THE CHALLENGE OF PLANT-CONTROL SEPARATION IN WAFER FAB SIMULATIONS

LEON MCGINNIS

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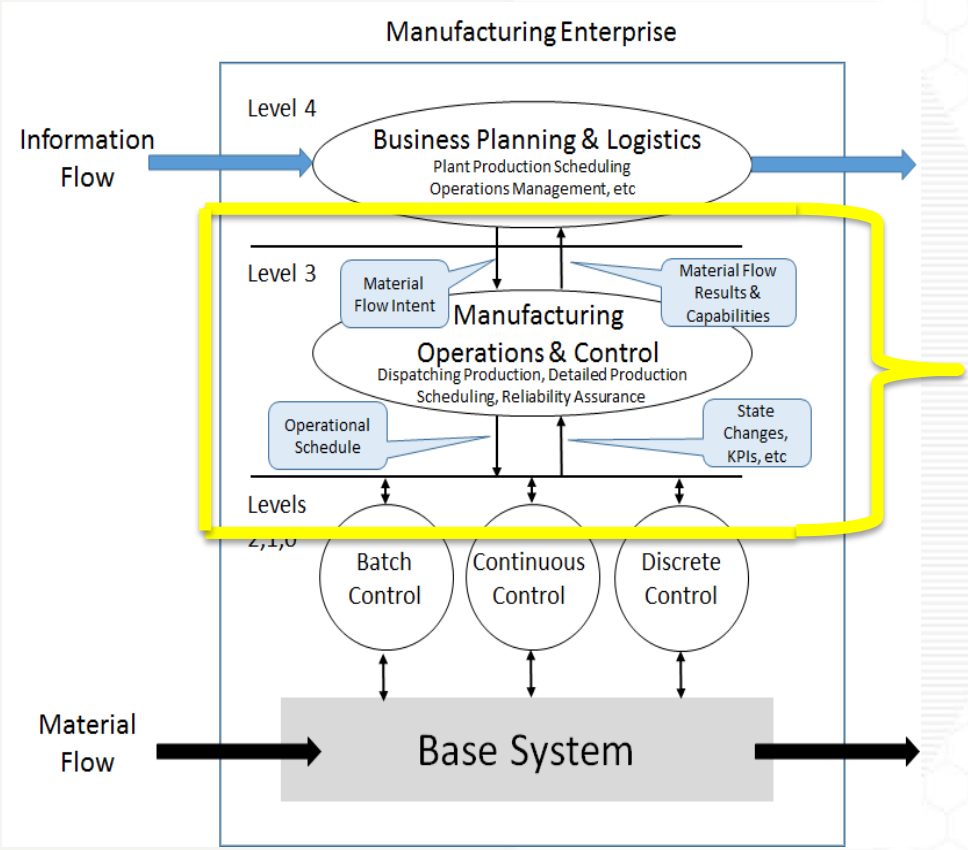
MOTIVATION

ISA 95 3 Level Control Hierarchy



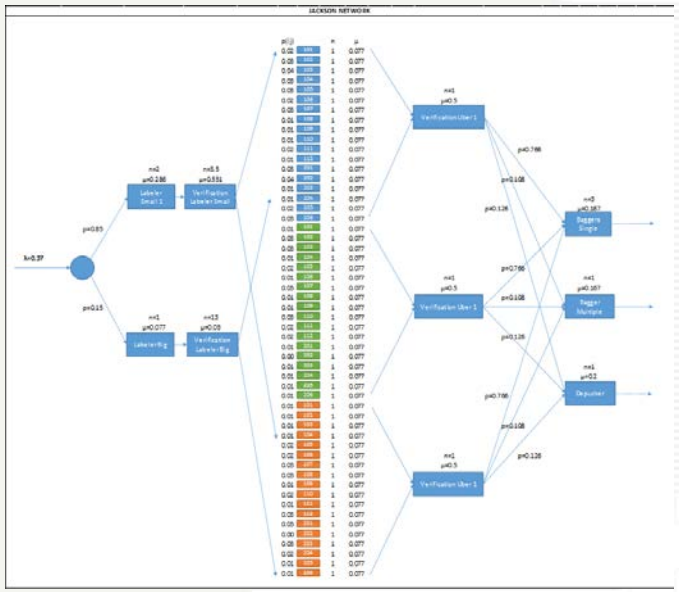
Goal: develop an implementable architecture for ISA 95 Level 3 smart manufacturing operations manager (SMOM). Consider interactions to Levels 2,1,0 for process control and Level 4 for planning. Demonstrate the architecture through testbed implementations representing two distinct application environments—central fill pharmacy and semiconductor wafer fab.

Will simulation even matter in the new world of AI, Big Data, Machine Cognition, Machine Learning, IIoT, Industrie 4.0, …. ?

If it does, then we MUST do something to make factory simulation better, faster and cheaper, because today it is not accurate enough, takes far too long to develop and use and costs far too much in terms of limited human resources.

HOW HAVE WE (RESEARCHERS) THOUGHT ABOUT MANUFACTURING?

Conceptual paradigm underlying all commercial simulation languages
The only “control” possible is the selection from a queue



We call it a “network of queues”,
not a “network of servers”

WHAT IS MANUFACTURING REALLY?

The fab is:

- Network of resources—OHT, stockers, process tools
- Each with specific behaviors, or capabilities to execute processes
- Product—foups—move through this network of resources, where resources execute processes to transform the product to a more valuable state
- Control systems tell these resources which behaviors to execute and when
- An example of a ‘discrete event logistics systems”, or DELS

FUNDAMENTAL DISCONNECTS

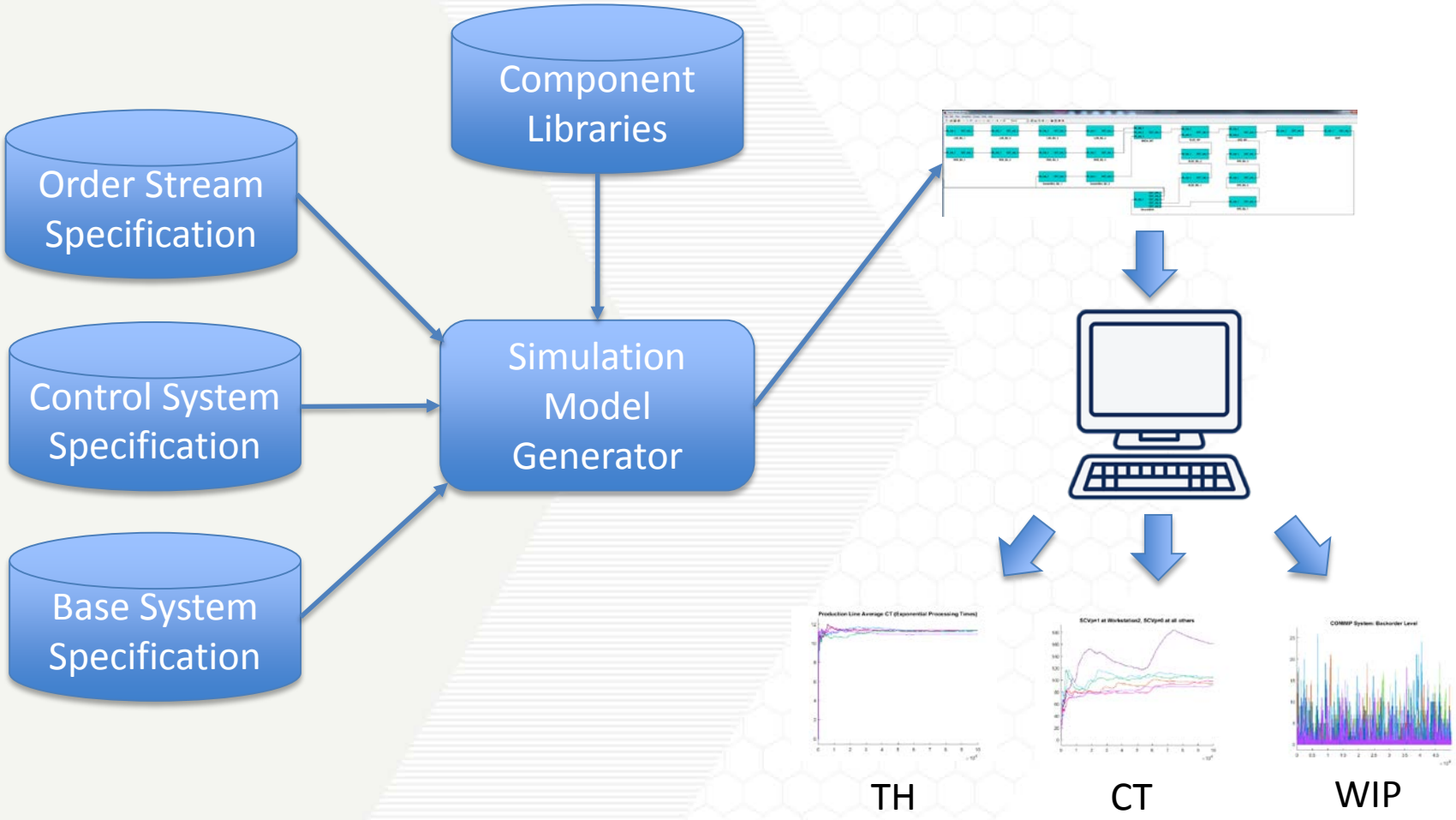
- The queueing paradigm has a very limited capability for representing control
  - This is a crippling limitation for researchers
  - This is a tremendous cost sink for practitioners
- In manufacturing, there are no queues, only resources with behavioral capabilities (this is not quite true—I'll discuss this more in a minute)
  - Control engineers write software that drives these resources
- Up until now, there has not been an effective methodology for bridging the gulf between the "language of queues" and the "language of control"

BRIDGING THE GULF

- Formal models of discrete event logistics systems, capturing resources, interfaces, behaviors, controls, products, processes
- At multiple levels of abstraction (***just like for integrated circuits!***)
- Ability to use models of DELS instances as the baseline for creating decision support analysis models (***so our results can be effectively communicated to controls engineers and actually used!***)
  - Even if the decision support is an agent/machine intelligence/AI….

A suggested approach to bridging the gulf

GOAL: A USEFUL "VIRTUAL FACTORY"



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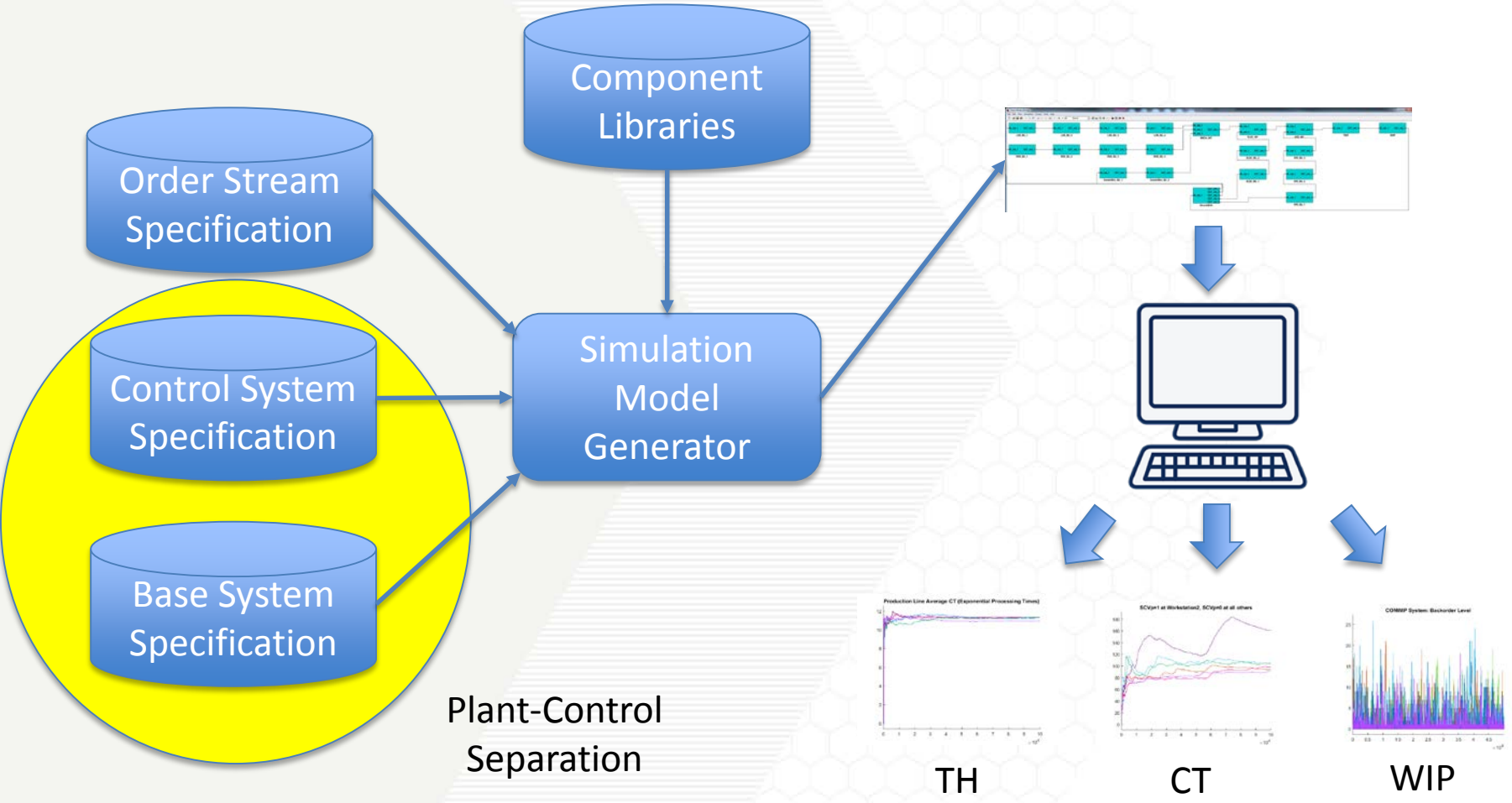


GOAL: A USEFUL "VIRTUAL FACTORY"

Adjustable
Synthetic Data

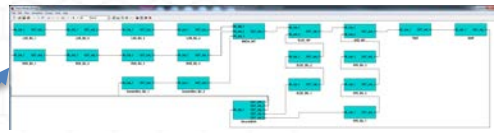
Order Stream Specification

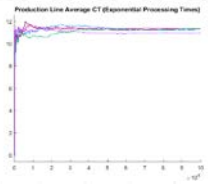
Component Libraries

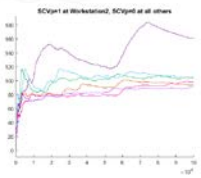
Control System Specification

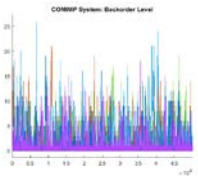
Base System Specification

Simulation Model Generator









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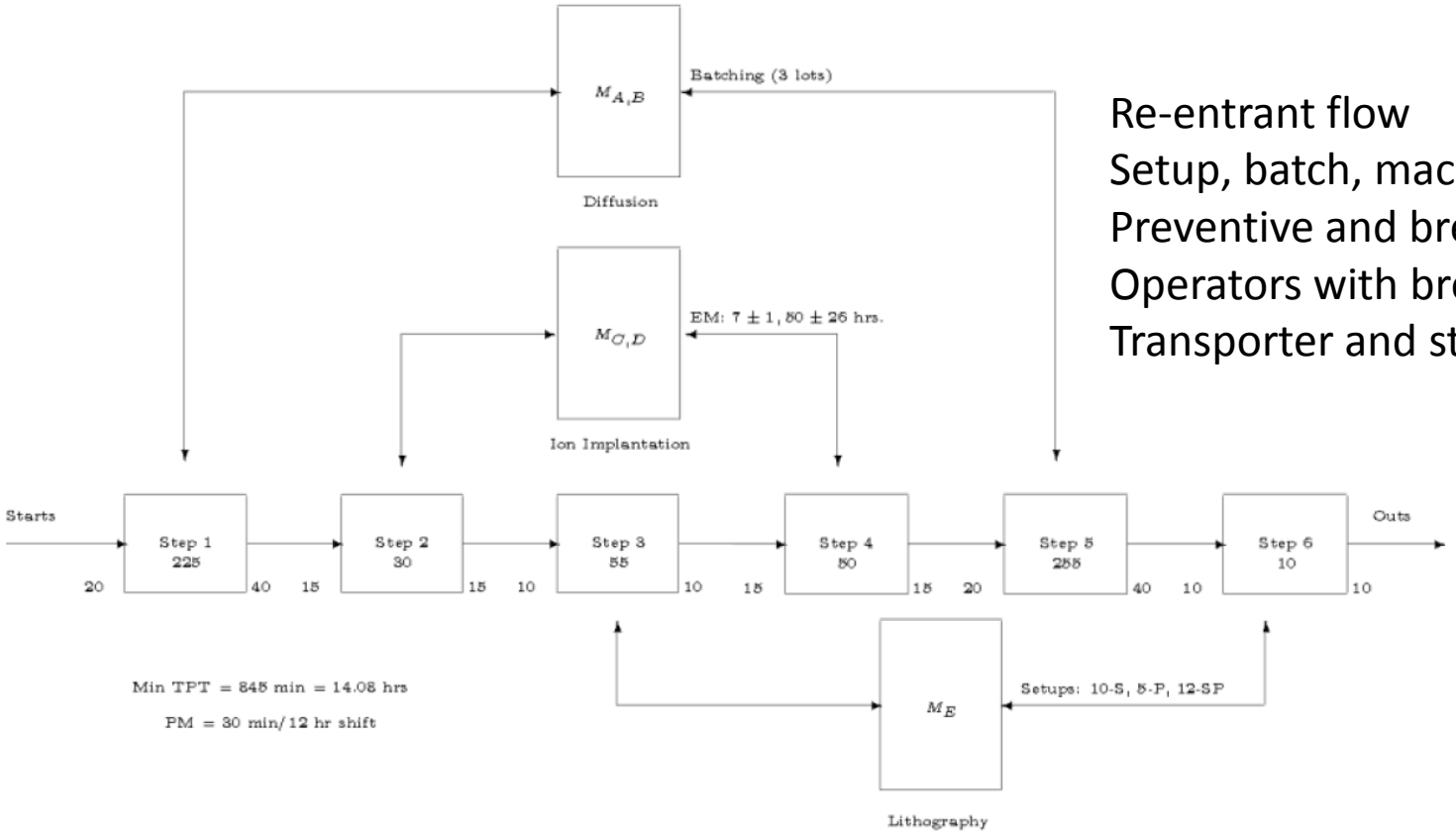
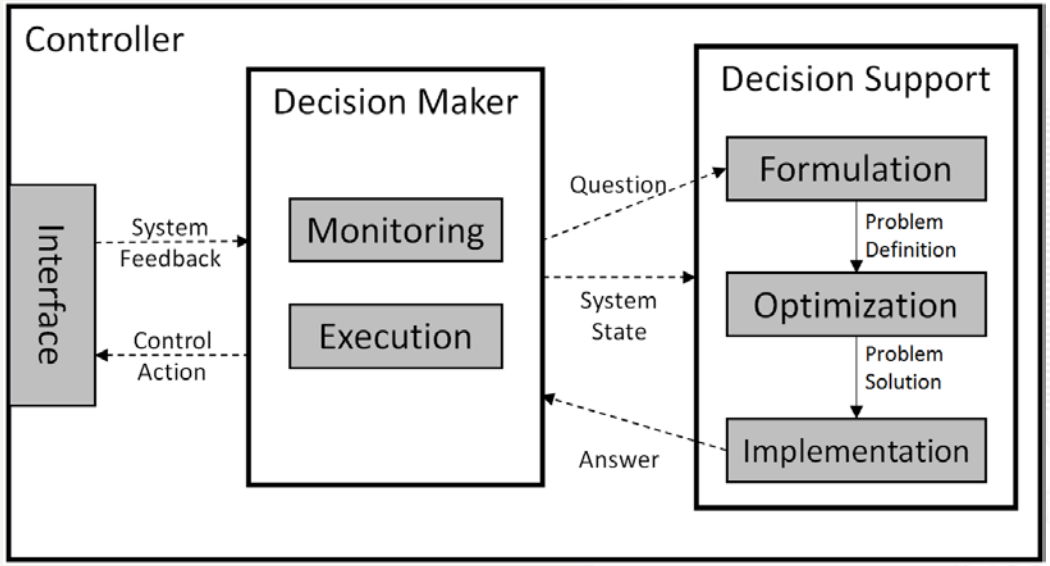
INTEL MINI-FAB PROBLEM



Re-entrant flow
Setup, batch, machine failure
Preventive and breakdown repair
Operators with breaks and mtgs
Transporter and stockers

If we are going to separate plant and control, we must have some conceptual model of “controller”

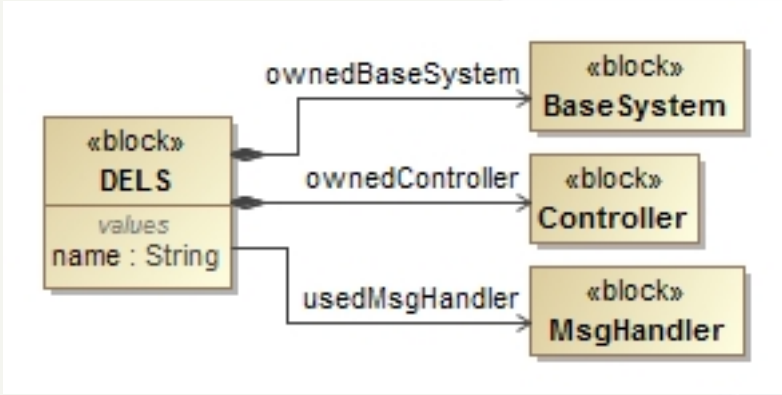
CONTROLLER CONCEPTUAL MODEL

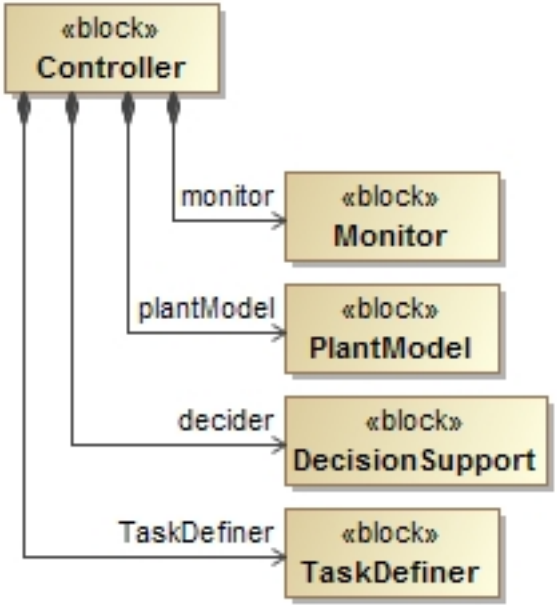


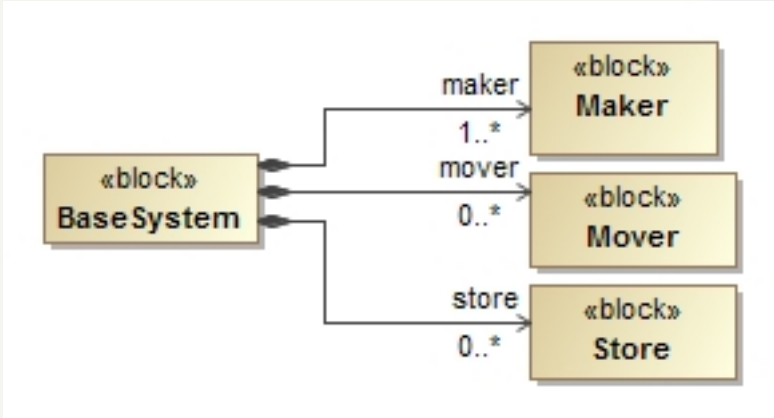
Controller requirements

- Event driven decision-making
- State-based decision-making
- All actuation via base system
- Decision support has well-defined interface

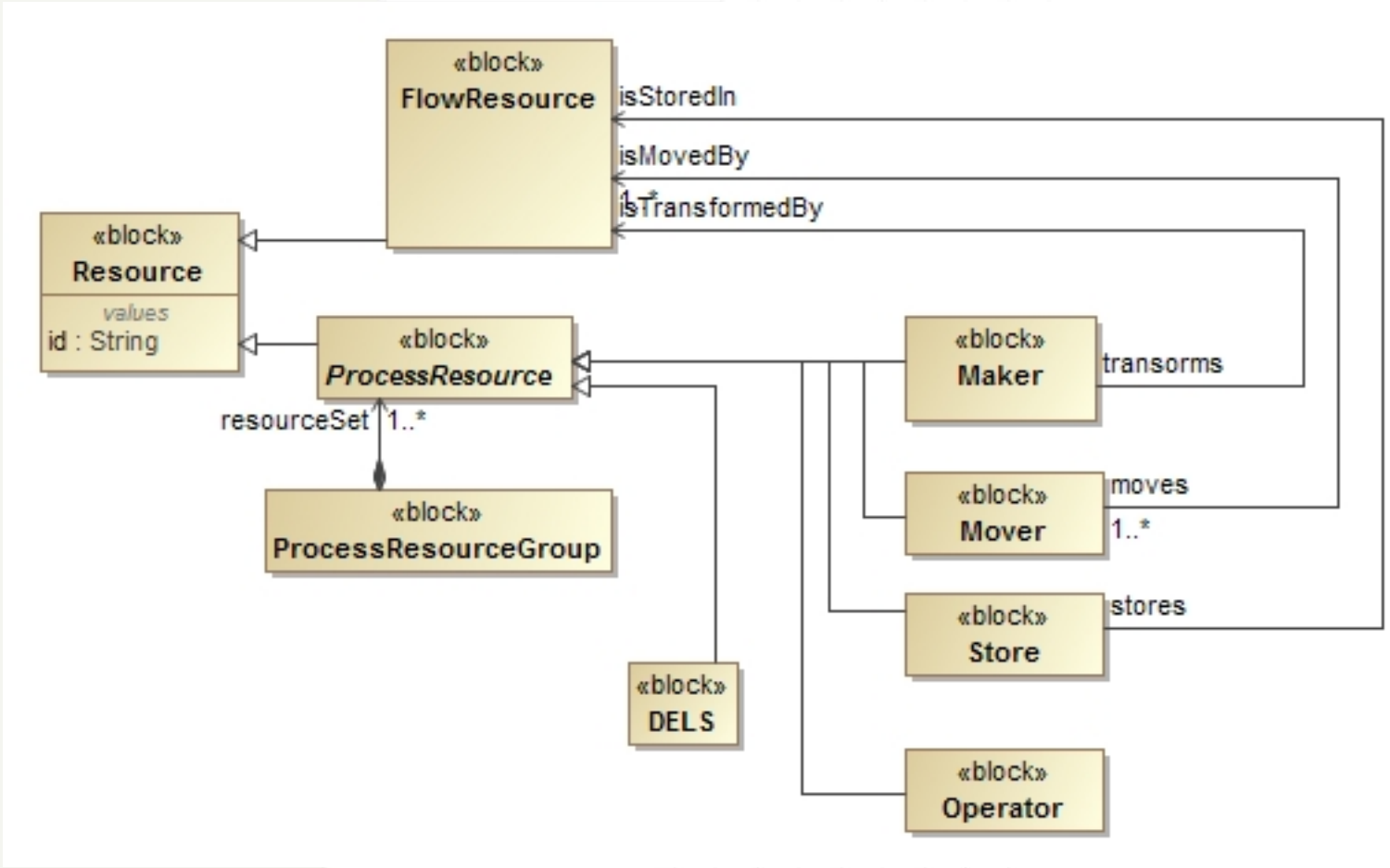
DEFINING DELS



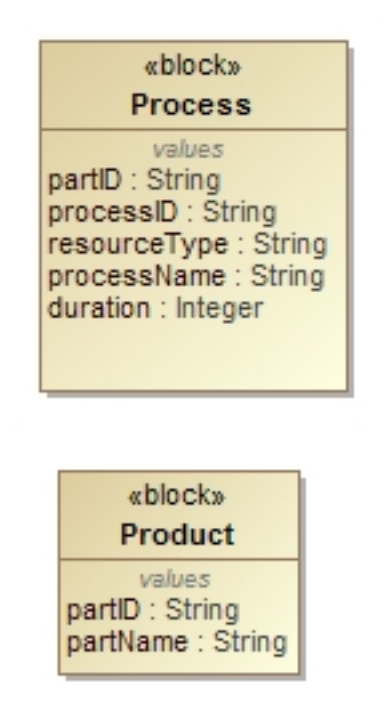




DELS RESOURCES



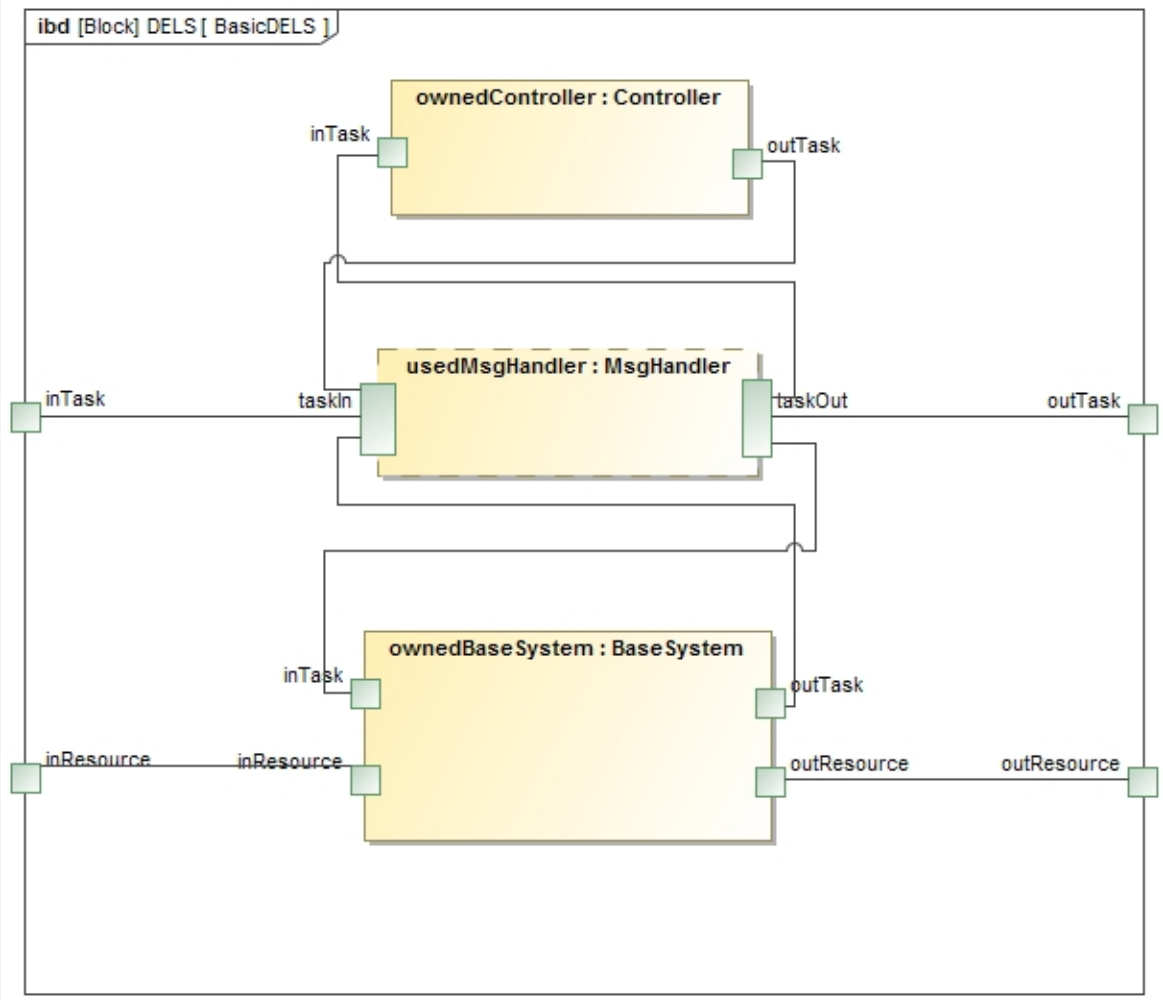
DELS PROCESSES



For a process to be executable, there must be some resource in the base system having the capability to execute that process (or the capability to be reconfigured to execute that process, where the reconfiguration itself is a behavioral capability)

A product has an associate process, and that process can “nest” multiple ‘sub’ processes, with constraints such a precedence, timing, etc.

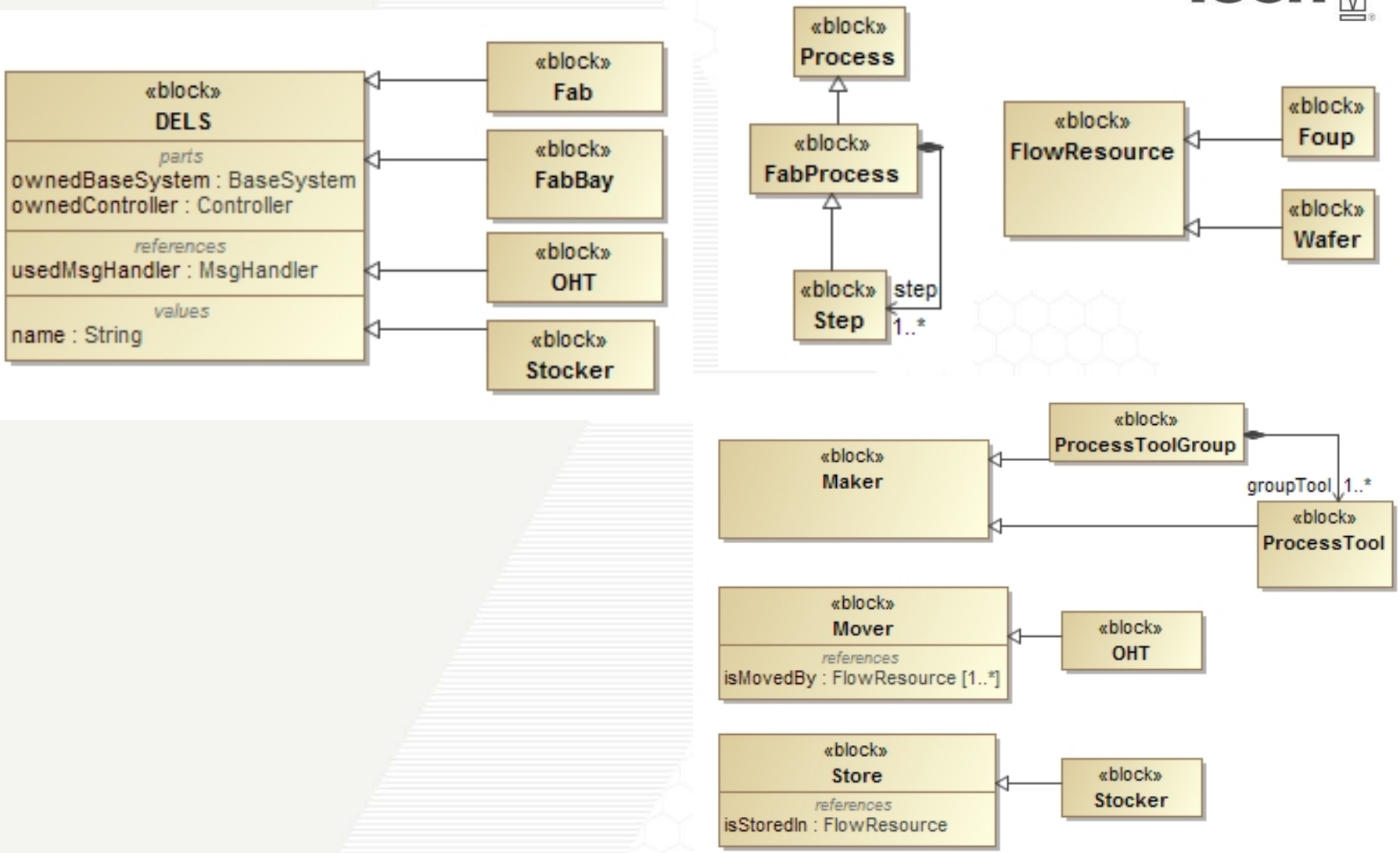
DELS



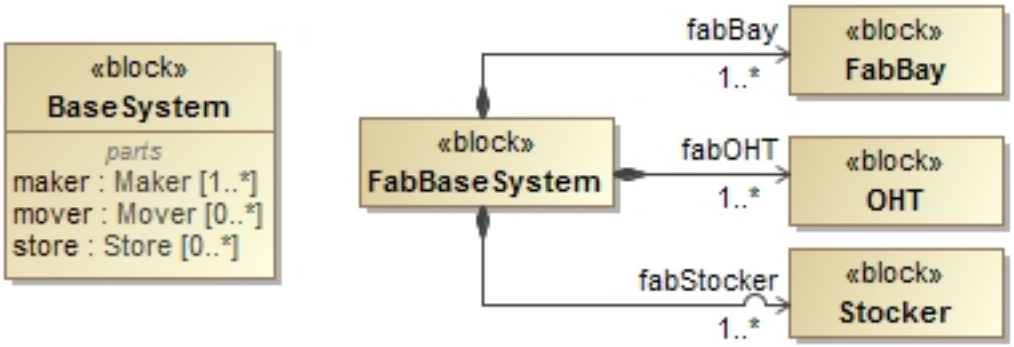
We must be able to precisely define what flows on the connections, and the detailed structure of the interfaces.

"Task" is used here to represent both "commands" to the base system and "event" messages from the base system.

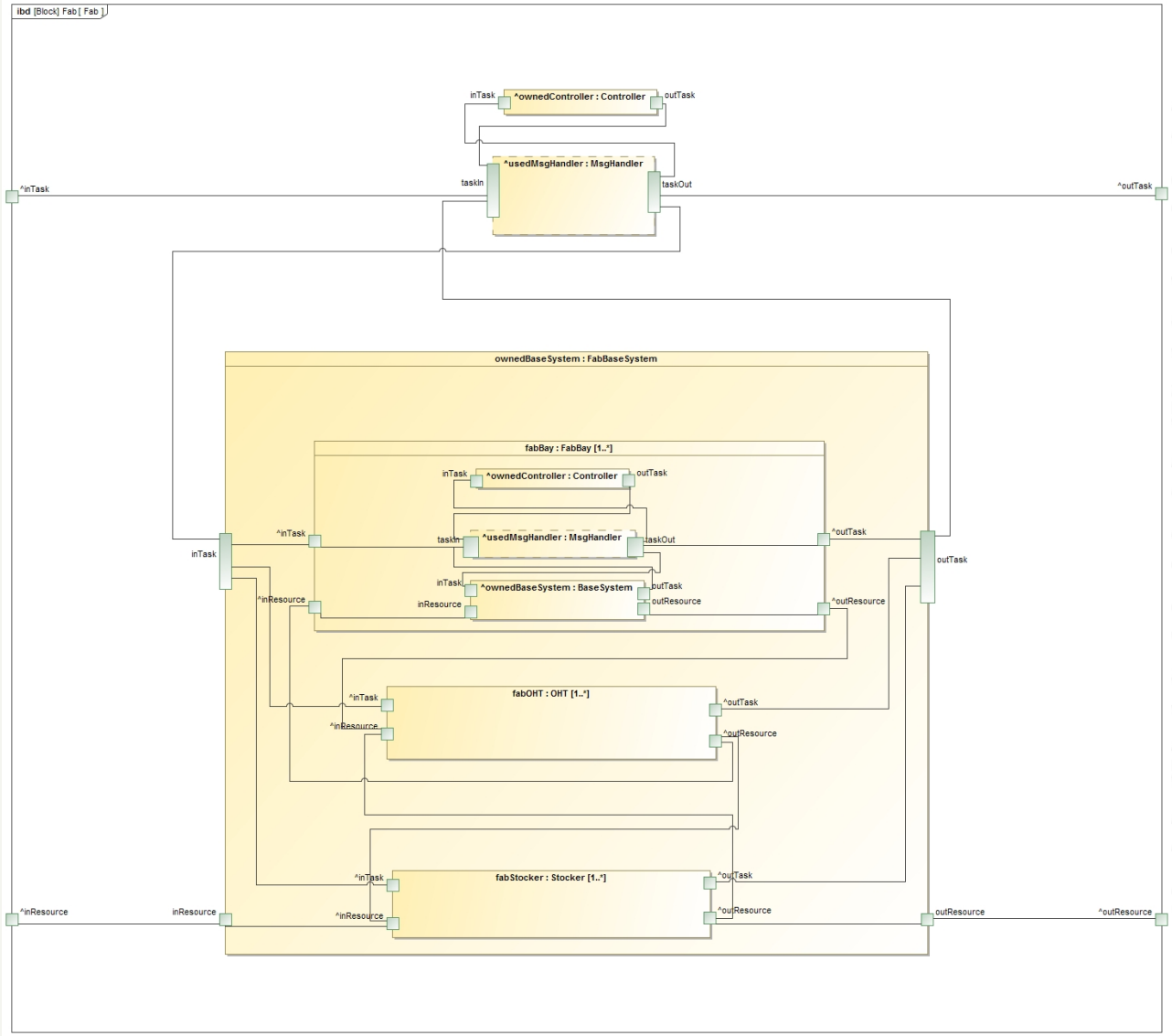
DOMAIN SPECIFIC CUSTOMIZATION



FAB DOMAIN DELS MODEL

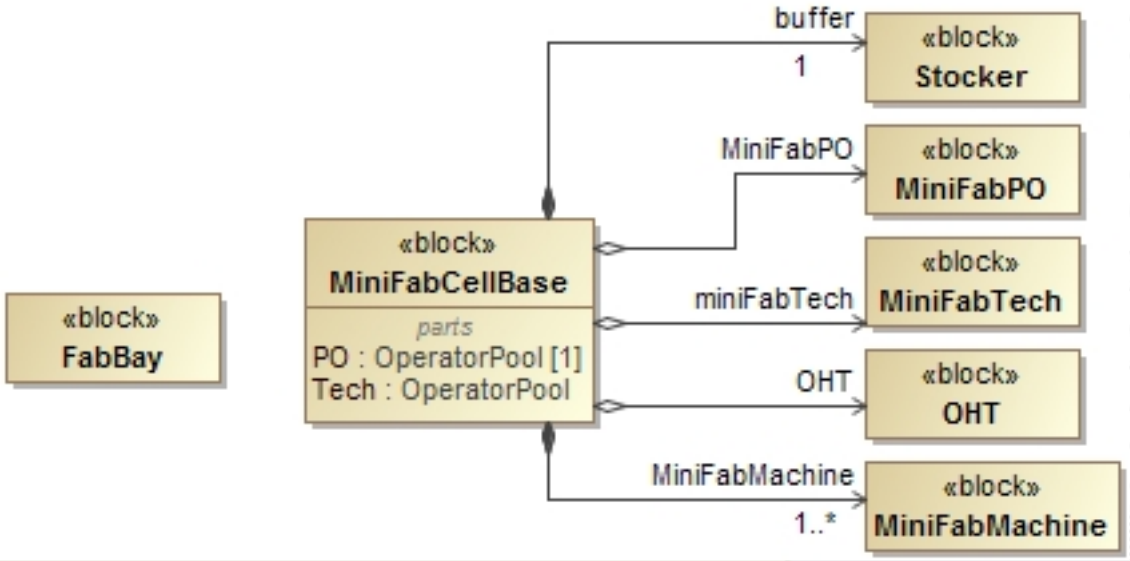


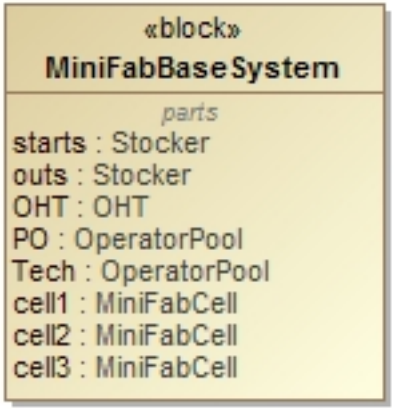
FAB LEVEL ABSTRACTION

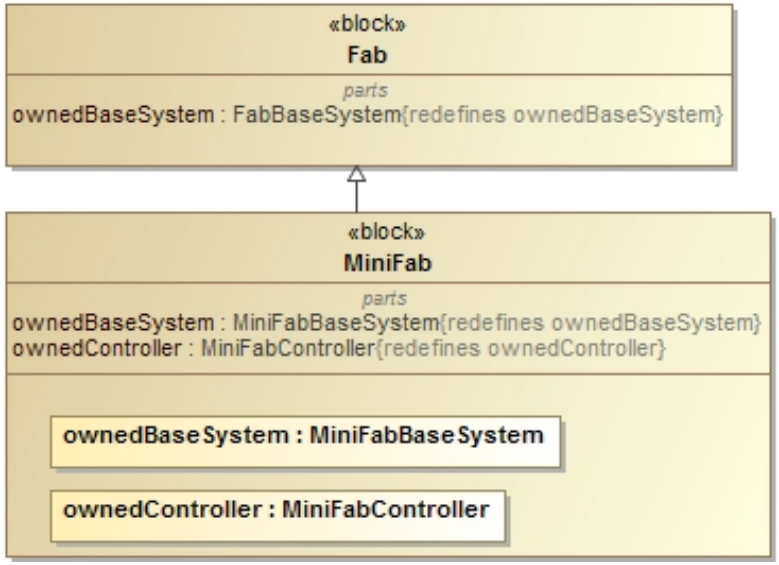


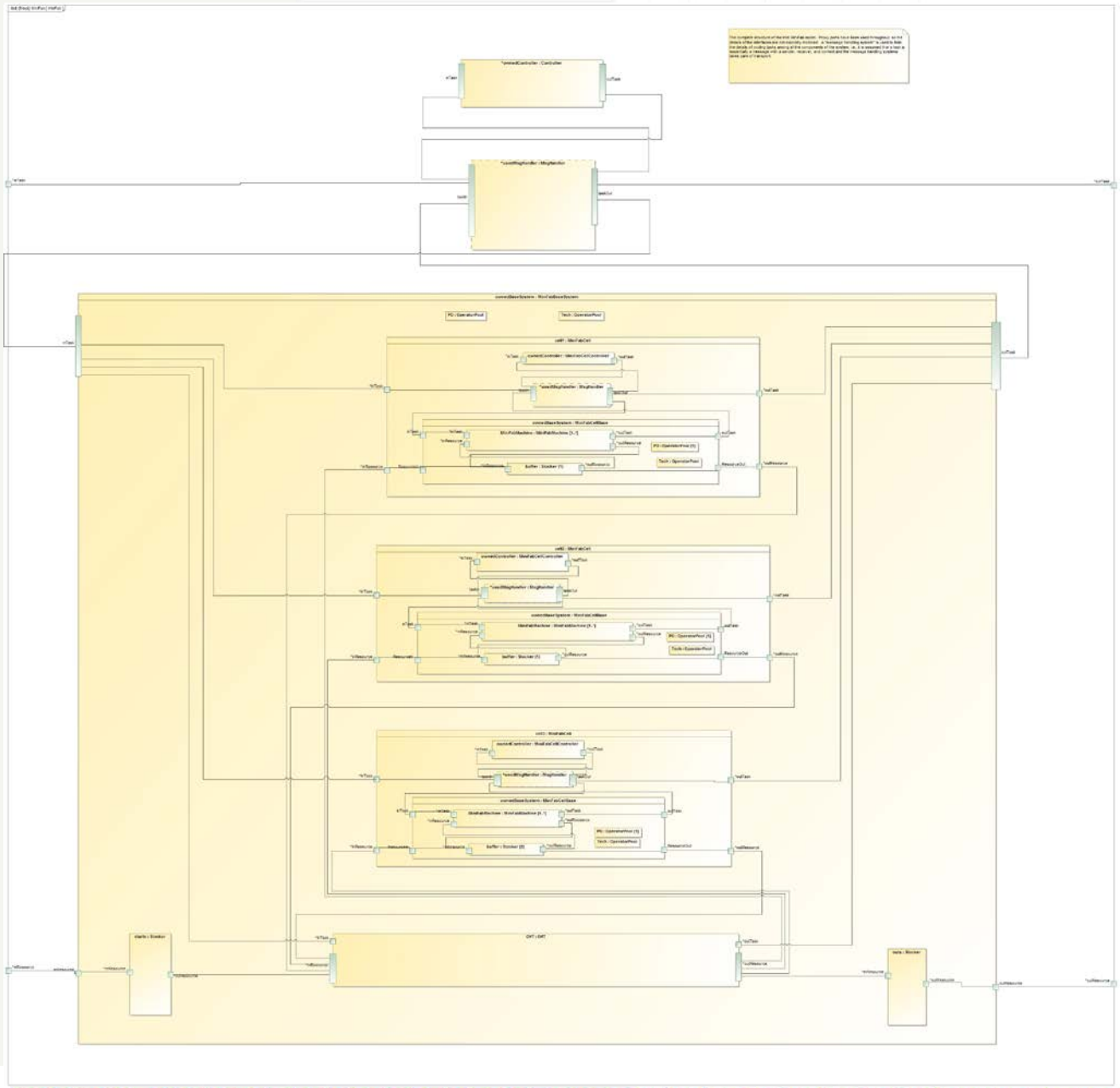
Only one “bay” is shown, but more don’t change the fundamental structure

INTEL MINIFAB DOMAIN









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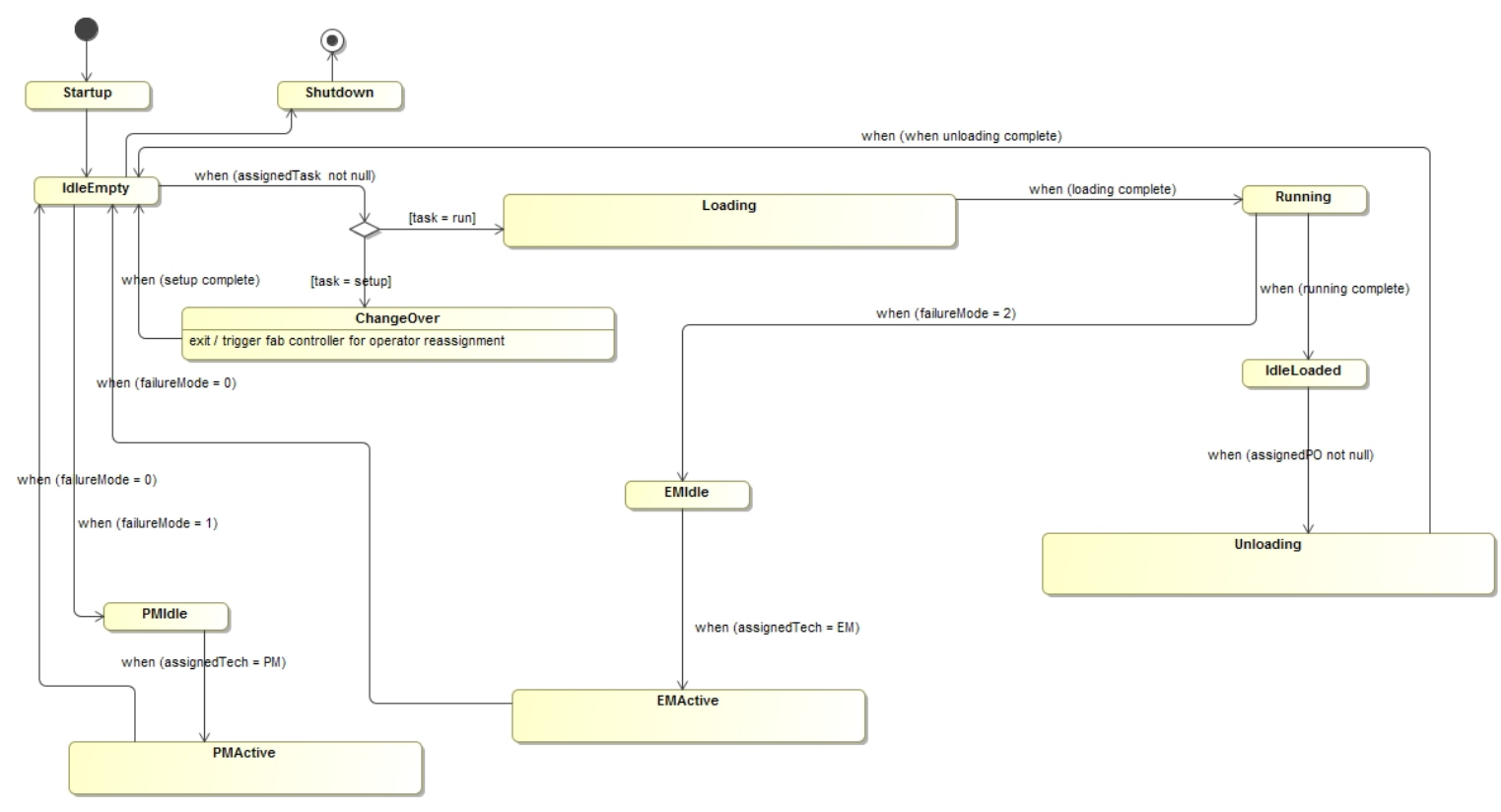
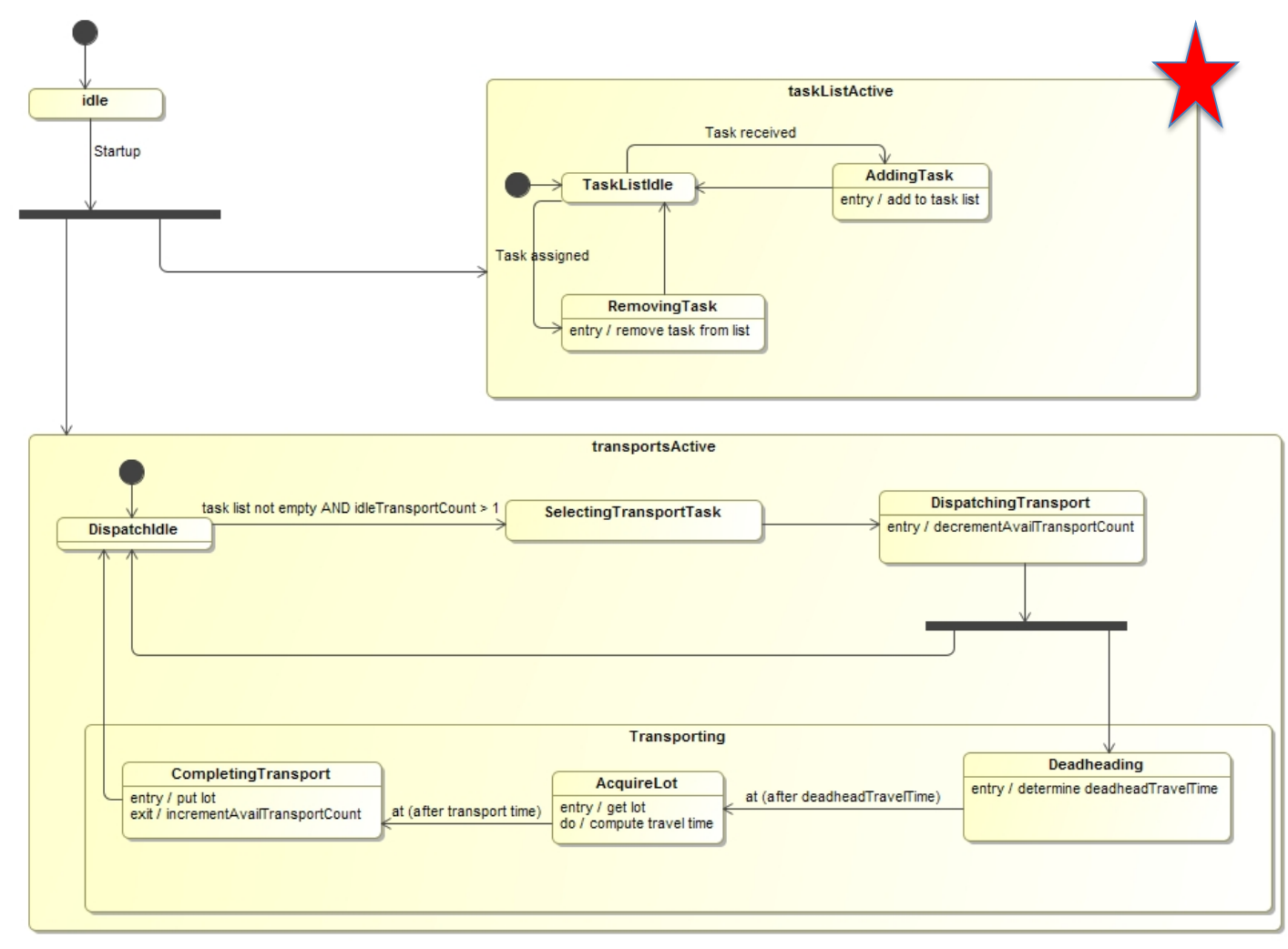
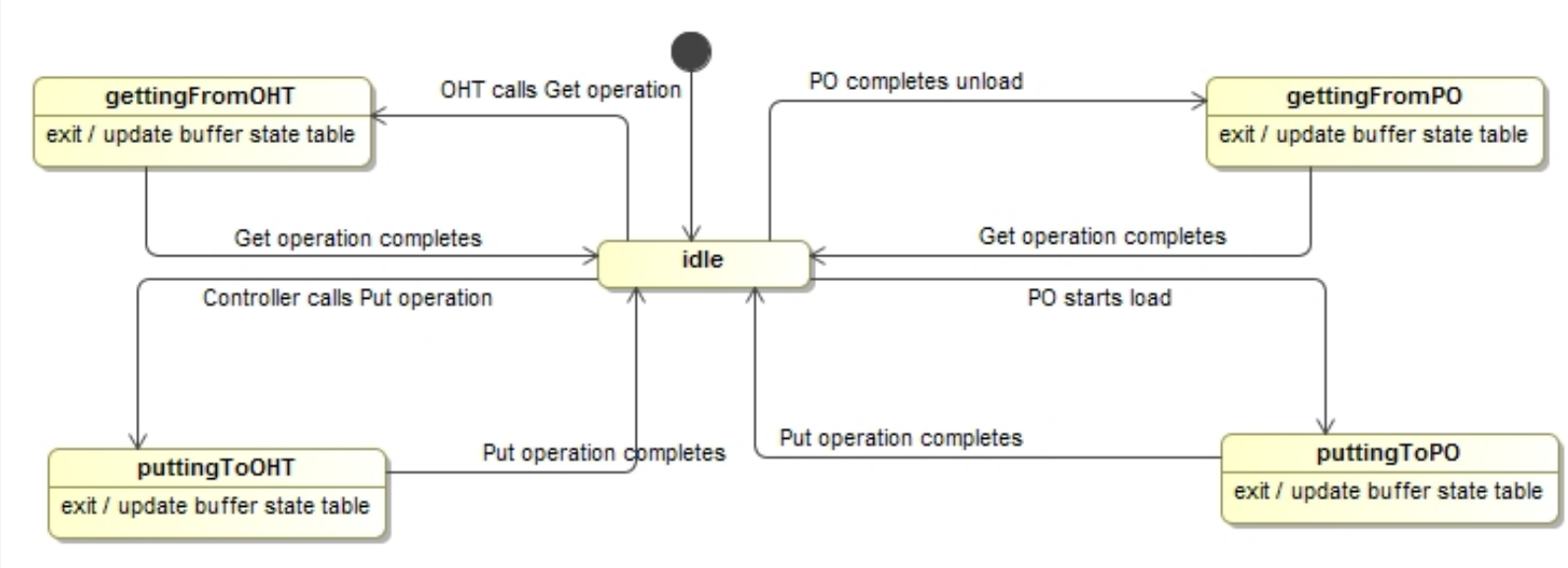
PROCESS TOOL BEHAVIOR (10 STATES)



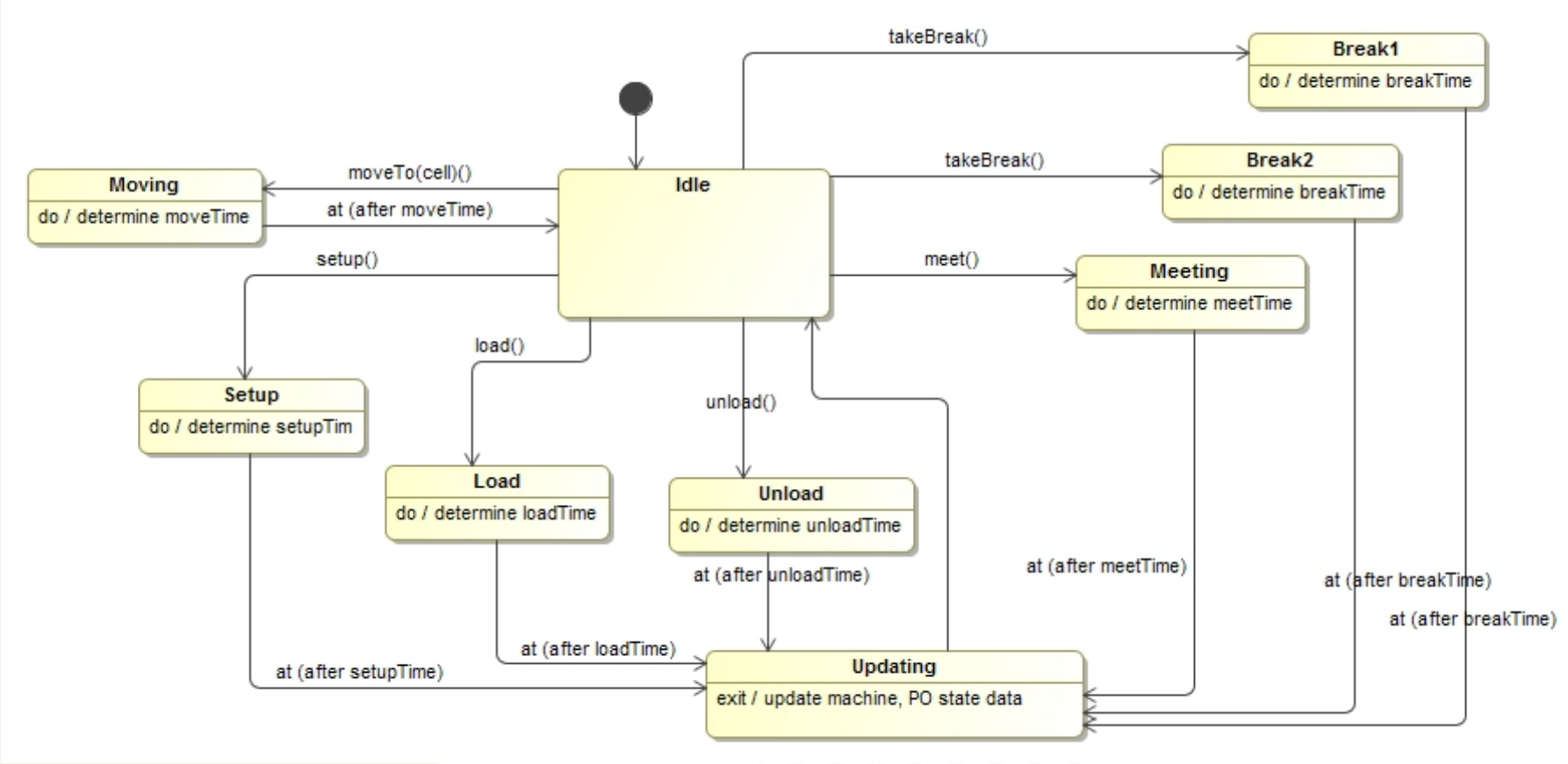
OHT BEHAVIOR



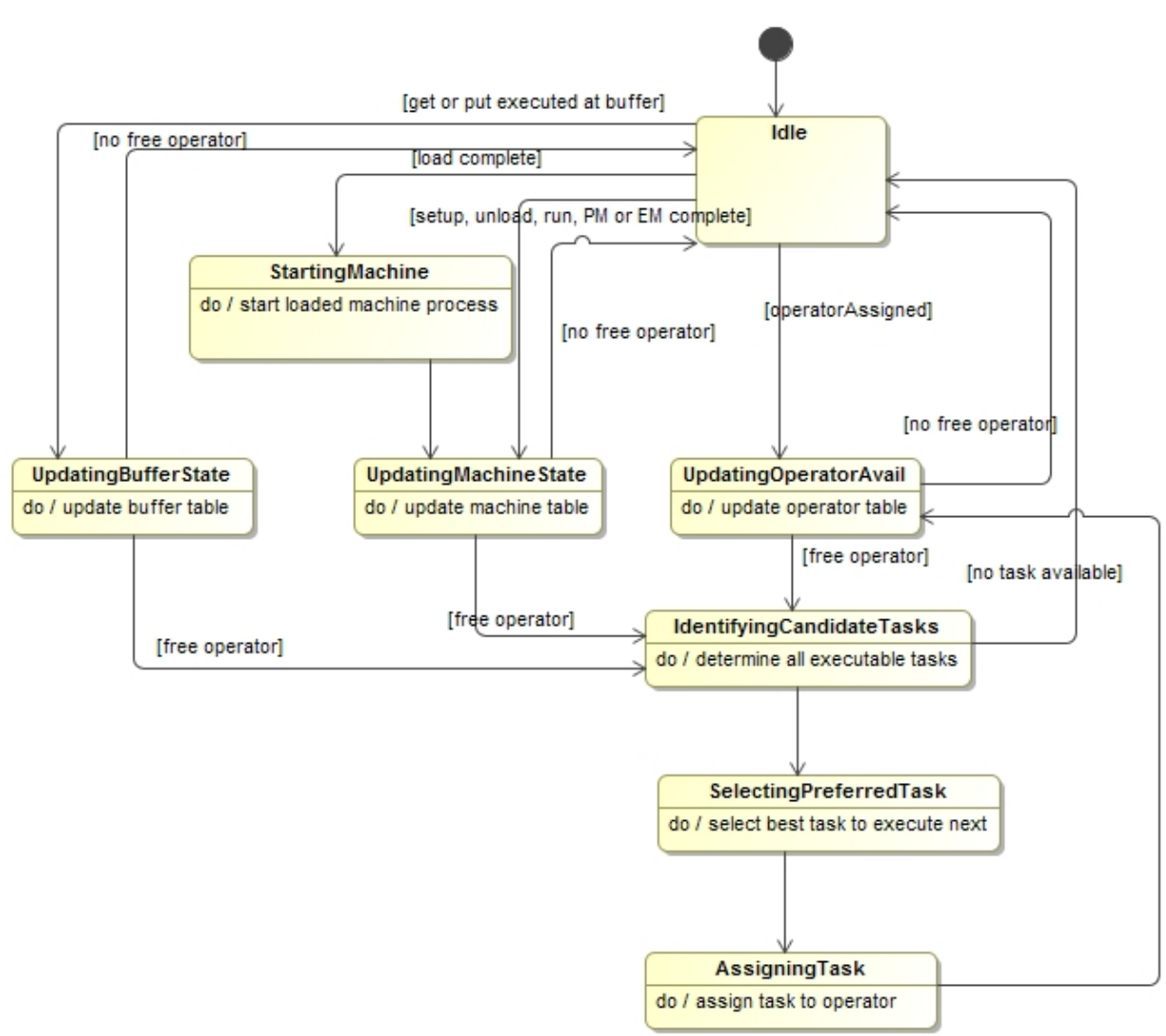
STOCKER BEHAVIOR



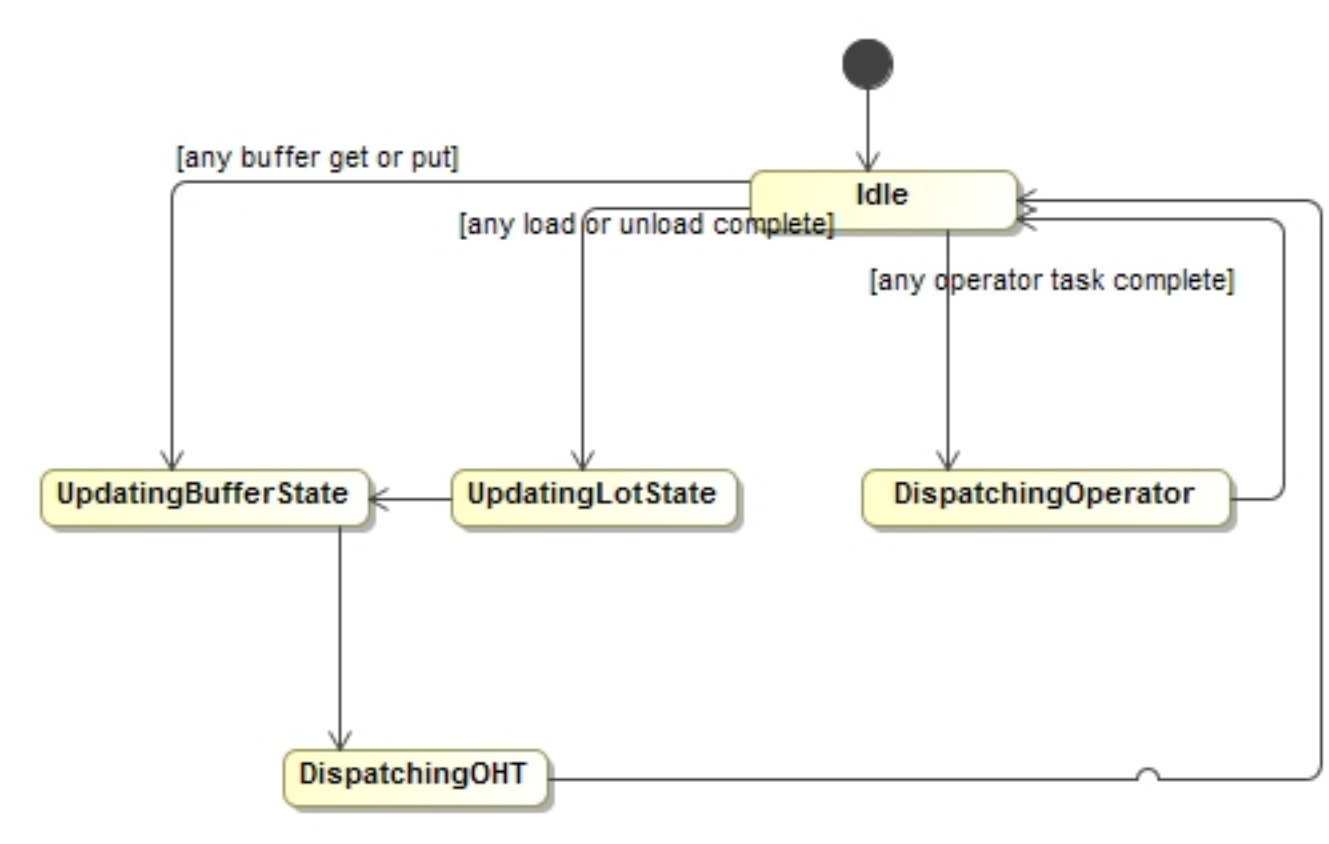
OPERATOR BEHAVIOR



CELL CONTROLLER BEHAVIOR



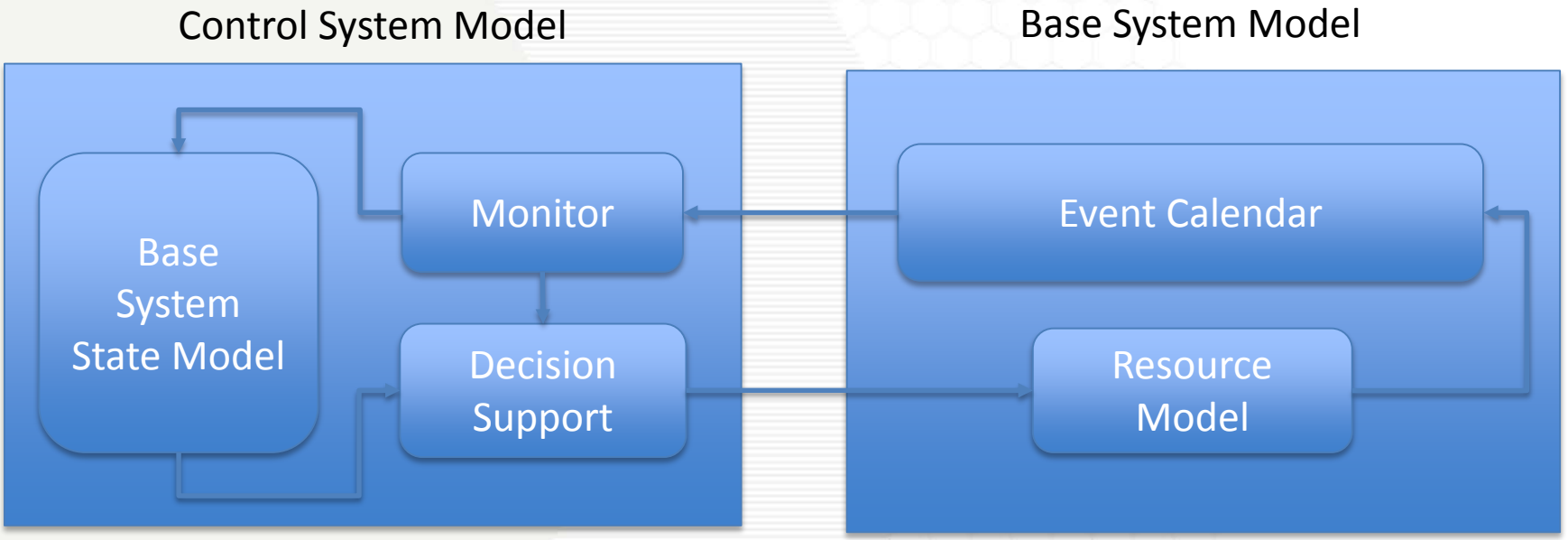
MINIFAB CONTROLLER BEHAVIOR



SO WHAT?

- This model captures all the (relevant) behaviors of the resources *and the controllers*
- Control decisions are described in terms of the behavior that implements them
- This model captures the events that trigger control behaviors
- The base system state model must provide the information needed by the decision making function (decision support function)

SUPPOSE WE WANT TO SIMULATE



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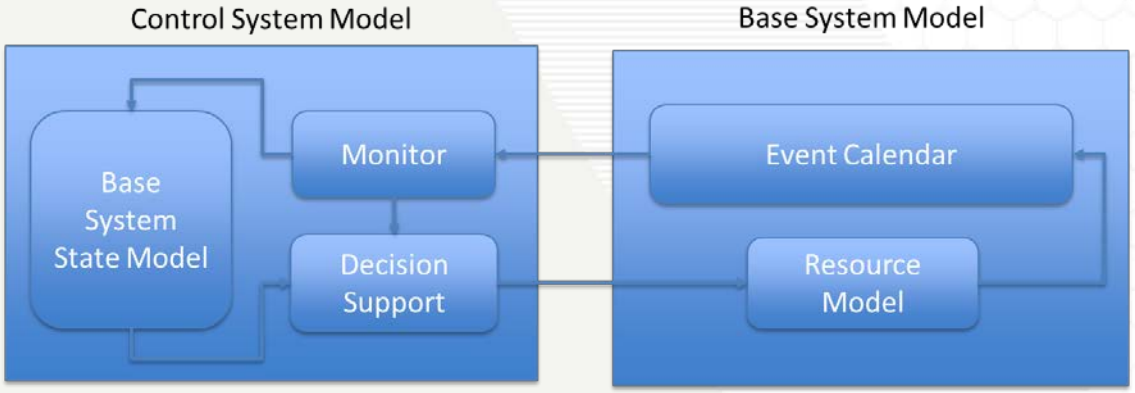

The remaining challenge is to create a control system reference model, with generic components having well-defined interfaces, so that particular decision support methods can be encapsulated. Then for a particular application, only the decision support code needs to be hand crafted. For standard applications, even that might become library models.

We have demonstrated, in multiple domains, that it is feasible to autogenerate the simulation model of the base system. What is required is a set of simulation components that can be mapped to the reference model, and populated with instance data.

FUTURE WORK

- We are doing this with Mathworks SimEvents and MATLAB (SimEvents permits "MATLAB function blocks" which we use to implement the controller)
- Any DES ***should*** be able to provide the same access to an underlying programming language ***and data space***
- For a specific domain, e.g., wafer fabs, ***can we identify a set of generic controller functions, and a generic schema for base systems state, so that libraries of DELS controller components can be distributed***?
- If we can do this for analysis of operations management decisions, can we extend these ideas to the interface between operations management and production planning?
- Can we extend these ideas to the modeling and analysis of supply chains?
  - Hint: the answer is yes

WHY WOULD WE WANT TO?

Because, whether we are designing conventional control systems, or developing “intelligent agents”, we will always need a “laboratory” in which we can train/test our designs. Setting them loose in the real world without such testing or training is not a feasible option.

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Questions?
Comments?