

FUTURE OF MH RESEARCH: ONE VIEW

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GEORGIA TECH

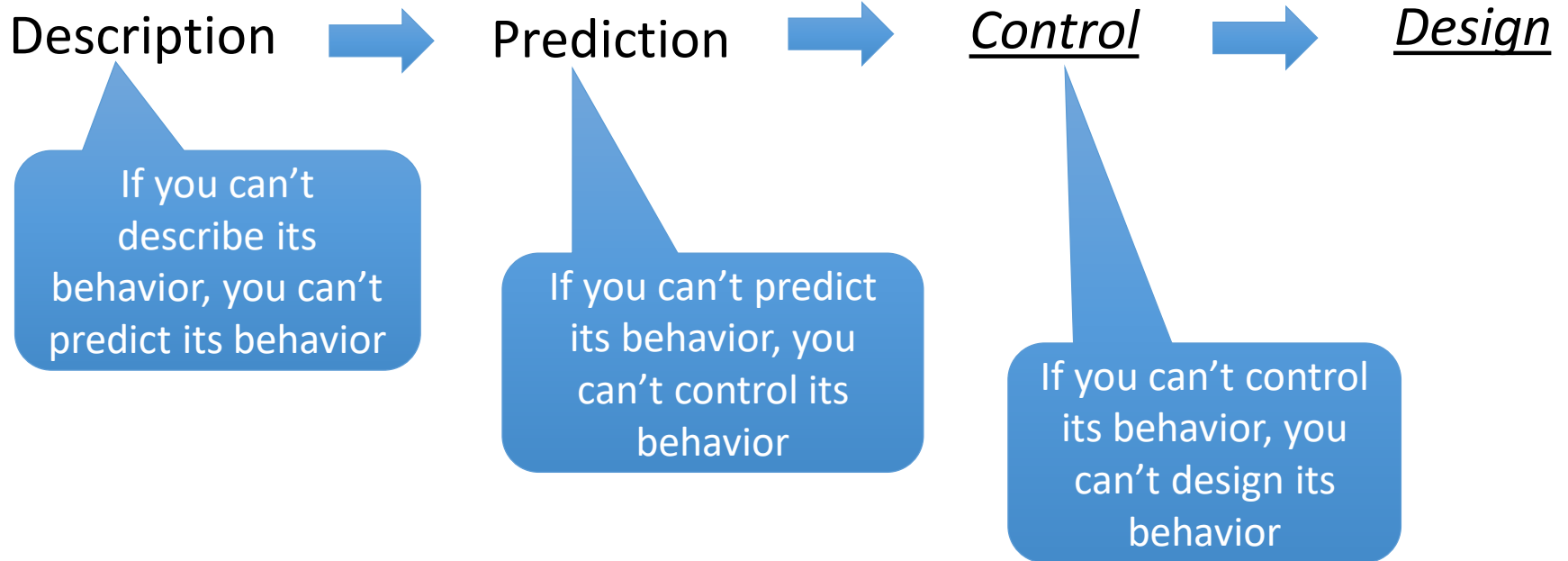
CREATING THE NEXT®







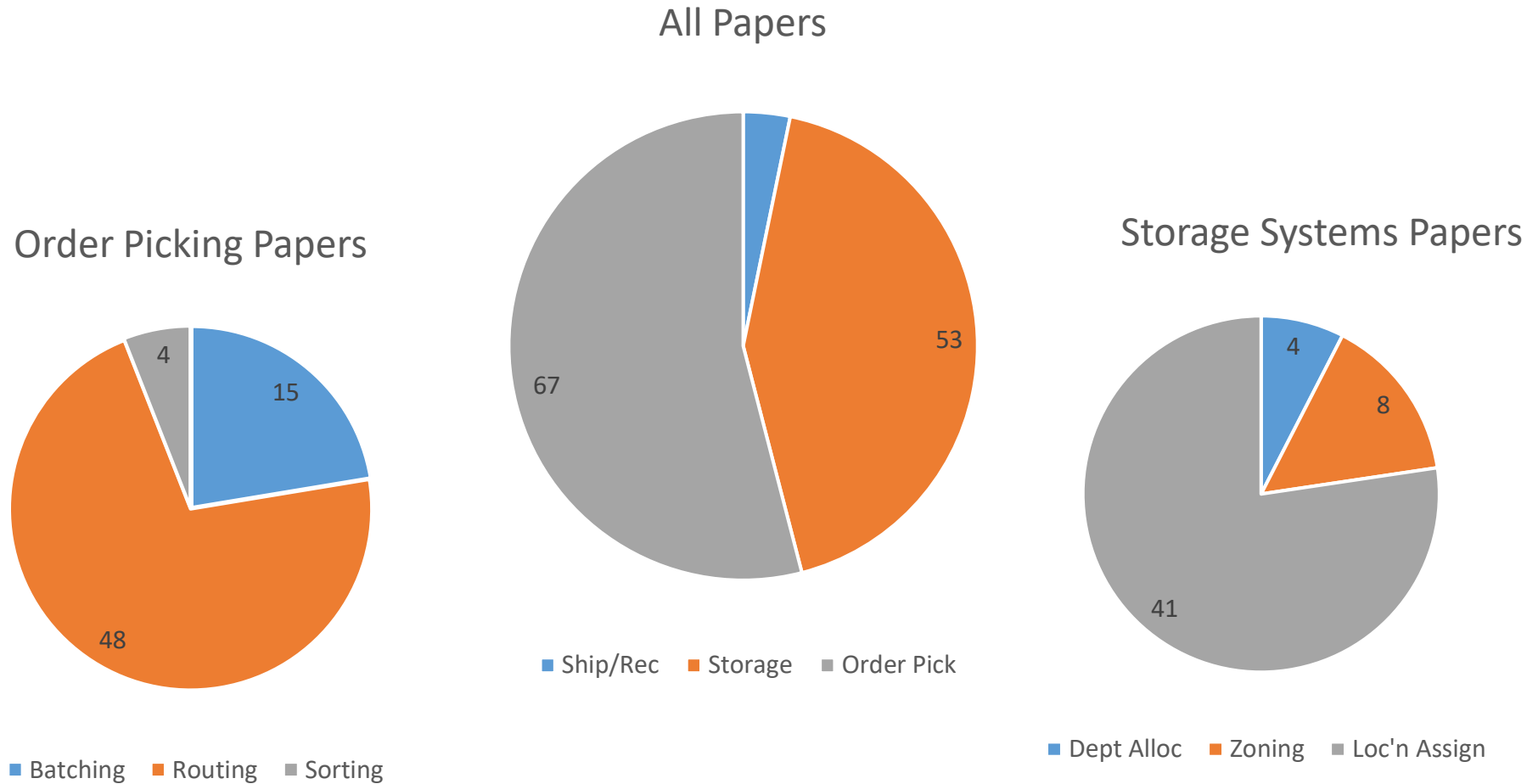
Engineered Systems Design



All our research is predicated on our ability to describe the engineered system of interest.

It is also limited by that ability!

How do we do our research?



From: [European Journal of Operational Research](#)
[Volume 177, Issue 1](#), 16 February 2007, Pages 1-21

Inescapable Conclusion

The collected body of research on warehousing is very highly concentrated on issues where the system of interest can be “adequately” described using our standard analysis methodologies—statistics, optimization, queuing theory, or discrete event simulation.

And some really great research has been done that has amazing impacts on the practice of MH!

Our “system modeling language” is, in fact, our analysis modeling language.

Like every generalization, this one is not 100% true!

These languages may be really good at
what they are good at, but ...

limited fidelity

limited scope

limited “consumability”

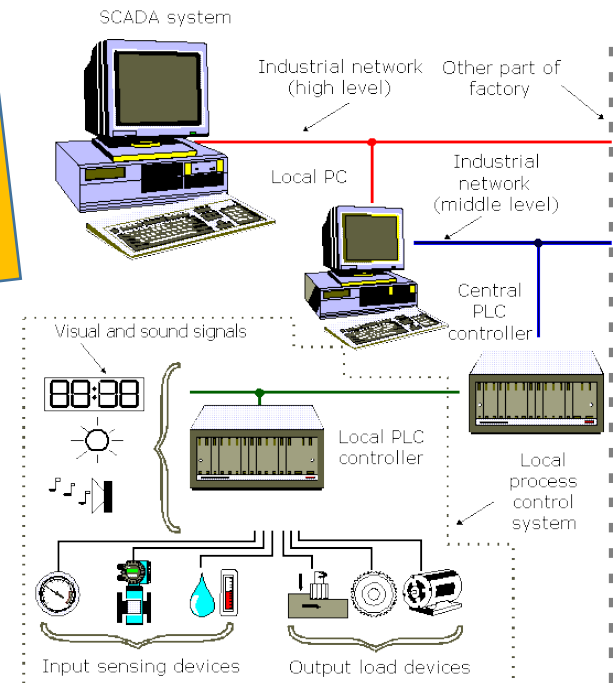
Consequences:

1. We are forced to make assumptions that greatly simplify the real problem, and we rarely are able to test the results to understand approximation error.
 - Steady state, expected value results are “good enough”
2. We turn away from problems for which an adequate system description cannot be created as one of these standard analysis approaches.
 - High density storage/mixing systems
 - Highly capacity constrained sorting systems
3. Our research does not achieve its potential for impact on practice

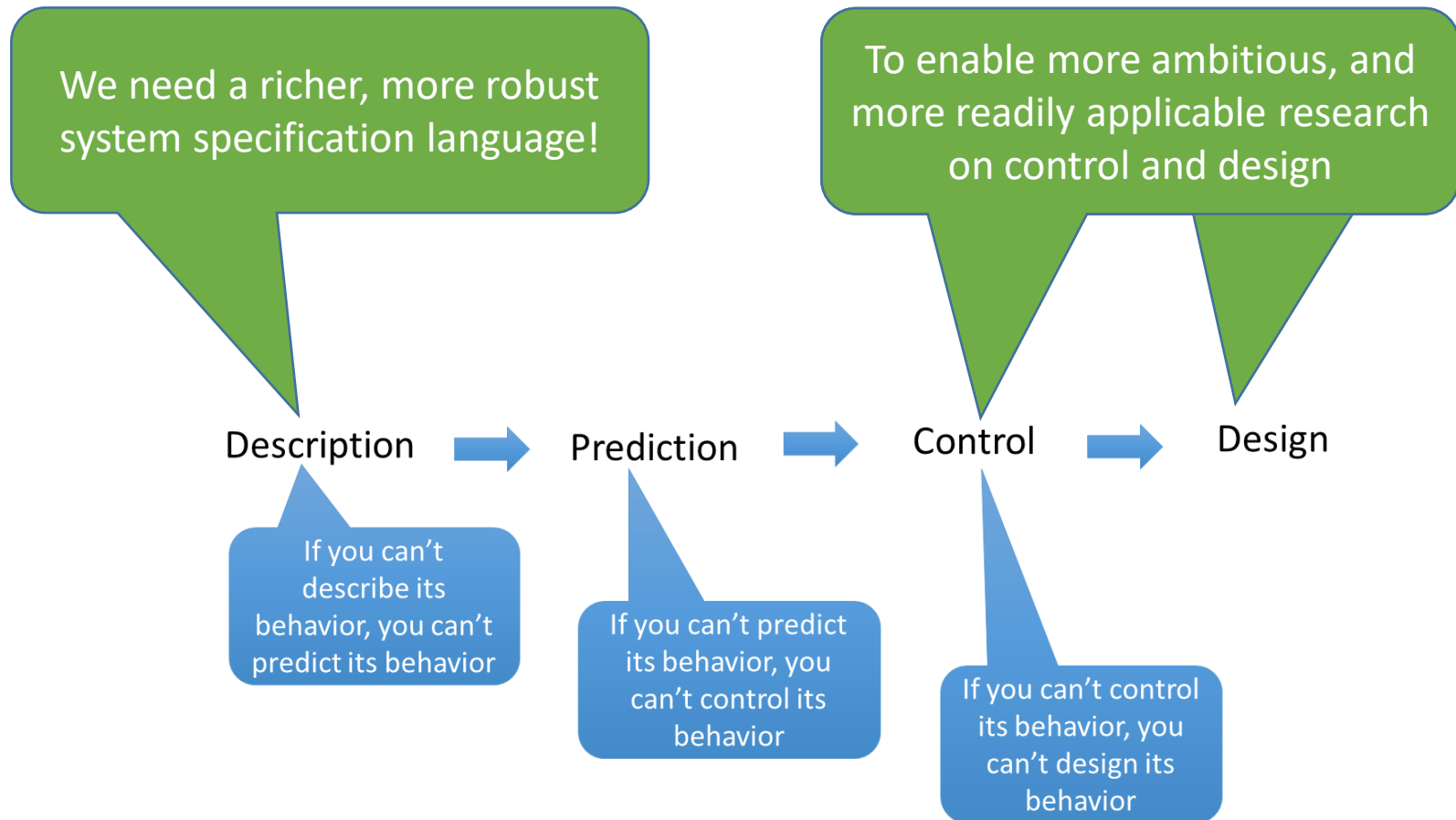
Worst of all:

Results,
recommendations
from our analyses

Implementation
Gap



How to expand our horizons?



A pattern to learn from

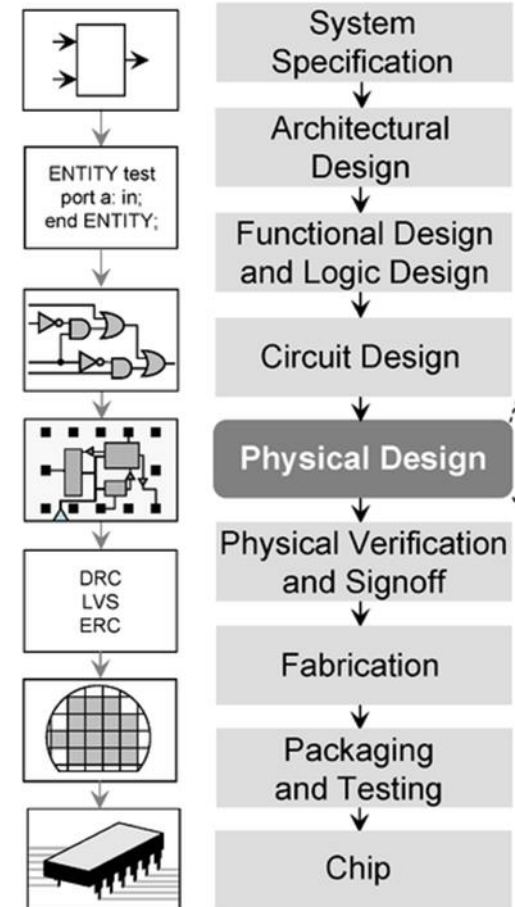
VHDL (VHSIC Hardware Description Language) is a hard used in electronic design automation to describe digita such as field-programmable gate arrays and integrated used as a general purpose parallel programming langua

<https://en.wikipedia.org/wiki/VHDL>

Summary: History of VHDL

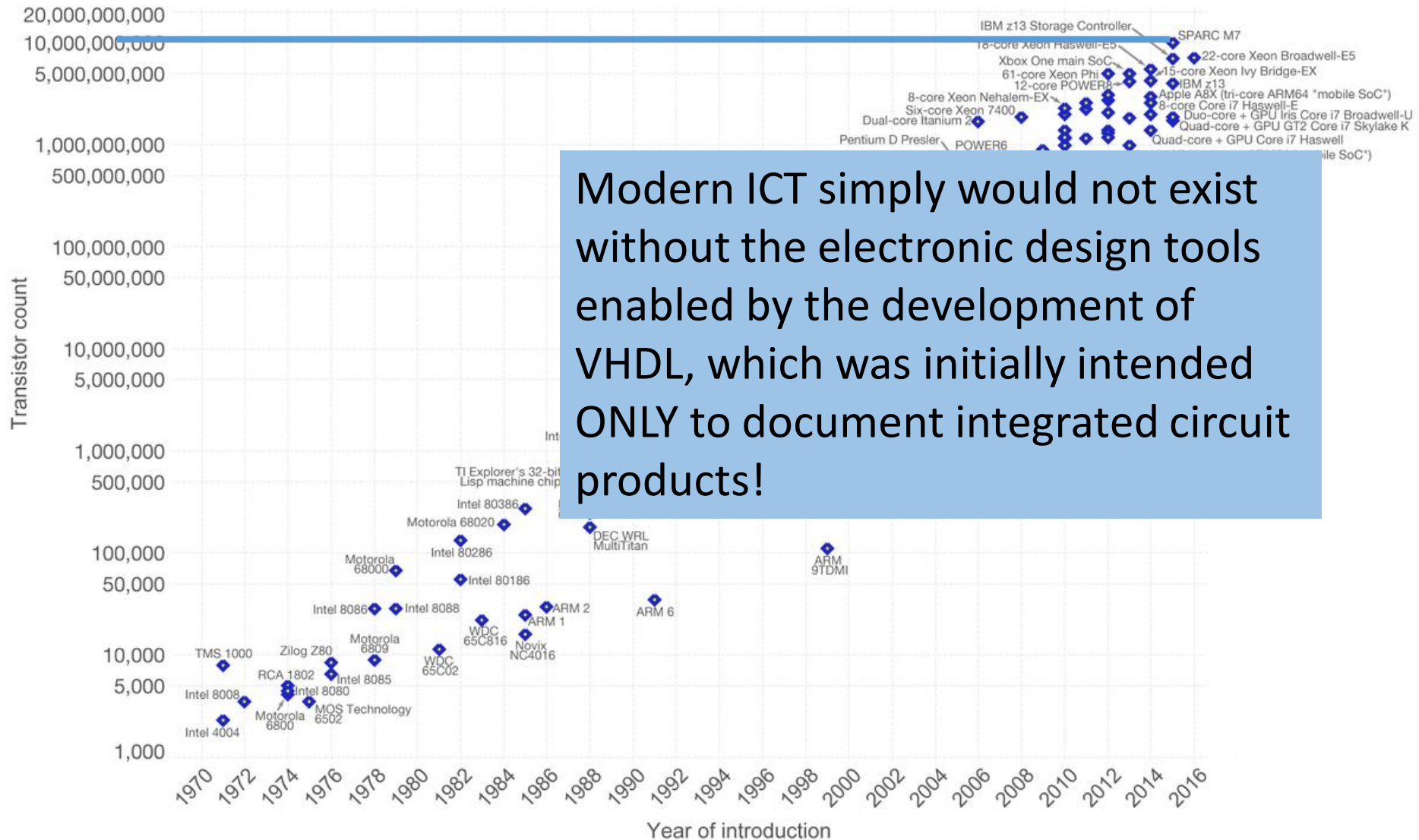
- 1981 Initiated by US DoD to address hardware life-cycle crisi
- 1983-85 Development of baseline language by Intermetric
- 1986 All rights transferred to IEEE
- 1987 Publication of IEEE Standard
- 1987 Mil Std 454 requires comprehensive VHDL descriptions
- 1994 Revised standard (named VHDL 1076-1993)
- 2000 Revised standard (named VHDL 1076 2000, Edition)
- 2002 Revised standard (named VHDL 1076-2002)
- 2007 VHDL Procedural Language Application Interface stand
- 2009 Revised Standard (named VHDL 1076-2008)

https://www.doulos.com/knowhow/vhdl_designers_guide/a_brief_history_of_vhdl/



Moore's Law – The number of transistors on integrated circuit chips (1971-2016)

Moore's law describes the empirical regularity that the number of transistors on integrated circuits doubles approximately every two years. This advancement is important as other aspects of technological progress – such as processing speed or the price of electronic products – are strongly linked to Moore's law.



Data source: Wikipedia (https://en.wikipedia.org/wiki/Transistor_count)

The data visualization is available at OurWorldinData.org. There you find more visualizations and research on this topic.

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Logistics centers designed for the Physical Internet

Transit Center
facilitating the
truck-to-truck
transshipment
of trailers along
relays networks
through the
Physical Internet



Reference: Mellor, R.D., B. Montreuil, C. Thirviège & Z. Montreuil (2012), *Functional Design of Physical Internet Facilities: A Road-Based Transit Center*, in *Progress in Material Handling Research*, 2012, MHA, Charlotte, NC, to appear (2012).



Physical Internet
Efficient Sustainable Logistics



Physical Internet Manifesto, version 1.11
Professor Benoit Montreuil, CIRRELT, Université Laval
Québec, 2012-11-19, 36/76

Logistics centers designed for the Physical Internet

Transportation
facilities
structure
transportation
of transportation
relays
the
Physical

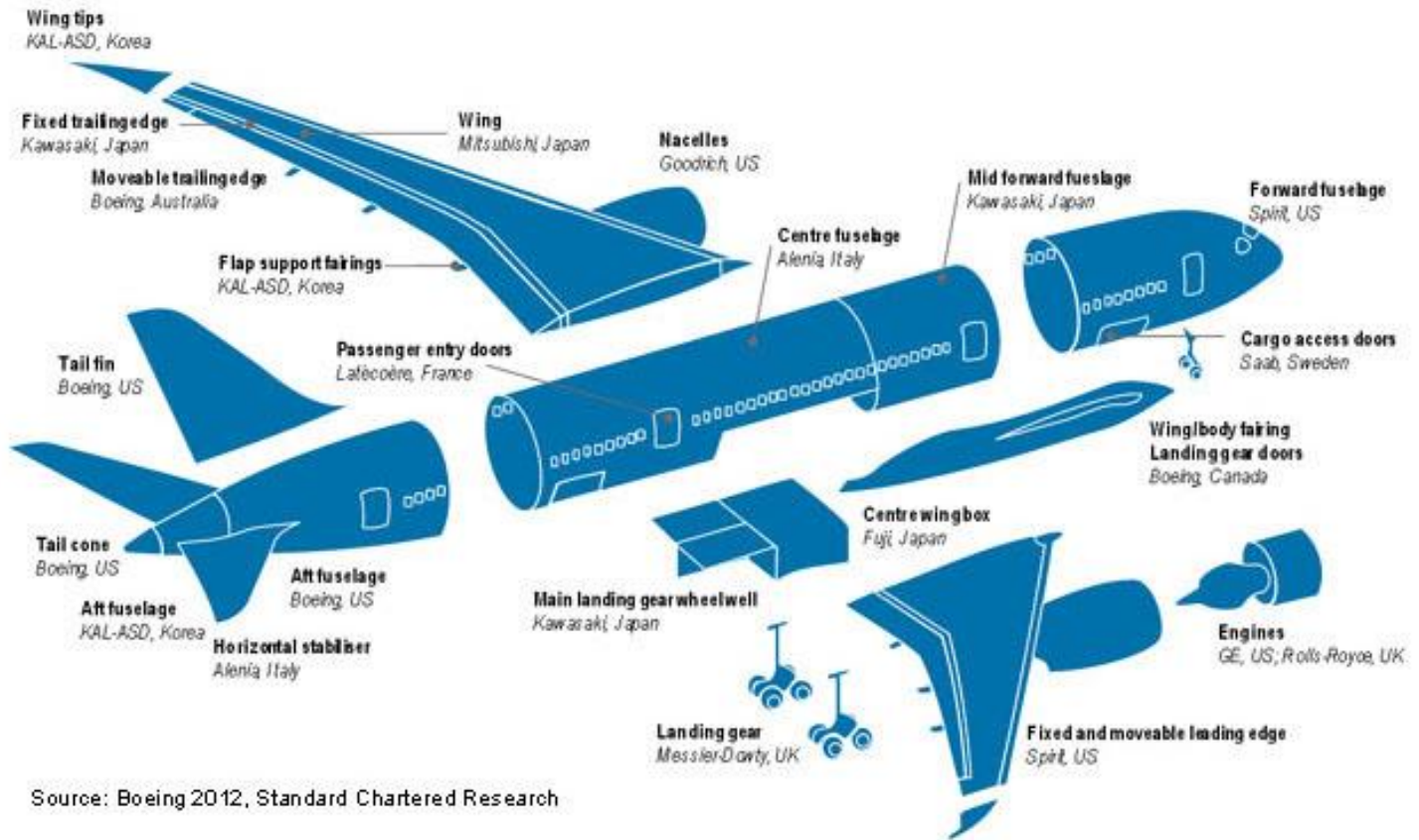


Reference: Miller
Charlotte, NC, to



Logistics centers designed for the Physical Internet

Transportation
facilities
structure
transportation
of transportation
relays
the
Physical



Source: Boeing 2012, Standard Chartered Research

Reference: Miller
Charlotte, NC, to



Logistics centers designed for the Physical Internet

Transportation
 facilities
 structures
 transportation
 of transportation
 relay
 the
 Physical

Wing tips
 KAL-ASD, Korea

Fixed trailing
 Kawasaki Ja

Mov
 Boei

Tail fin
 Boeing, I

Tail cone
 Boeing, US

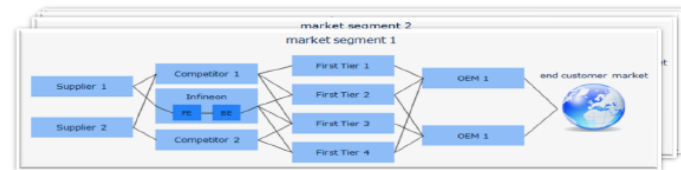
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Reference: Moller
 Charlotte, NC, to

Modeling & Simulation Levels From Equipment up to End-to-End Supply Chain



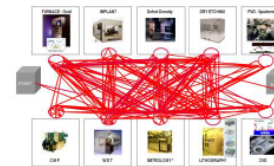
> **Level 4:**
 End-To-End SC



> **Level 3:**
 Semiconductor company SC

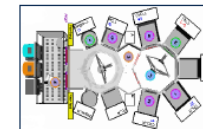


> **Level 2:**
 Factory Supply Chain SC



Source: E

> **Level 1:**
 Cluster/Equipment SC



What the world needs

- Ability to design (control, predict, specify) the large scale socio-technical, cyber-physical systems that sustain modern life, because they enable the *flow of material through networks of resources that transform that material to higher value*
- This is our domain!

Fundamental Truths

- Operational control of these systems does not exist without material handling
- The physical processes of material handling, *vis-à-vis control*, often are not considered explicitly in systems design—they are effectively an afterthought

OPPORTUNITY!

Fundamental Truths

- By and large, we are still hand-building decision support analysis models *that we already know how to build!*
- As a result, we are too slow, too expensive (and not well integrated with other decisions) so we are not used well
- And our analysis methods are becoming commodities

Even if we are happy to work at the individual process level, we will have a lot of competition

Fundamental Truths

- By and large we are still hand-building decision

supp › **Level 4:**
to b End-To-End SC



how

- As a well use › **Level 3:**
Semiconductor company SC

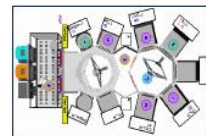


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Factory Supply Chain SC



- › **Level 1:**
Cluster/Equipment SC



Even if we are happy to work at the individual process level, we will have a lot of competition

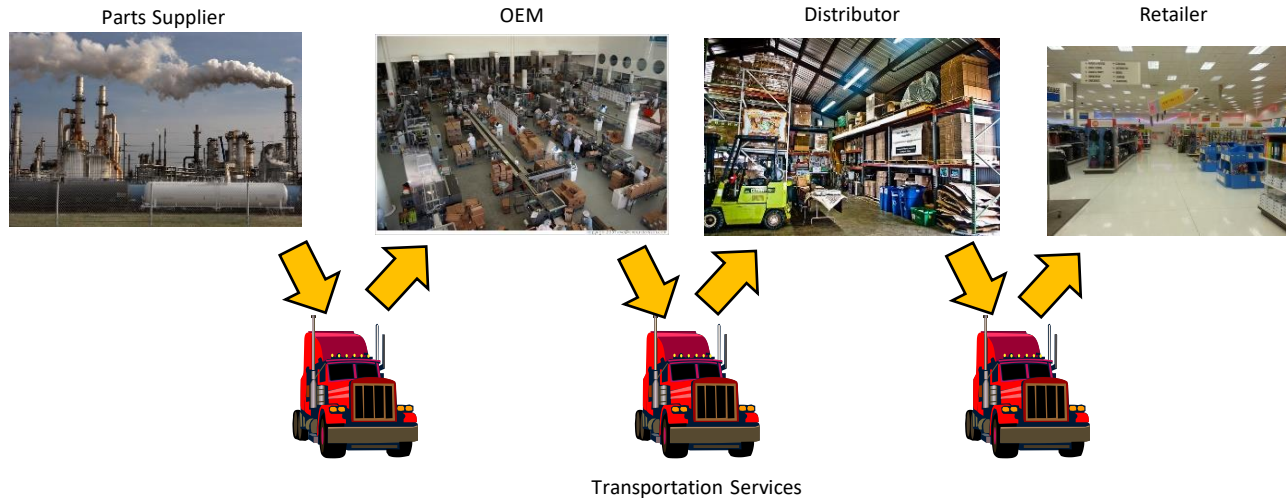
Conclusion

- Future material handling research, as we know it, must have a systems perspective, must integrate decisions about MH system design and operational control with other systems-level design and operations decisions
 - Domain experts will always know more than we do about the system of interest
 - We must know something that is not a commodity, that contributes effectively to systems design and operational control decision making
 - We must translate our results into implementable recommendations

How might we reach that future?

- Shared, unifying framework for system specification
- ➔ • *Lingua franca* for system specification (a la VHDL)
- Specification authoring and editing tools
- Framework for decision-making, both for system design and system control
- Decision support analysis automation
- Decision support analysis integration with system specification

Discrete Event Logistics Systems

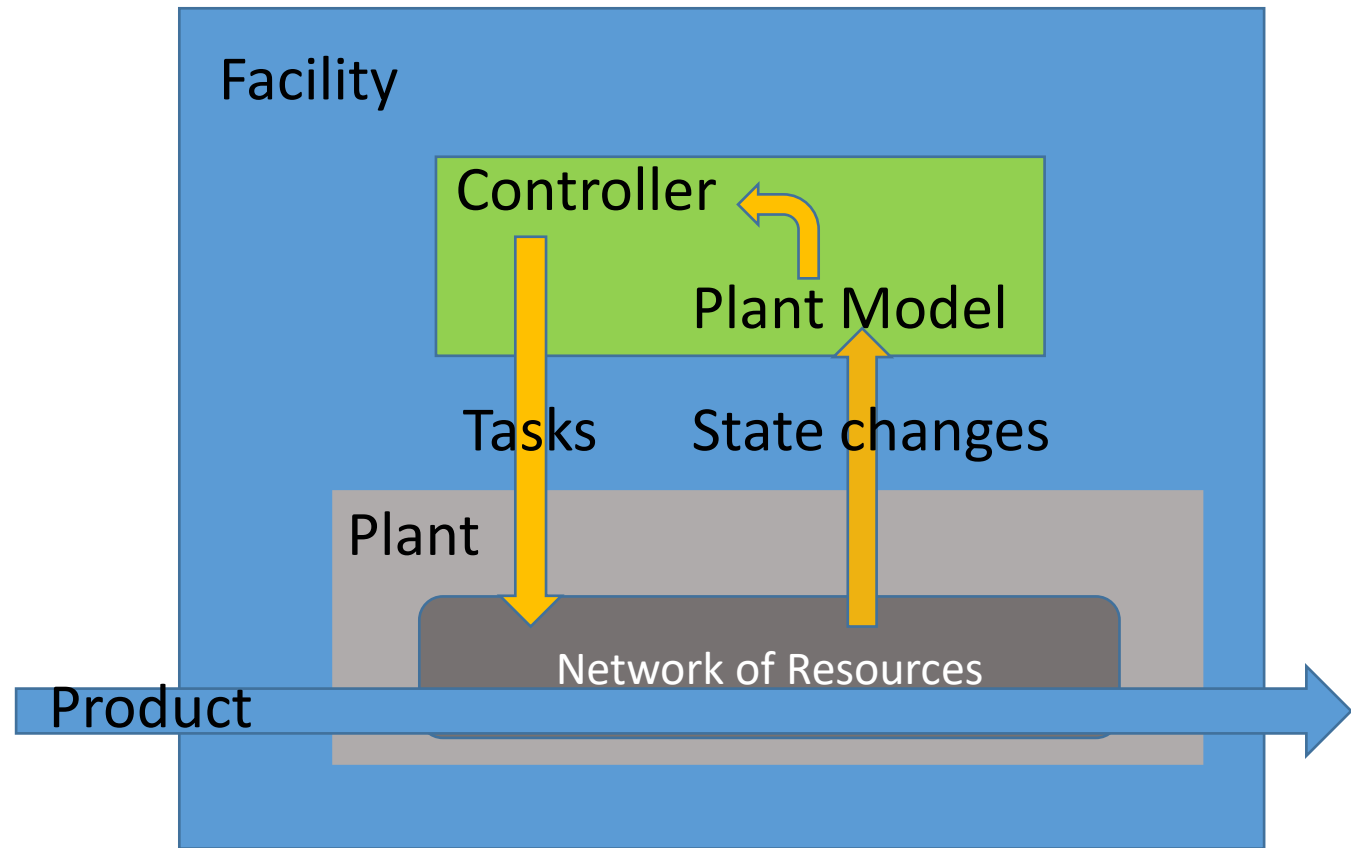


Units of flow move through a network of resources, which execute processes that transform the units of flow in some way—location, age, configuration, information, etc. These are **“discrete event logistics systems” or DELS**.

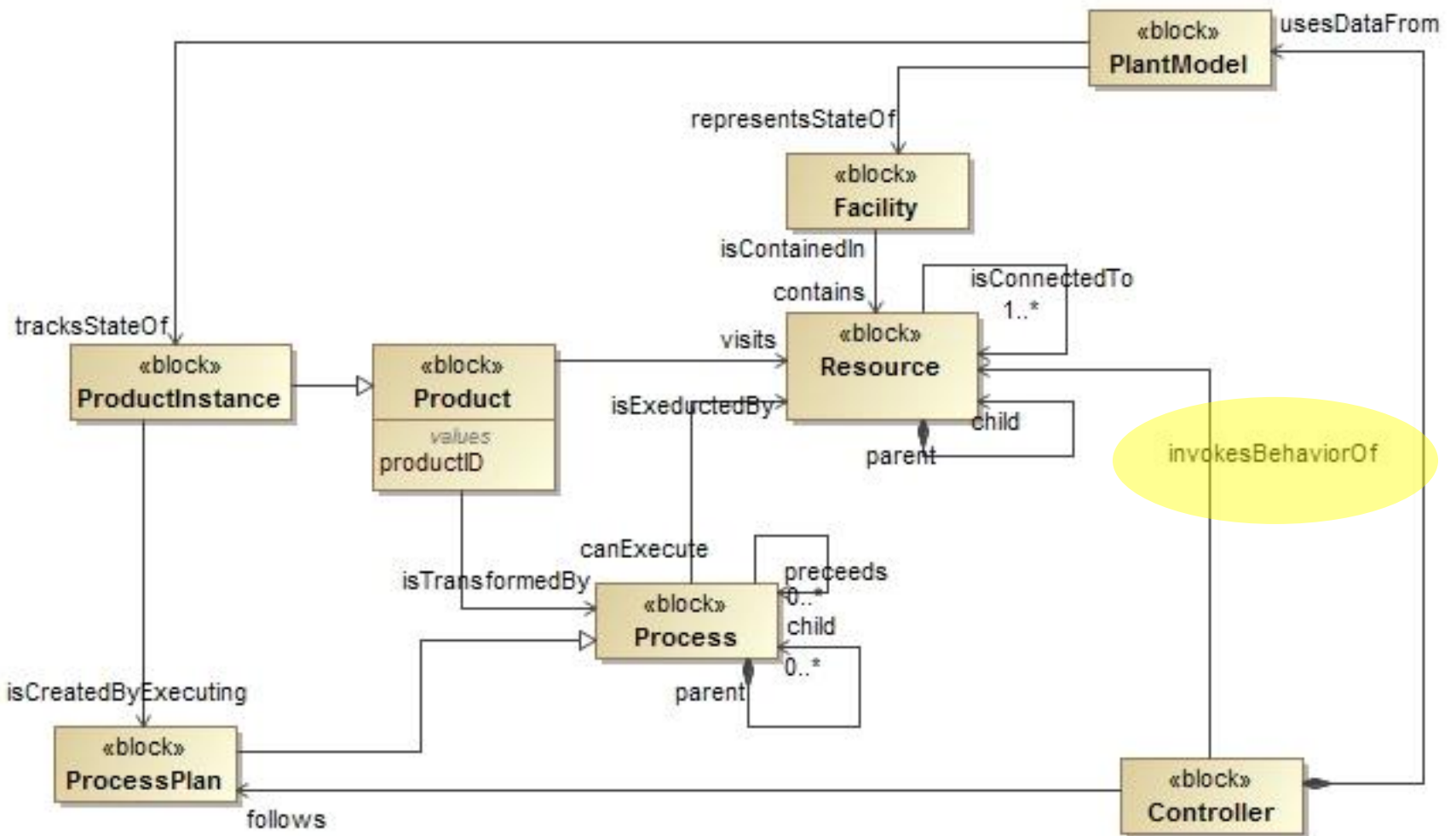
Transformations can be adequately described by their start and end events, and by the summary description of the state change accomplished.

Toward a language for DELS

- Product
- Process
- Resource
- Facility
- Control
- Plant Model



Resource capabilities: make, move, store (get, put)



Purdue Enterprise Reference Architecture (PERA)

Level 4

Business Planning & Logistics

Plant Production Scheduling,
Business Management, etc

4 - Establishing the basic plant schedule - production, material use, delivery, and shipping. Determining inventory levels.

Time Frame

Months, weeks, days, shifts

Level 3

Manufacturing Operations Management

Dispatching Production, Detailed Production Scheduling, Reliability Assurance, ...

3 - Work flow / recipe control to produce the desired end products. Maintaining records and Deciding which capabilities will be invoked, in what order, at what time. Making technology *perform*.

Level 2

Manufacturing Control

Basic Control, Supervisory Control, Process Sensing, Process Manipulation,...

Managing the execution of innate capabilities, e.g., AGV travel, conveyor movement. Making technology work.

Level 1

the production process

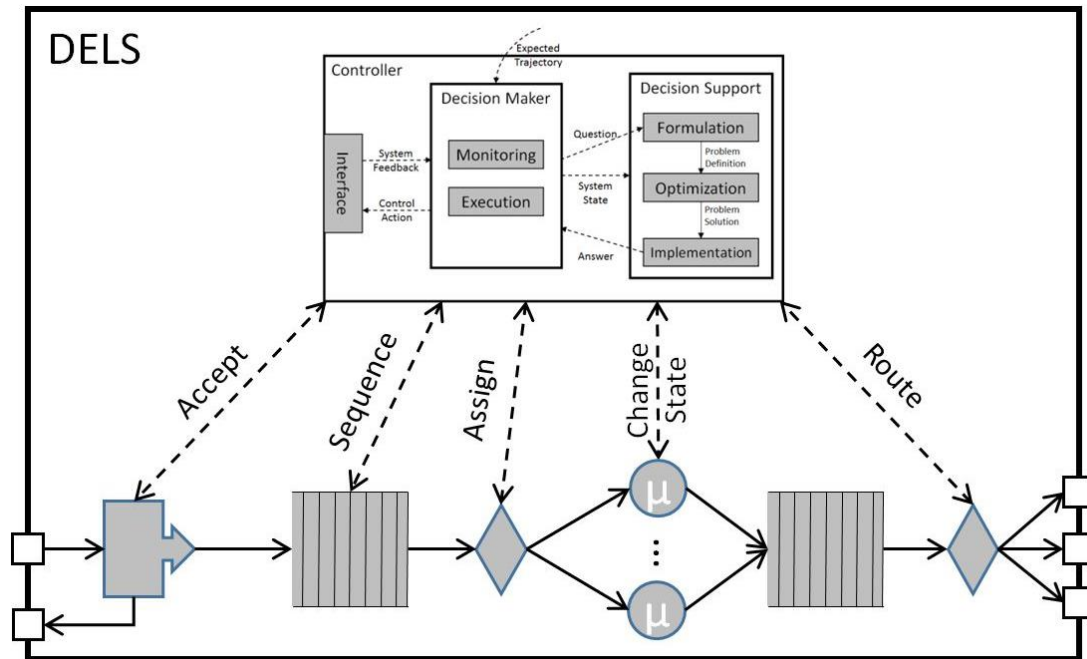
Level 0

0 - The physical production process

Operational control decisions are implemented by moving material!

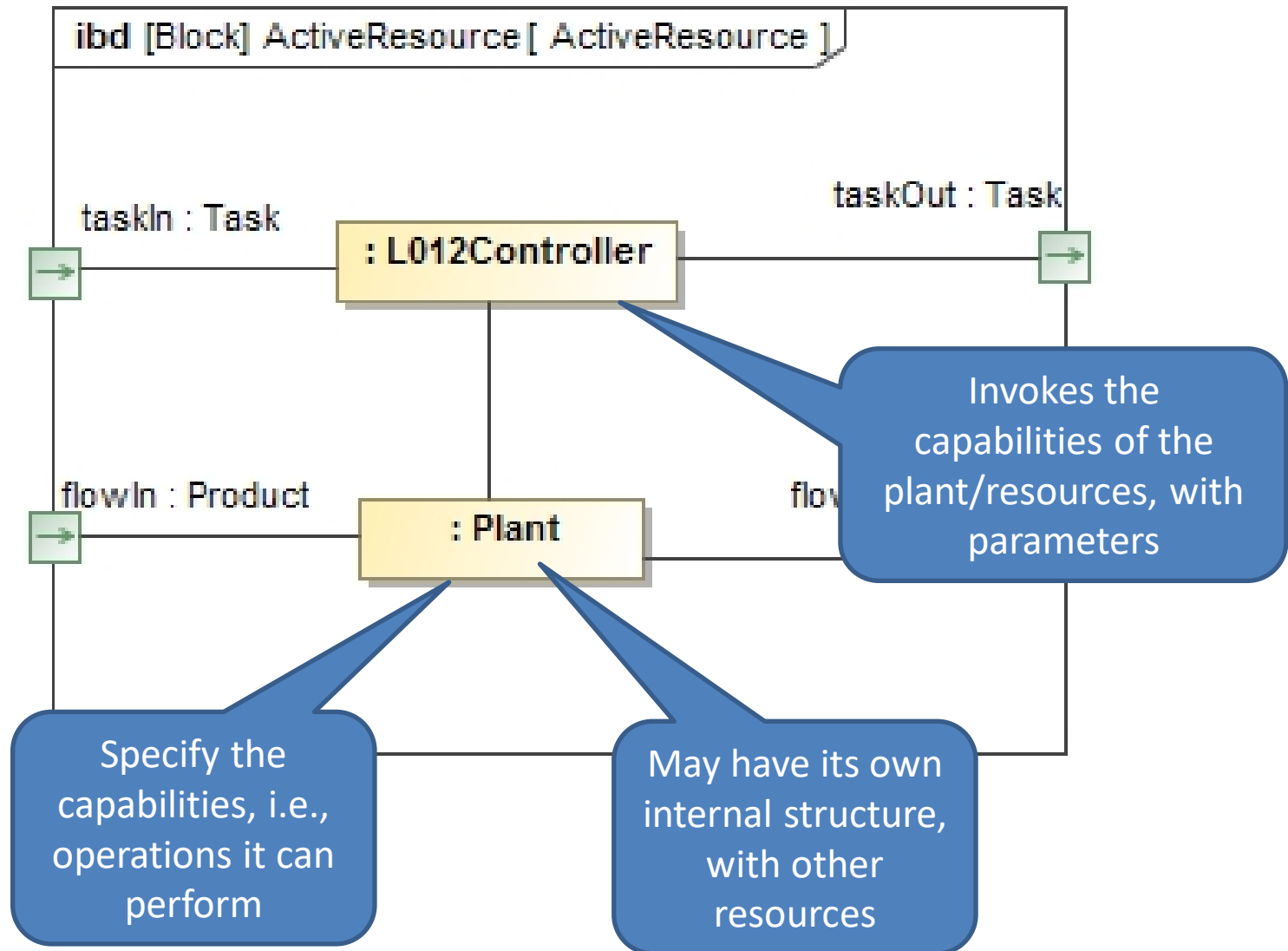
“Make” is not an operational control decision!

Control questions provide a mapping from a formal functional definition of control activities for DELS to formal (math programming) analysis models.



- Which tasks get serviced? (Admission/Induction)
- When {sequence, time} does a task get serviced? (Sequencing/Scheduling)
- Which resource services a task? (Assignment/Scheduling)
- Where does a task go after service? (Routing)
- What is the state of a resource? (task/services can it service/provide)

PLANT/CONTROL SEPARATION



A motivating example

A central fill pharmacy (CFP) is “a pharmacy which is permitted by the state in which it is located to prepare controlled substances orders for dispensing pursuant to a valid prescription transmitted to it by a registered retail pharmacy and to return the labeled and filled prescriptions to the retail pharmacy for delivery to the ultimate user” (21 CFR 1300.01 (44) [Title 21 Food and Drugs; Chapter II Drug Enforcement Administration, Department of Justice; Part 1300 Definitions]).

Scale and Scope

- Thousands of drugs (associated Pareto for orders)
- 30,000 scripts per day
- Several hundred to a thousand local pharmacies (with associated Pareto for orders)

High speed filling
into vials in pucks



High flexibility robotic filling into vials deposited in totes



Unit of use



Bagging

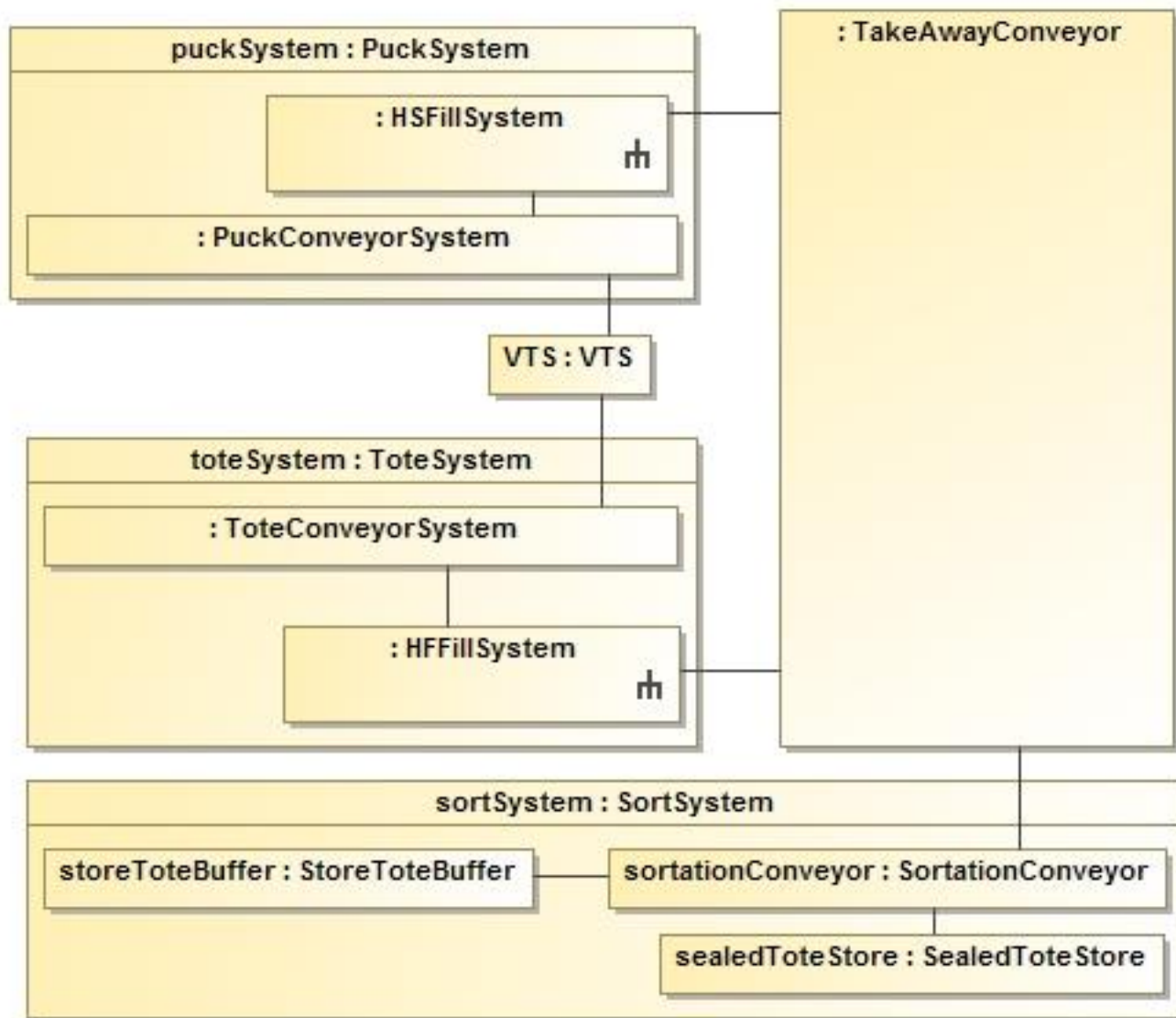


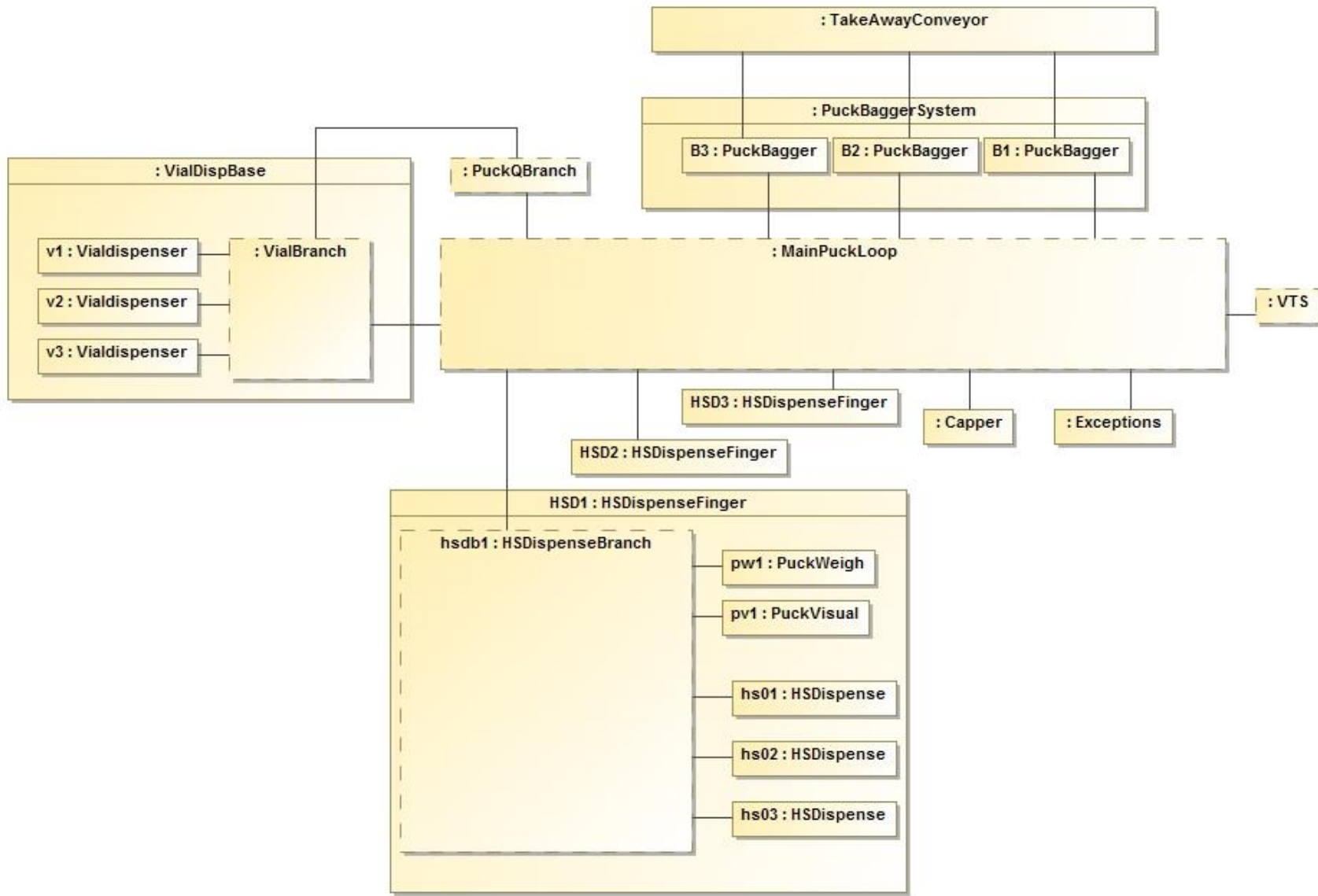
Sorting

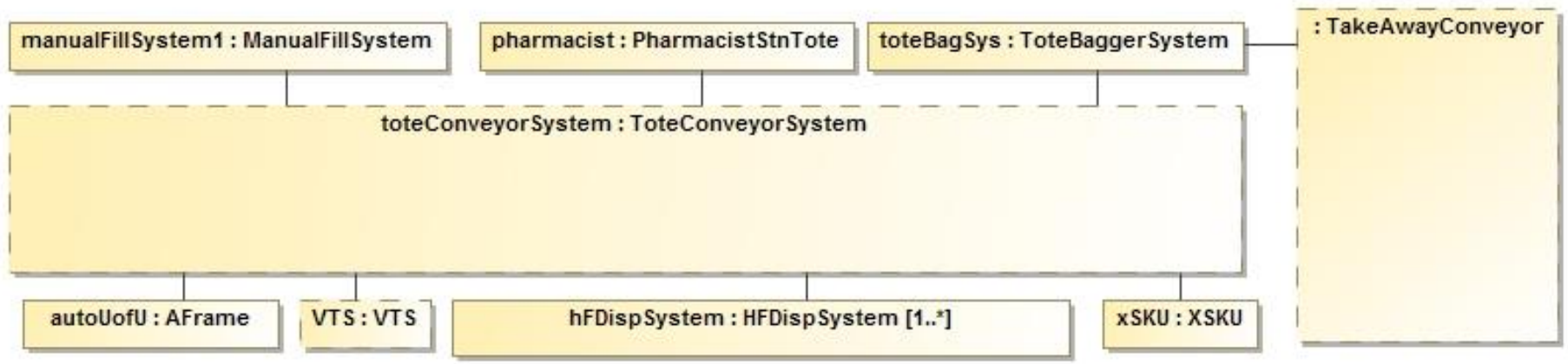


Product

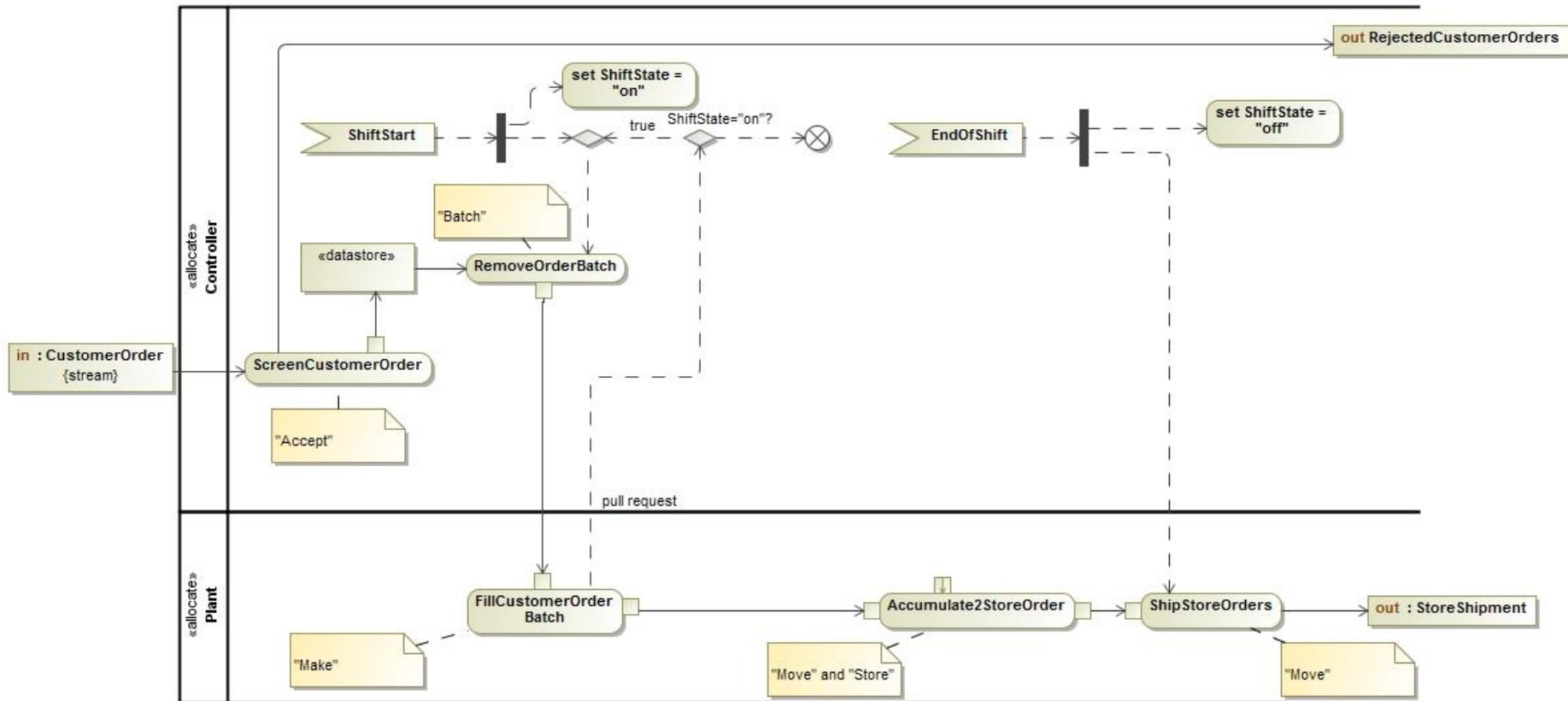
- The product of a CFP is a set of assembled orders ready to ship to the originating local pharmacy
 - Customer order may have one or more scripts
 - Scripts may be automatically dispensed from either the puck line or the tote line
 - Scripts may be manually dispensed from the tote line
 - An order must contain only scripts for drugs that are available in the CFP
 - All the orders for a local pharmacy must be collected for shipment overnight





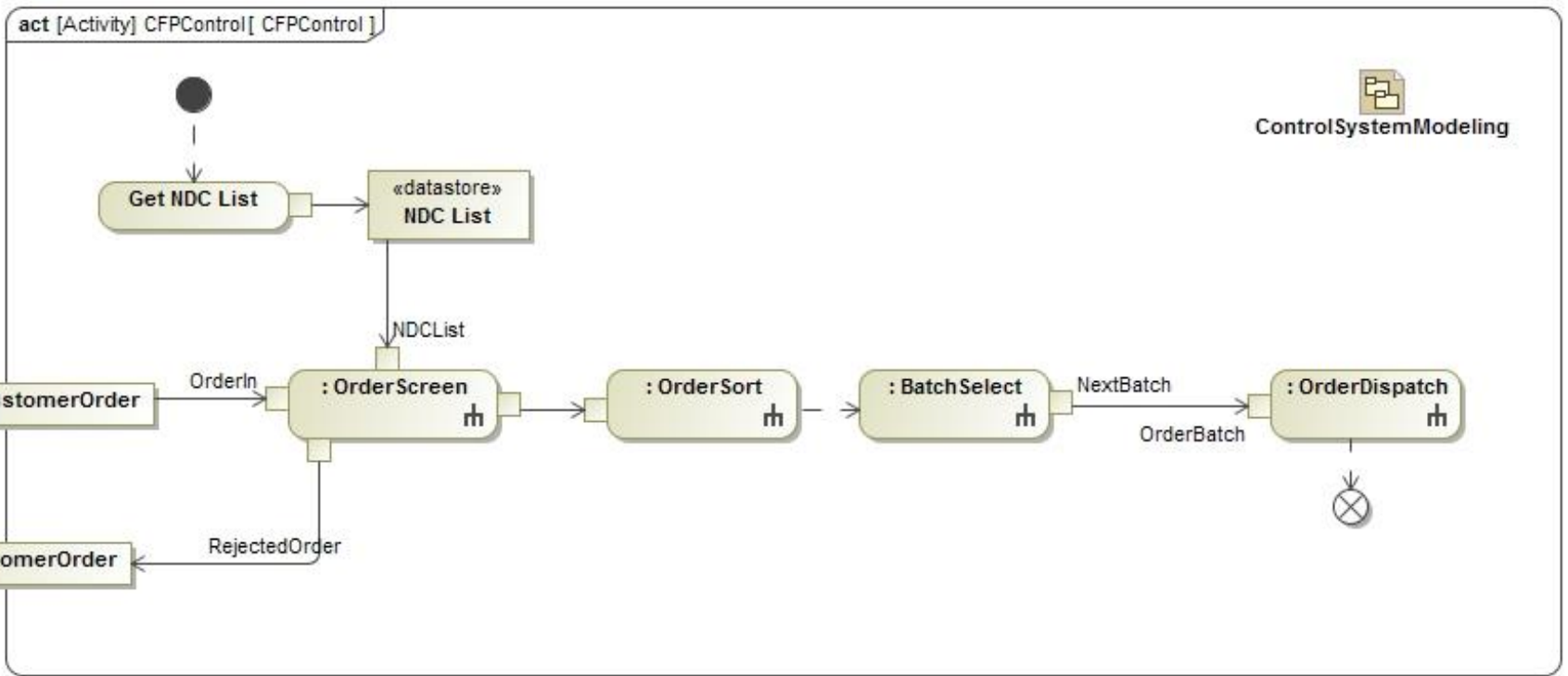


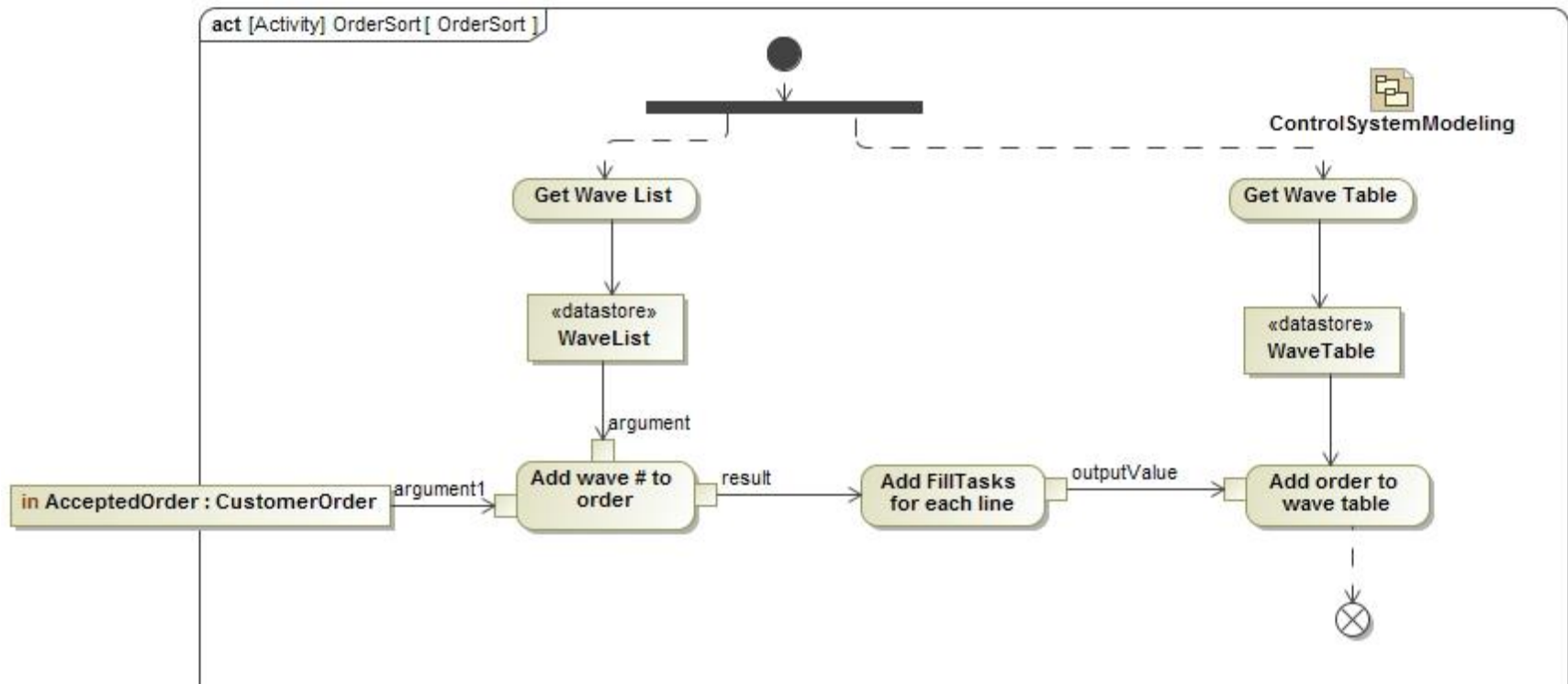
Basic processes





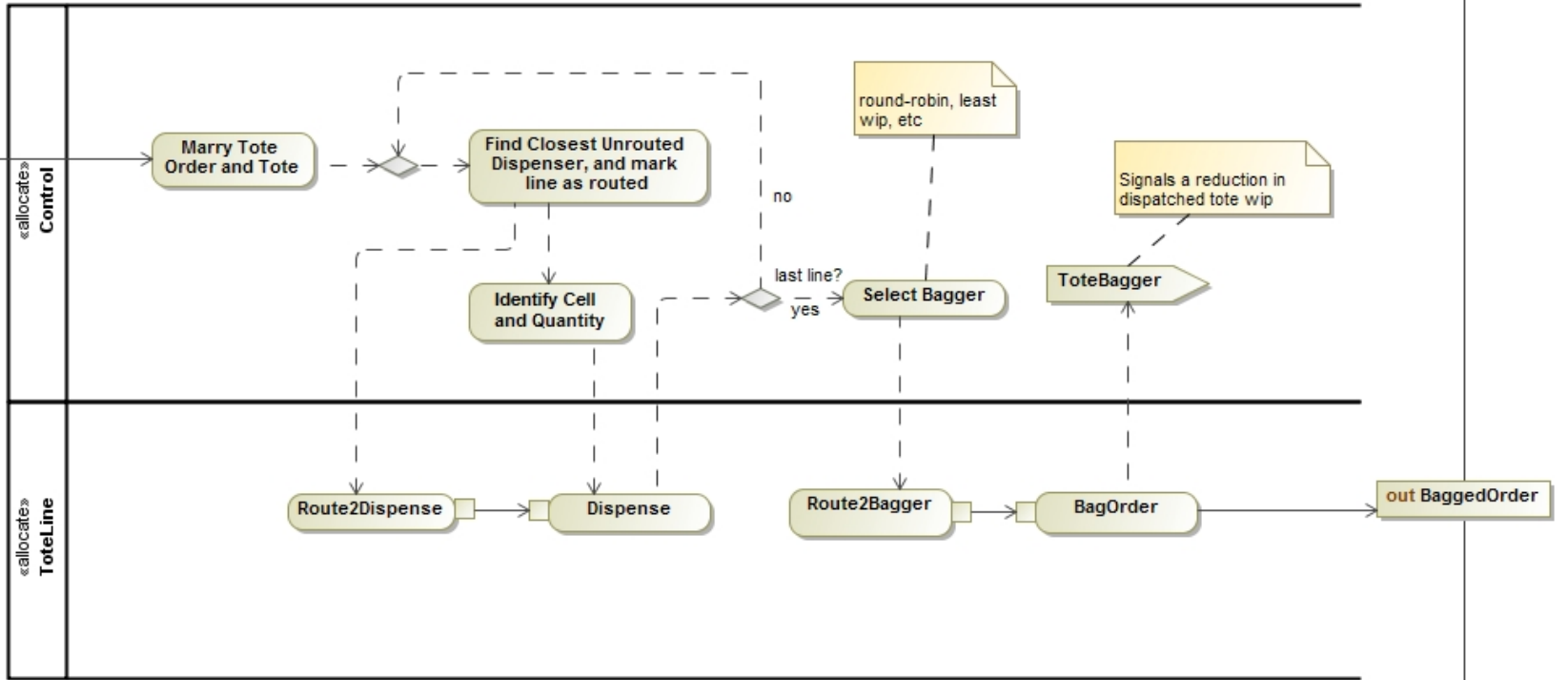
ControlSystemModeling





act [Activity] FillToteOrder [FillToteOrder]

ControlSystemModeling



Why is this worth doing?

- No ambiguity about the system concept or architecture
- Ability to specify any variation of this basic “style” of CFP
- Single source of truth for analyses to support all planning and operational control
- Specification for simulation model that enables experimentation with control rules and parameter settings

Conclusions

- It's worth doing
- It's really hard (at first), but so was DES and optimization
- We are gaining experience and fleshing out a hierarchical abstraction
- I don't see another way for us to get where we need to be—remember VHDL!

Thank you
and
Safe Travels Home!