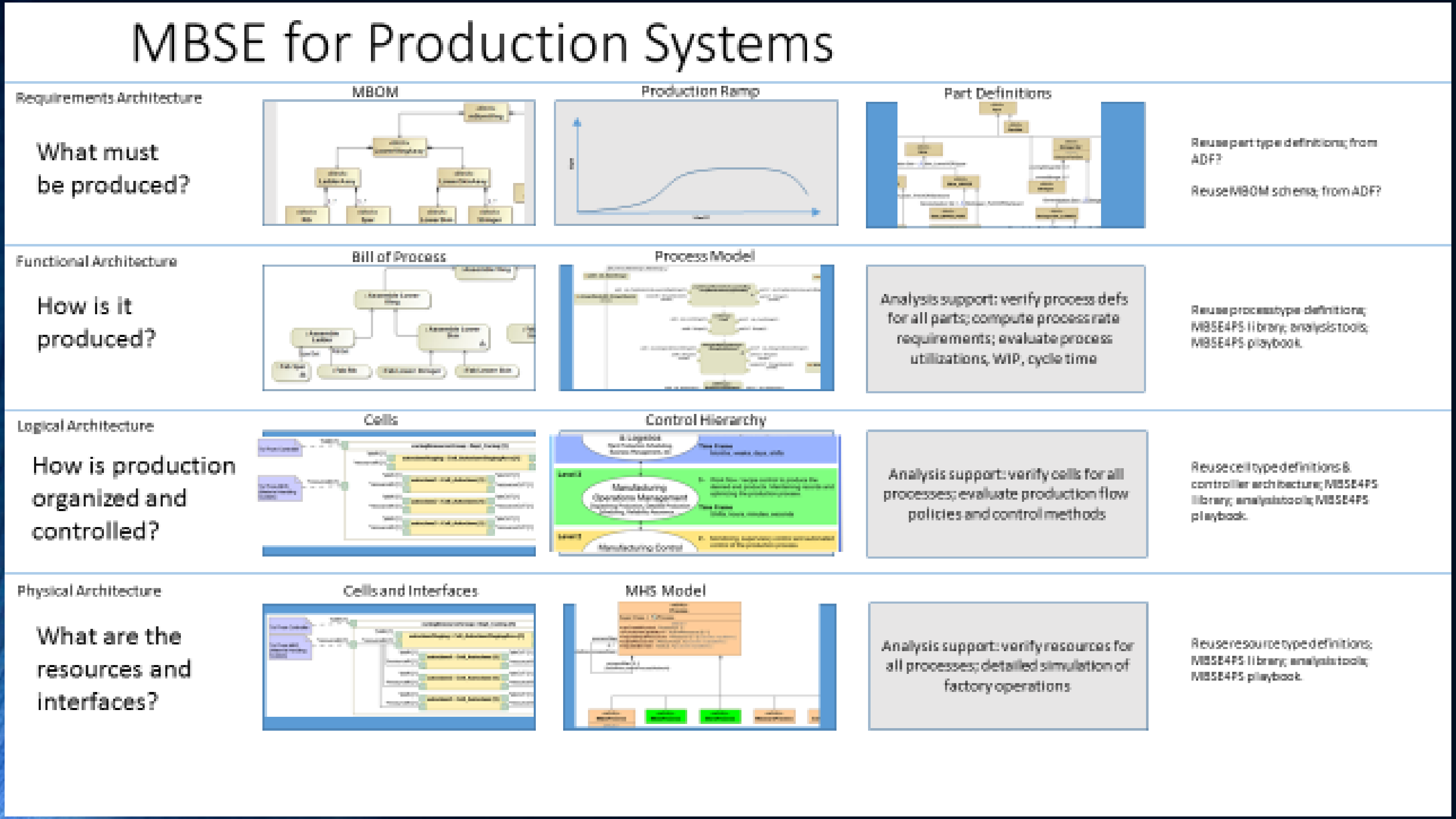
Challenge #1 Semantics and Syntax

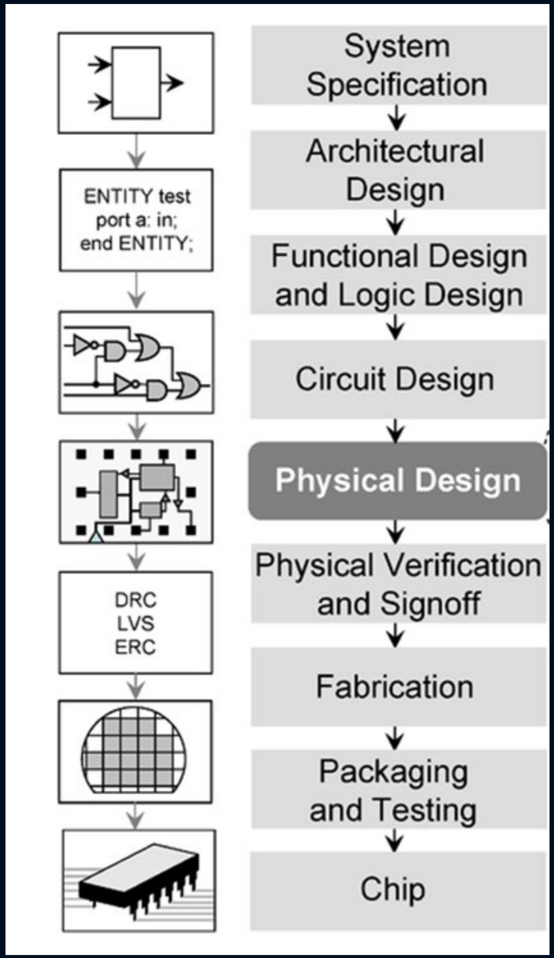


There is not a common, shared way of using words to describe the elements of a production system.

Contrast to, e.g., electronics or hydraulics, where there are standard vocabularies (semantics) and formal modeling tools (syntax)

Challenge #2 Object-Oriented Thinking





Challenge #3 Analysis Integration

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

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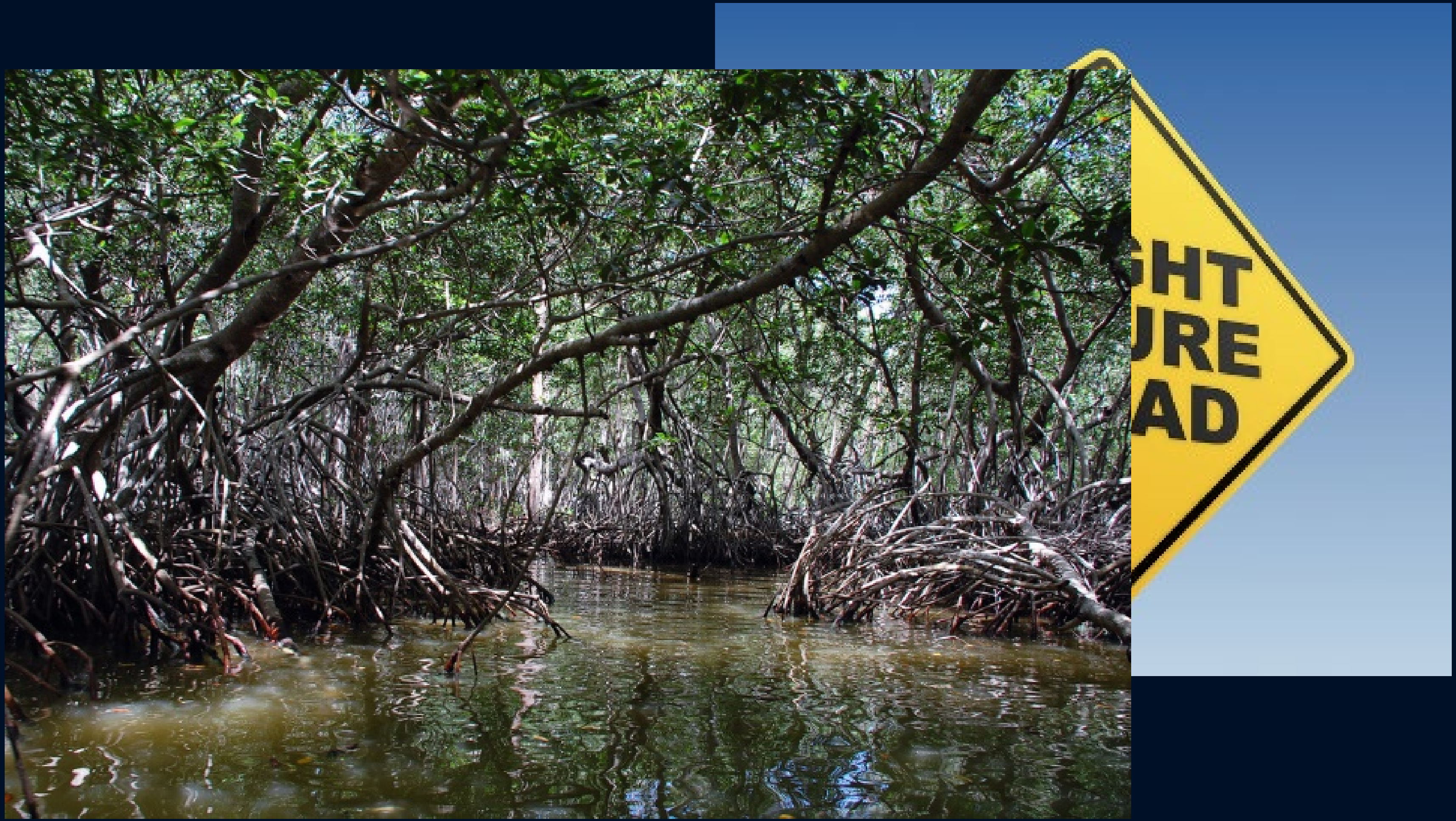

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Ways to get involved:

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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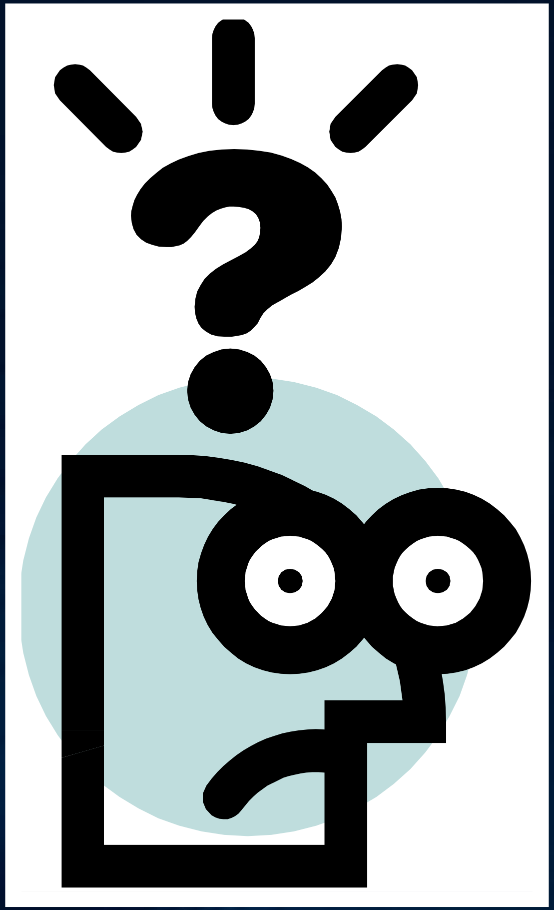
Your turn



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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