2018
Annual INCOSE
international workshop
Jacksonville, FL, USA
January 20 - 23, 2018

Production and Logistics Systems Modeling Challenge Team

Timothy Sprock[a], Leon McGinnis[b], & Conrad Bock[a]

[a] National Institute of Standards and Technology, [b] Georgia Tech

www.incose.org/IW2018

Overview

- Who are we?
- Challenges: why do we exist?
- Collaboration Paradigm
- Making Models and MBSE Ubiqutious

Challenge Team Purpose

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.

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.

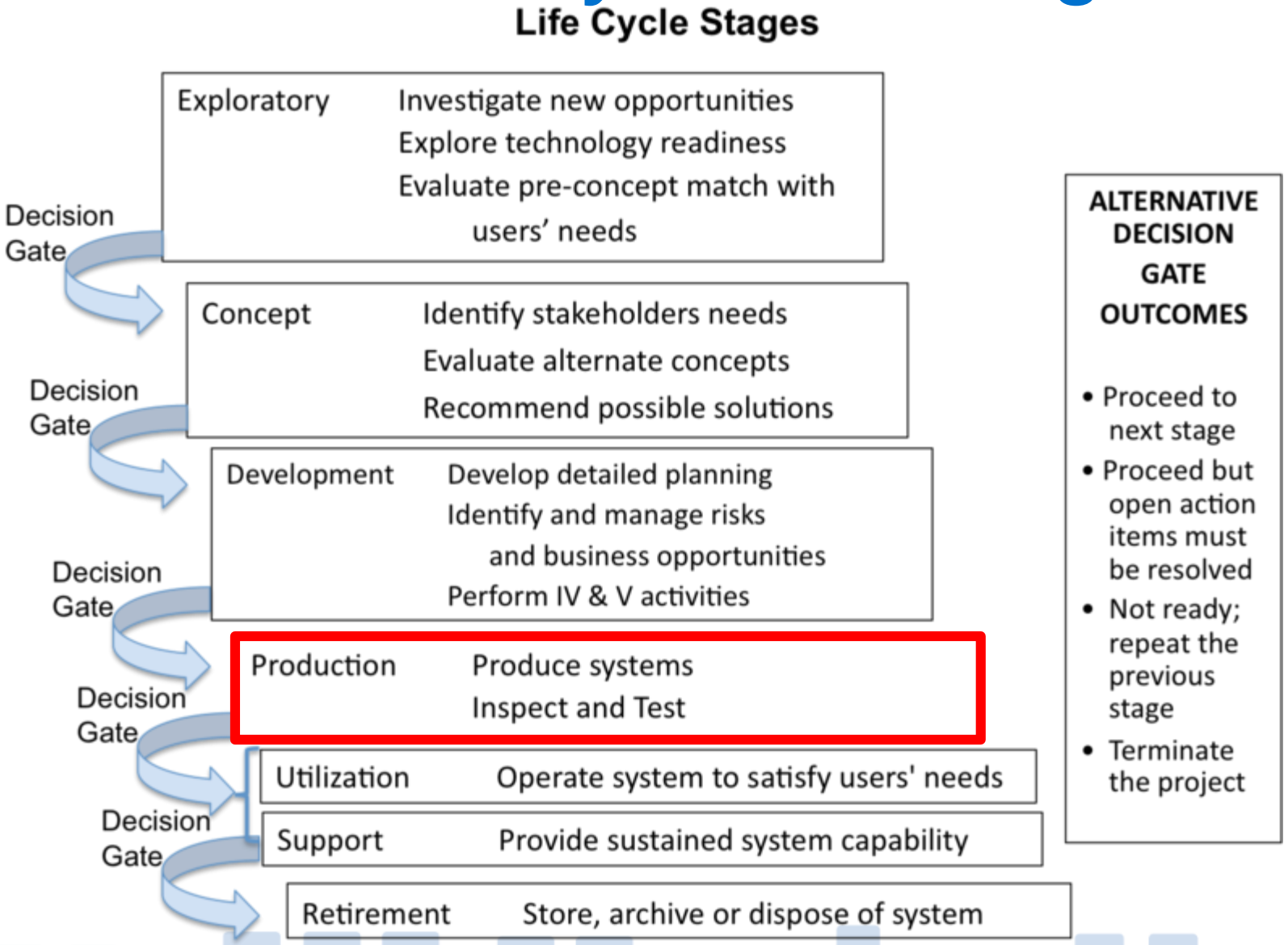
Production and Logistics Modeling Drivers

- Heterogenous System Integration
  - Move away from dedicated (silo'd) domains
  - Design, planning, and operational Control
- "Smart" Systems
  - Cyber-physical components
  - Multi-disciplinary design
- Evolving quickly

Need for Model-Based Methods

- Current methods and tools are limited for production systems engineering
  - Formal specification & analysis automation
  - Design and teaching
- Documentation & Organization of Knowledge
  - Existing Systems Models (industry)
  - Existing Analysis Models (academia)
- Bridge between system and analysis models
  - Interoperability between different analysis models of the same system
  - Greater reusability of analysis: collaboration and automation
  - Modeling & Simulation Interoperability (MSI); Systems Analysis Integration (SAI)

Integrated Production System Design?

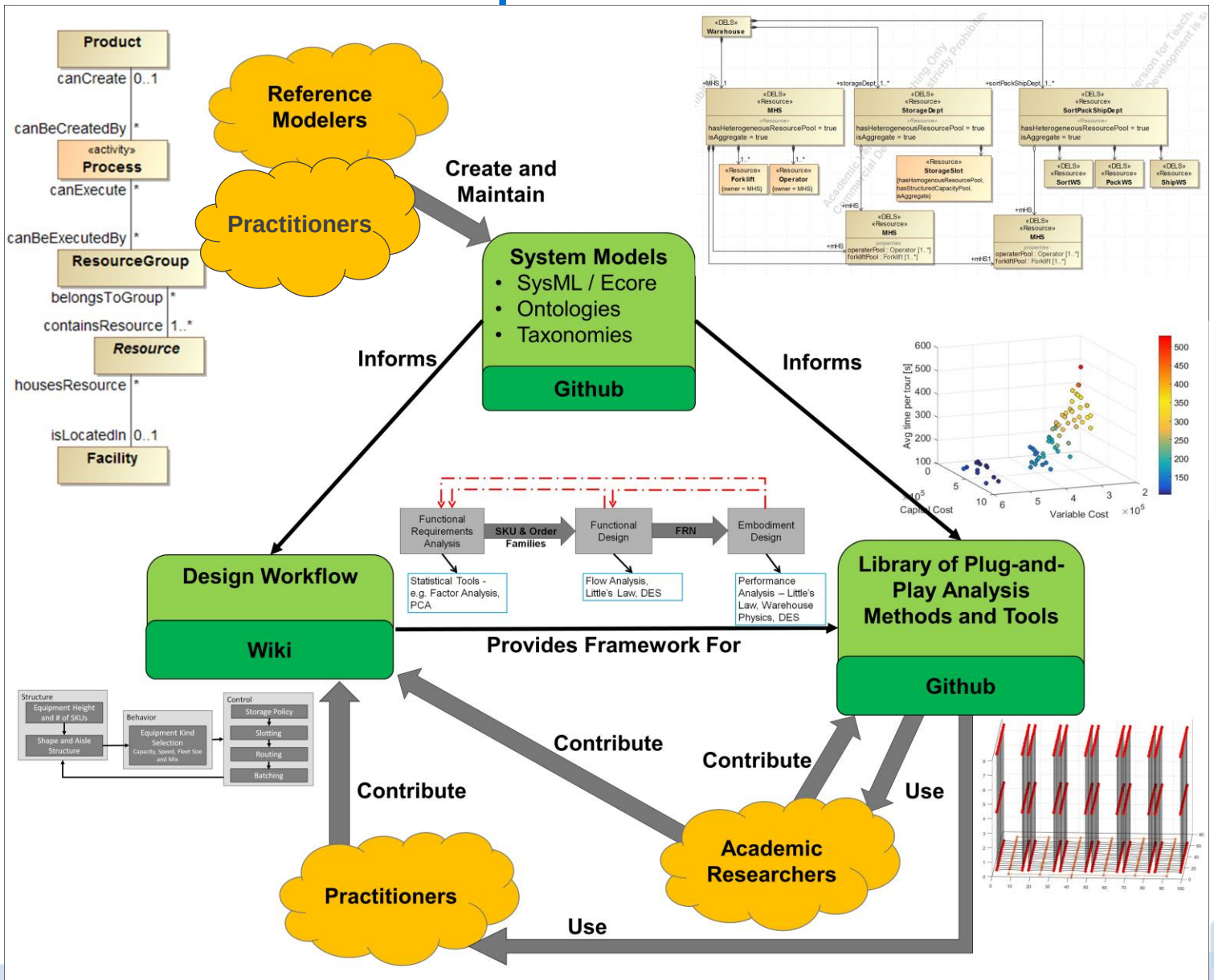


http://sebokwiki.org/wiki/System_Life_Cycle_Process_Models:_Vee

(Re-)Design Scenarios

- New product – Can the supply chain & factory support it? In addition to existing products, as a replacement?
- New Technologies – Automation: material handling, storage systems … How “big”?
- New Control Strategies – Releasing work into plant, assigning most specialized workers

Mechanisms for development collaboration



Ubiquitous System Models: Where to start?

- Product, Process, Resource, & Facility
- How do you control your system?
- What do you want to know about the system?

INCOSE can have a big impact on this domain

- In the design of logistics systems, we don't have good SE tools and practices
- In addition to the SE best practices, MBSE has been transformative!
- Explicit modeling and design methods
  - Consensus on how we talk about our artifacts and design them
- What are the things we need to do to have an impact:
  - Reference models, common design process, conforming and supporting analysis models and tools.
  - Build a community around a shared vision of DELS MBSE

It’s (long past) time to bring the power of (model based) systems engineering to production systems and global supply chains!

What does it take to do that?

Where are we in the journey?

Monday @ 1:00pm in Boardroom 2

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conrad.bock@nist.gov

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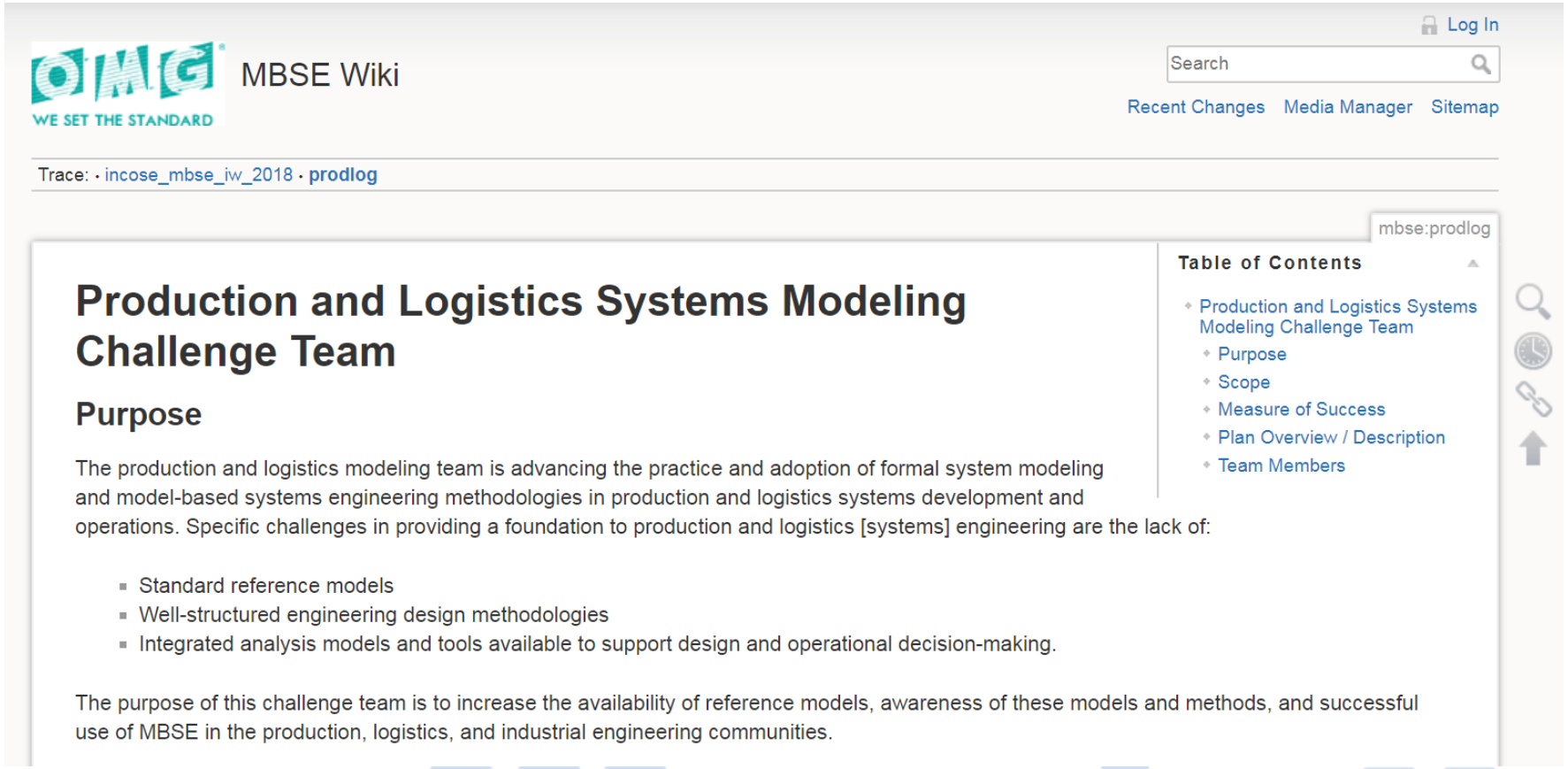
Agenda

- Charter Overview
- Reference Models for Semiconductor Wafer Fabrication
  – Leon McGinnis, Georgia Tech
- System Analysis Integration: Value Stream Mapping
  – George Thiers, Modgeno, Inc.
- Roadmap:
  - Document existing models and make them available
  - Identify a Case Study: System Modeling Example
  - Identify Potential Liaisons

Production and Logistics Systems Modeling Charter Overview

- http://www.omgwiki.org/MBSE/doku.php?id=mbse:prodlog



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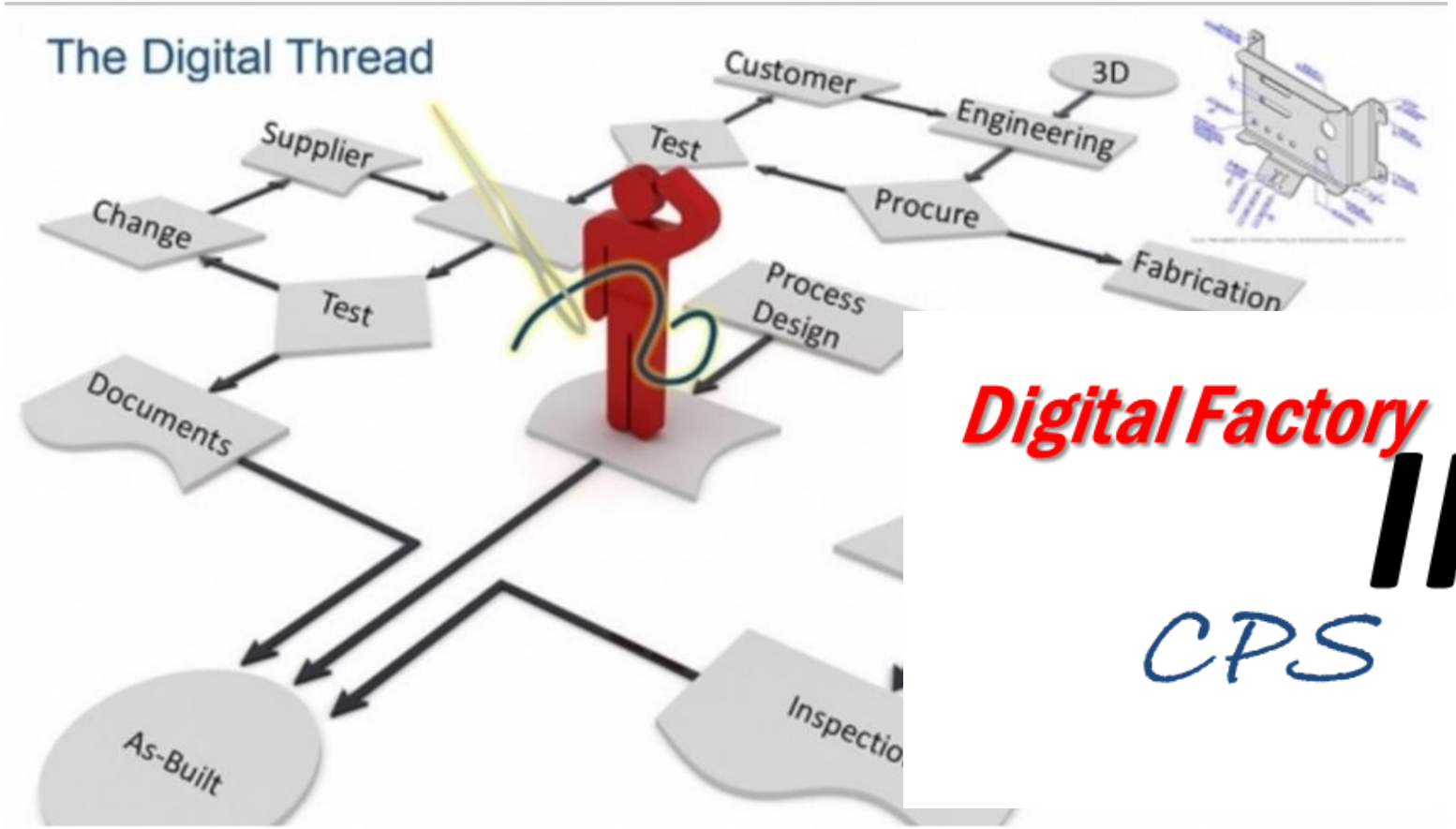
Context



Digital Factory

Industry 4.0

IIoT

CPS

Brilliant Factory

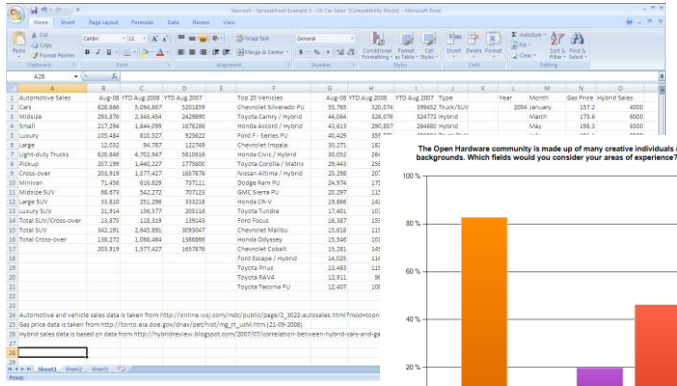
http://www.industryweek.com/systems-integration/demystifying-digital-thread-and-digital-twin-concepts?page=2

Why do it?

- Better decision making
  - Better: decision support analysis
  - Faster: integrate processes
  - Cheaper: automate the routine

Better decision support is a target-rich environment!

System Models



System Model Sufficiency

- Complete enough for the decision at hand
- Correct enough for the decision at hand
- Accessible and usable for the decision at hand

Where are we today?

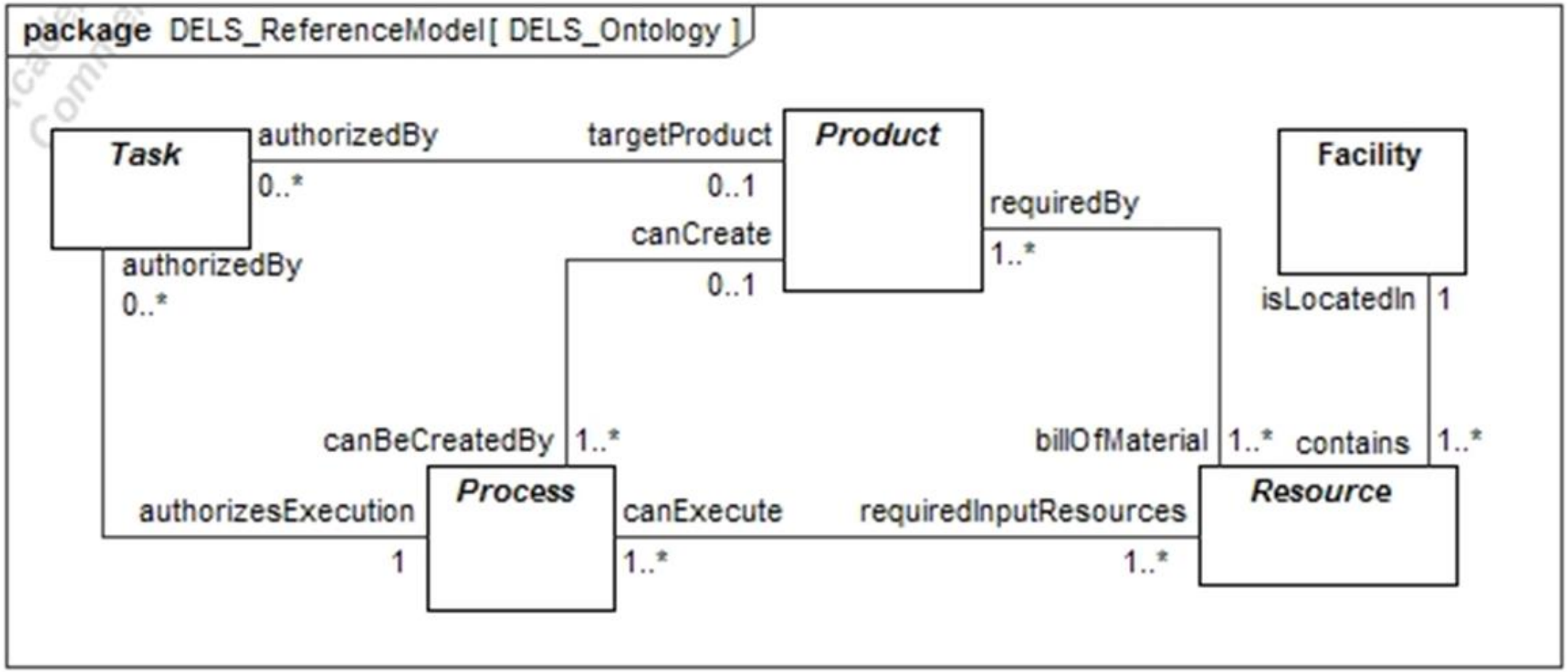
- Spreadsheets
- AutoCAD drawings
- Wetware

We need better production system models!

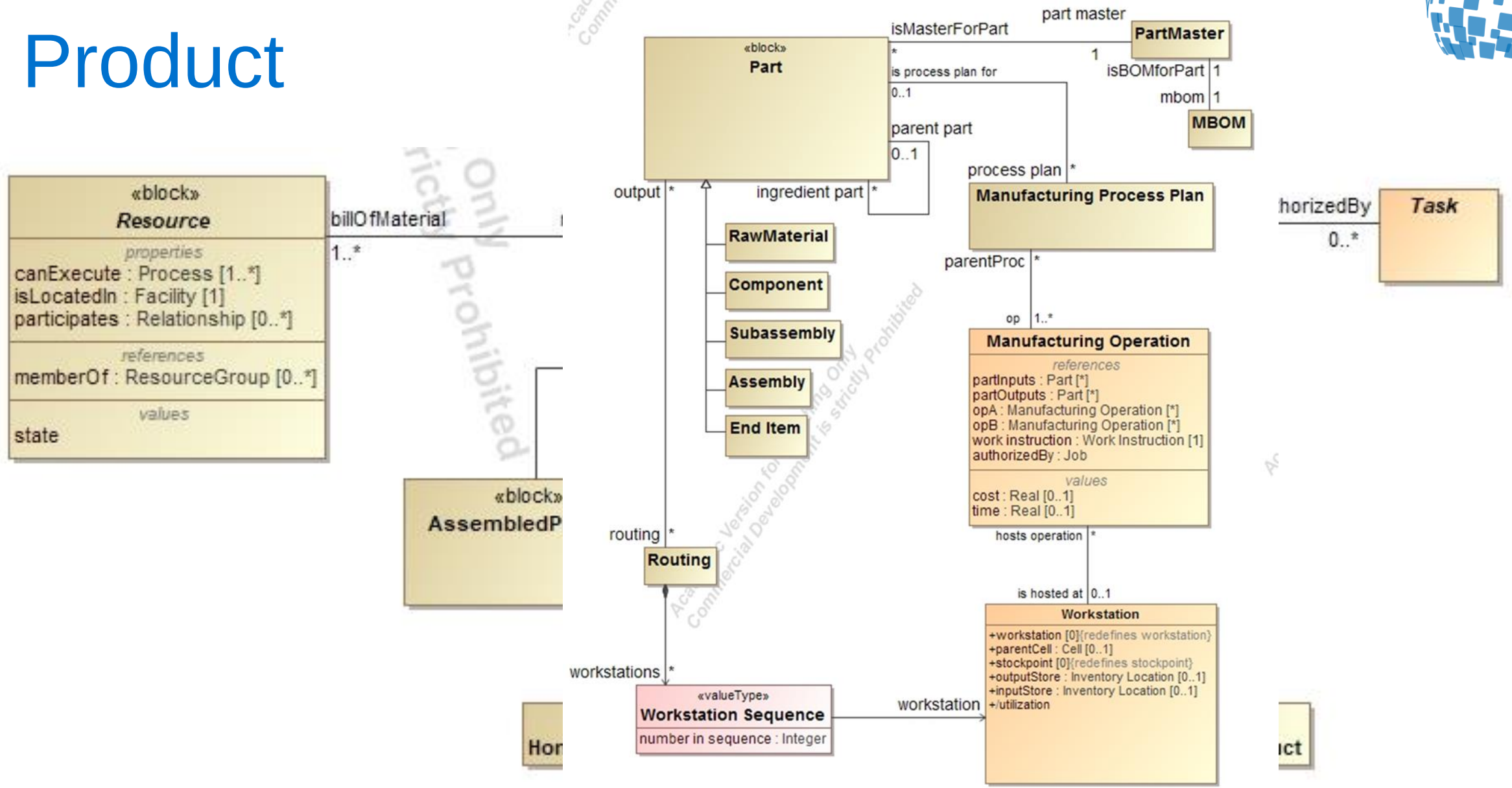
Progress from the Keck Virtual Factory Lab

- DELS: discrete event logistics systems—
  products move through a network of resources executing processes that transform the product to higher value
- Modeling framework:
  - Product/process/resource/facility
  - Plant/control separation
  - Control abstractions
- Reusable abstractions

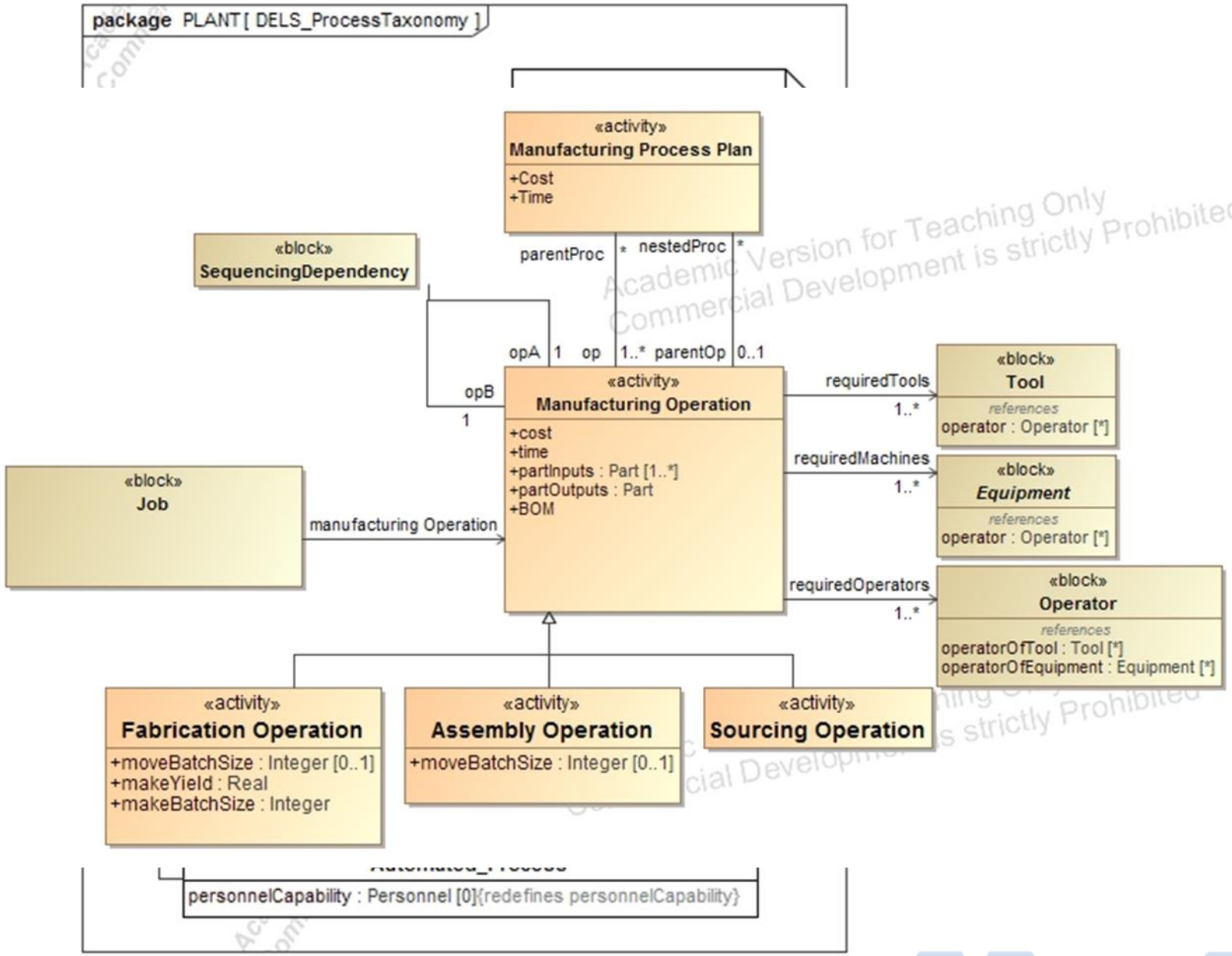
Framework


package DELS_ReferenceModel[DELS_Ontology]
Task
authorizedBy
0..*
targetProduct
0..1
Product
Facility
canCreate
0..1
requiredBy
1..*
authorizedBy
0..*
isLocatedIn
1
canBeCreatedBy
1..*
billOfMaterial
1..*
contains
1..*
Process
Resource
authorizesExecution
1
canExecute
1..*
requiredInputResources
1..*

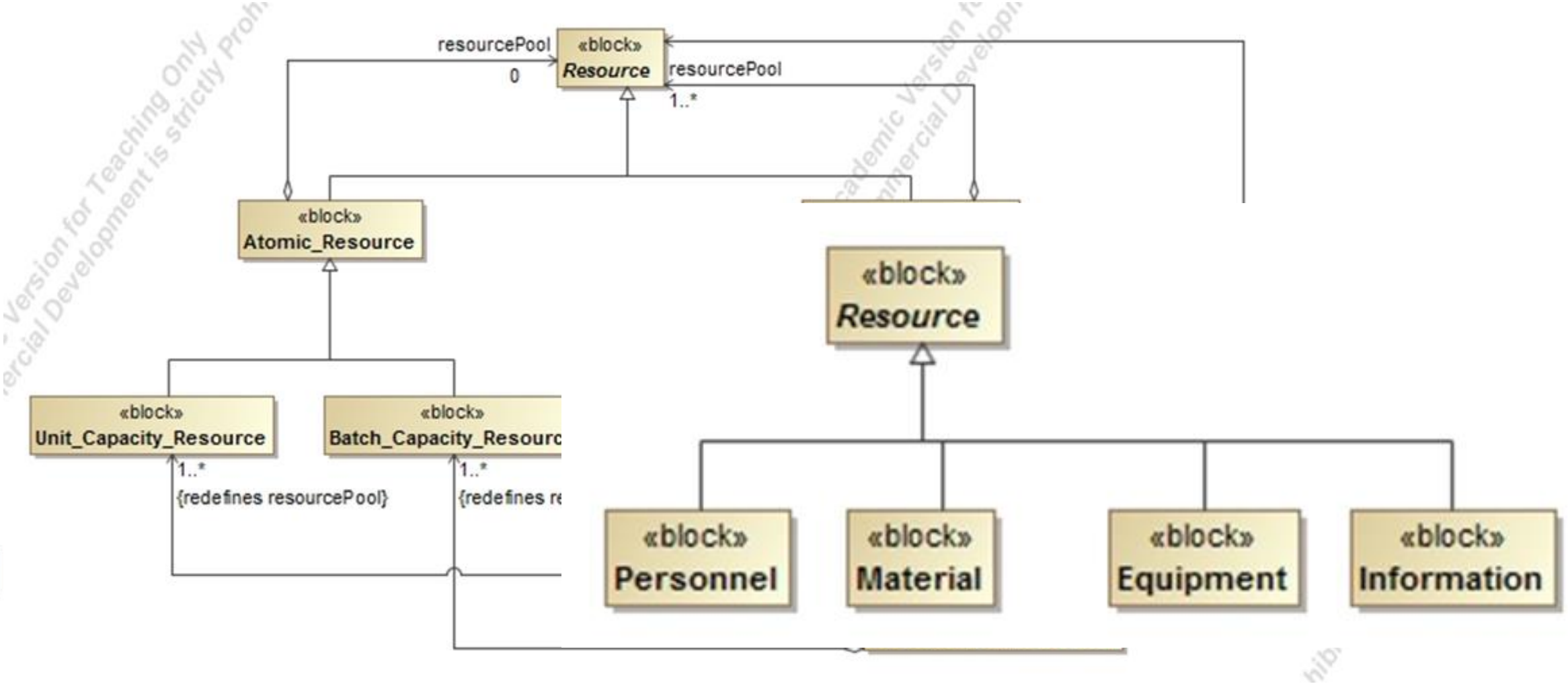
Product


«block»
Resource
properties
canExecute : Process [1..*]
isLocatedIn : Facility [1]
participates : Relationship [0..*]
references
memberOf : ResourceGroup [0..*]
values
state
billOfMaterial
1..*
«block»
AssembledP
Hor
«block»
Part
isMasterForPart
part master
PartMaster
isBOMforPart
mbom
MBOM
is process plan for
0..1
parent part
0..1
process plan
Manufacturing Process Plan
output
ingredient part
RawMaterial
Component
Subassembly
Assembly
End Item
parentProc
op
1..*
Manufacturing Operation
references
partInputs : Part [*]
partOutputs : Part [*]
opA : Manufacturing Operation [*]
opB : Manufacturing Operation [*]
work instruction : Work Instruction [1]
authorizedBy : Job
values
cost : Real [0..1]
time : Real [0..1]
hosts operation
is hosted at
0..1
routing
Routing
workstations
«valueType»
Workstation Sequence
number in sequence : Integer
workstation
Workstation
+workstation [0]{redefines workstation}
+parentCell : Cell [0..1]
+stockpoint [0]{redefines stockpoint}
+outputStore : Inventory Location [0..1]
+inputStore : Inventory Location [0..1]
+/utilization
horizedBy
0..*
Task
uct

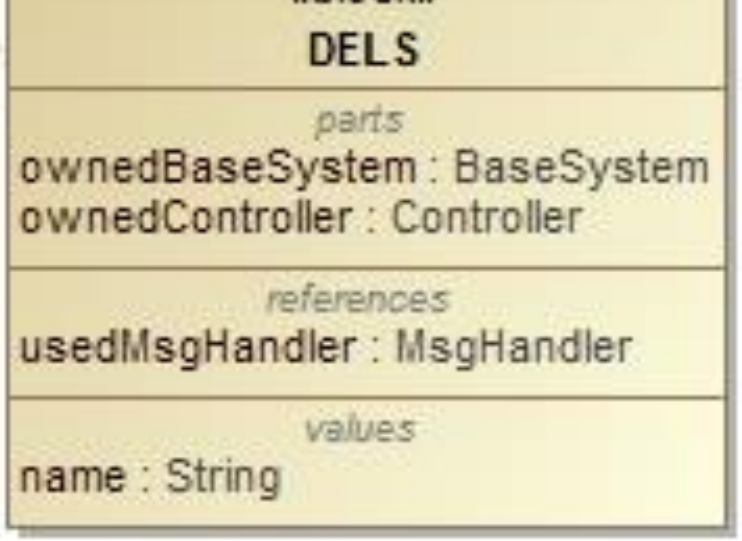
Process

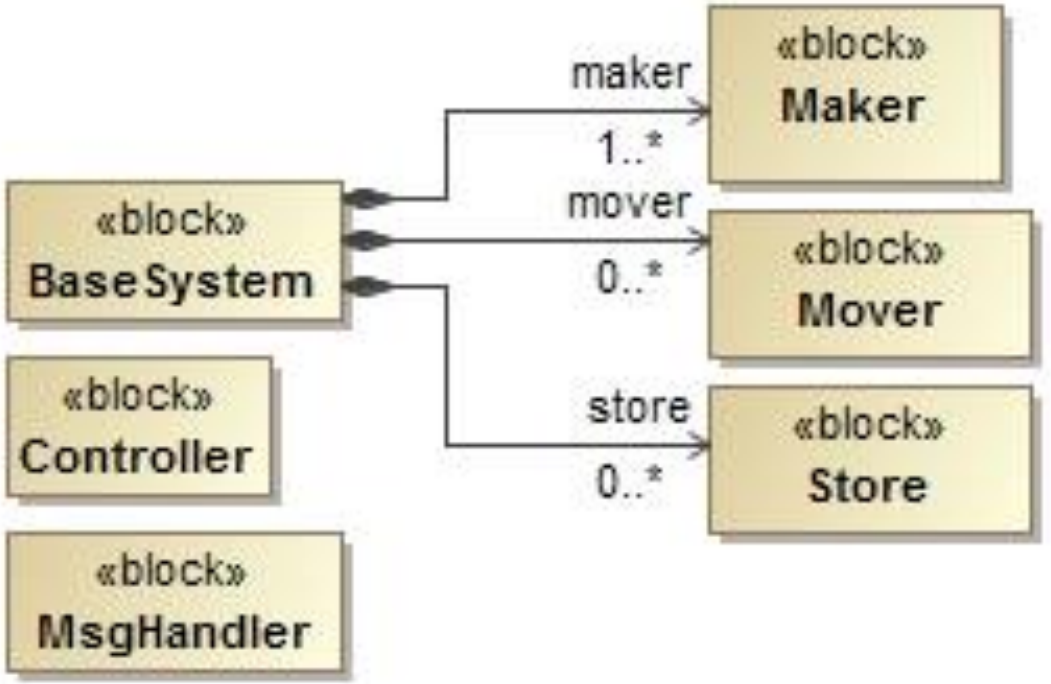


Resource

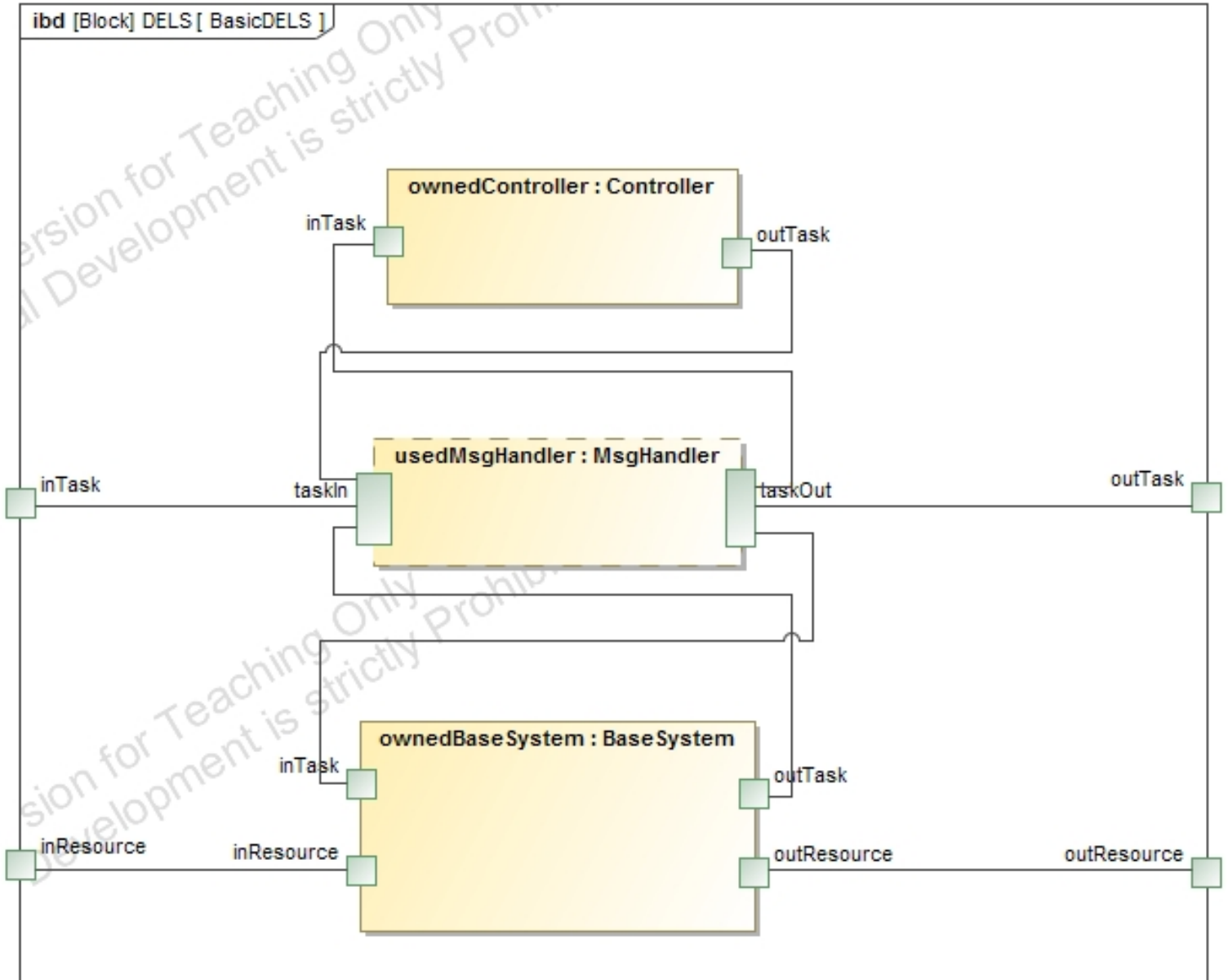

resourcePool
0
«block»
Resource
resourcePool
1..*
«block»
Atomic_Resource
«block»
Resource
«block»
Unit_Capacity_Resource
«block»
Batch_Capacity_Resourc
1..*
{redefines resourcePool}
1..*
{redefines re
«block»
Personnel
«block»
Material
«block»
Equipment
«block»
Information

Example: Basic DELS Elements

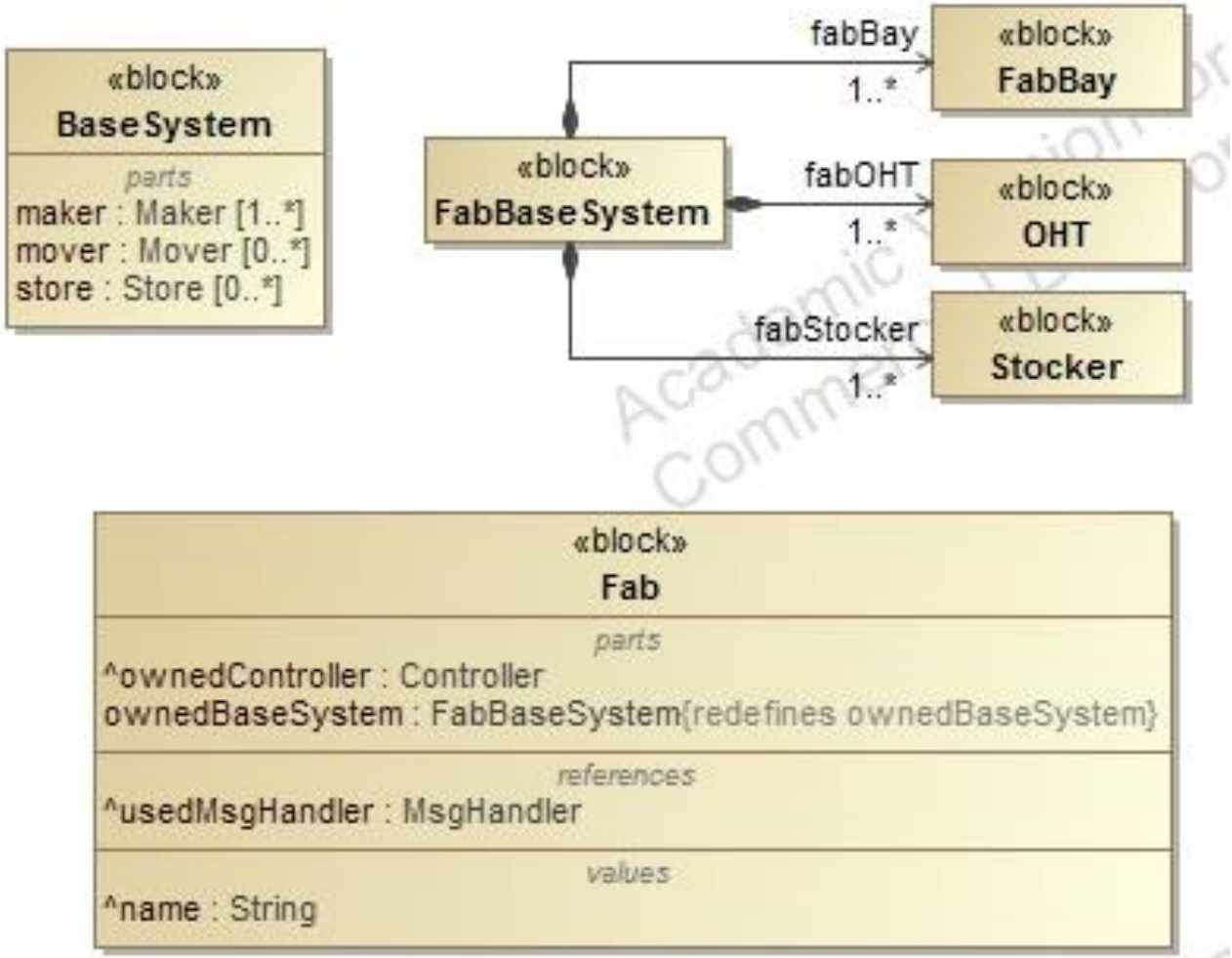




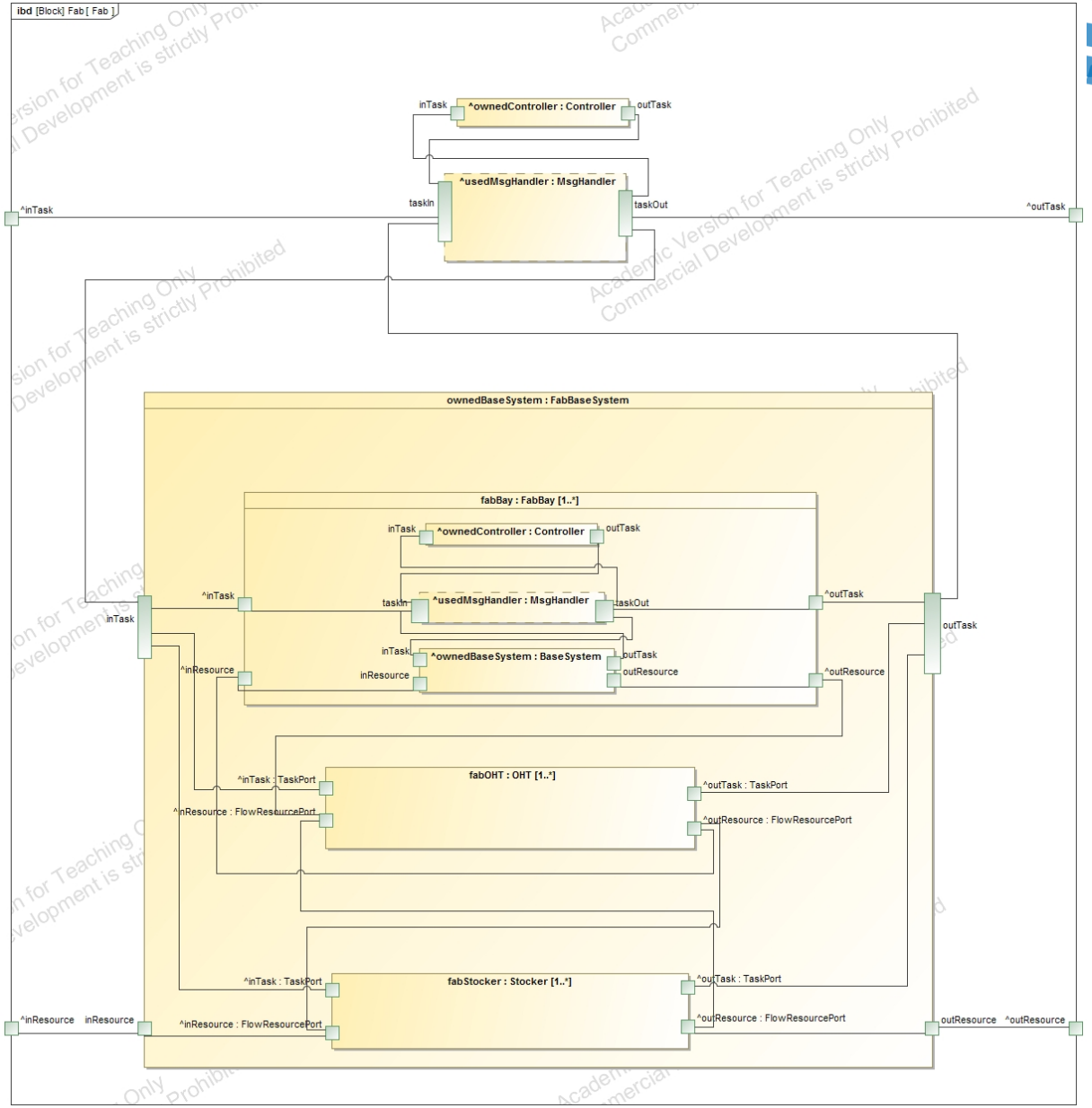
Basic DELS Structure



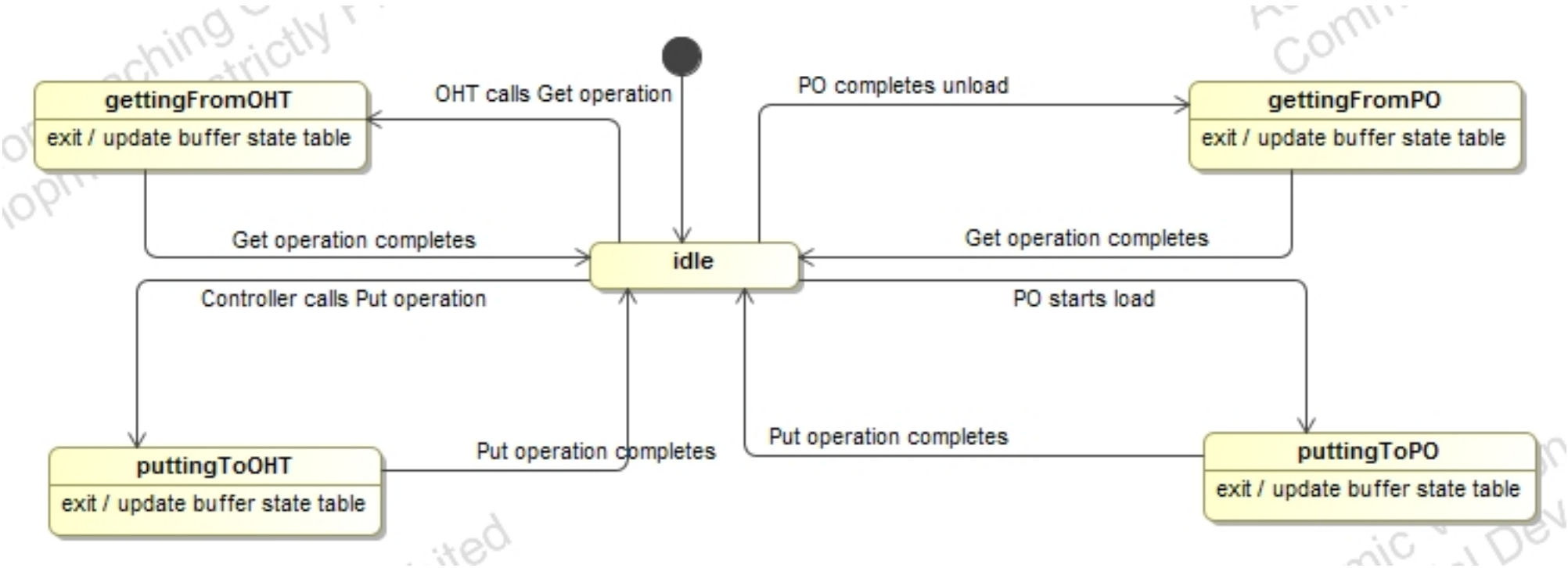
Wafer Fab Plant



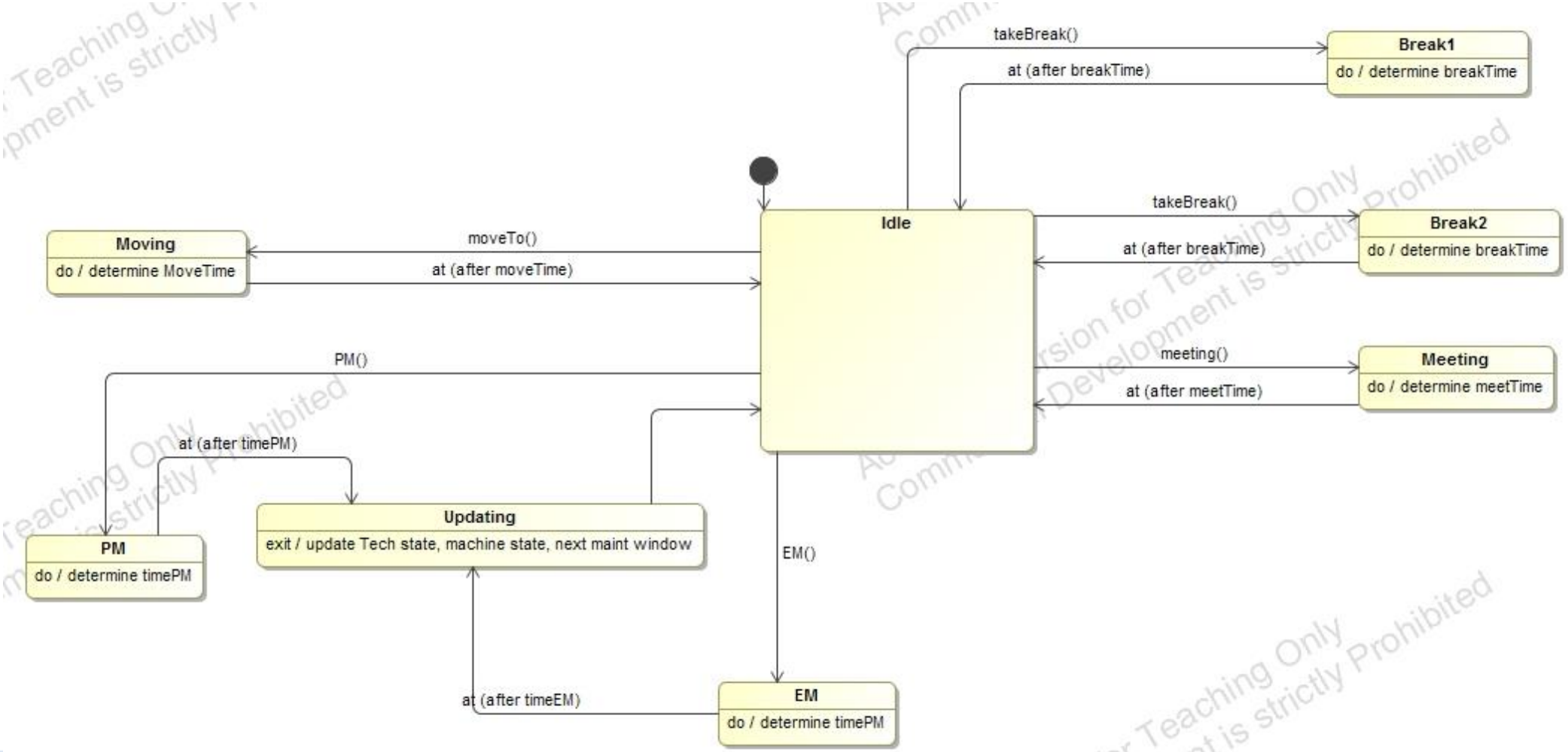
Wafer Fab Structure



Behavior of Stocker



Behavior of Operator



What have we gained?

- Very precise specification of structure and behavior
- Basis for system design, especially operational control
- Basis for a “digital twin”—a simulation model that approximates the physical system behavior
- Basis for software generation of simulations

Roadmapping

- Standard libraries of resource models
- Standard libraries of process models
- Standard libraries of behavior models
- Standard libraries of control models
- Exemplars of system models

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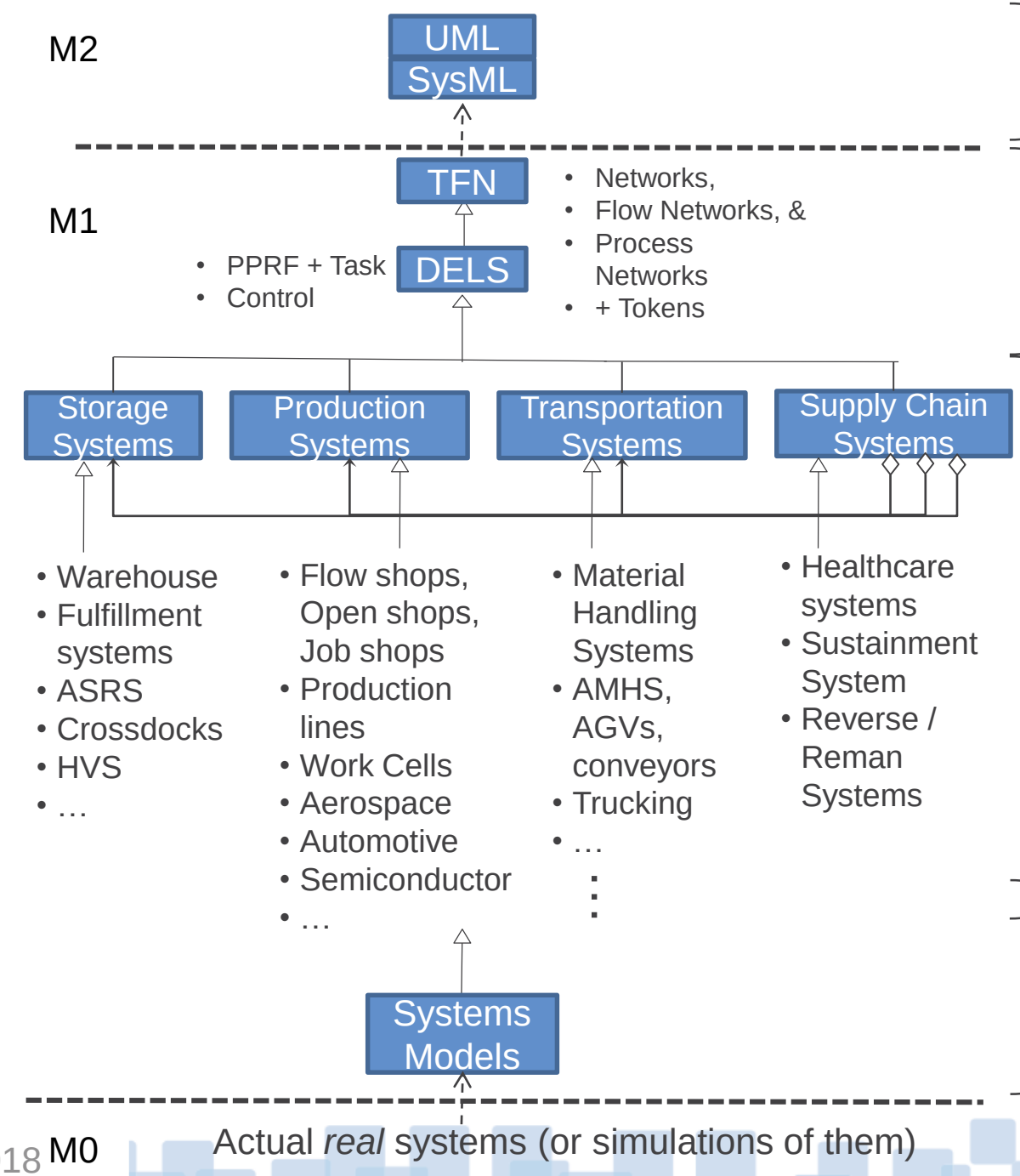
Roadmap – Document Existing Models

- Cleanup and Document Existing Models (Ongoing)
  - Supply Chain, (Aerospace) Manufacturing, Warehousing
  - Wafer Fabrication, Pharmaceutical Fulfillment
  - Discrete Event Logistics Systems (DELS) Abstraction
  - Transition from mdzip to xmi format

- https://github.com/usnistgov/DiscreteEventLogisticsSystems
- Email me at timothy.sprock@nist.gov for access
  - (need github account)



Language Layer

- May also include a TFN & DELS DSL

Top of M1

- **DELS Reference model**
- Network Abstractions
- PPRF Domain Ontology
- PPRF Taxonomies & Model Libraries
- Control Patterns

Middle of M1

- **(sub-) Domain-specific reference models and architectures**
- Generalization Set aligns with STORE, MAKE, & MOVE processes

Bottom of M1

- **System Models**
- "as-built" or "specification" models

Roadmap - Identify a Case Study

- "… advancing the practice and adoption of formal system modeling and model-based systems engineering methodologies in production and logistics systems development and operations."
- "Do you have any examples to get me started?"
- Sandy Friedenthal & Chris Oster – "Architecting Spacecraft with SysML: A Model-based Systems Engineering Approach"
  - http://sysml-models.com/spacecraft/index.html

Roadmap - Identify a Case Study

- Include all SysML diagrams and syntax
- Domain-specific concepts:
  - Product, Process, Resource, & Facility
  - How do you control your system?
  - What do you want to know about the system?
  - System Architecture

Roadmap - Liaisons

- ManTIS
- IISE
- SDOs
- Others?

Contact Us:
timothy.sprock@nist.gov
leon.mcginnis@isye.gatech.edu
conrad.bock@nist.gov

Links:

http://www.omgwiki.org/MBSE/doku.php?id=mbse:prodlog

https://github.com/usnistgov/DiscreteEventLogisticsSystems

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