From Smart Machines to Smart Supply Chains: Some Missing Pieces

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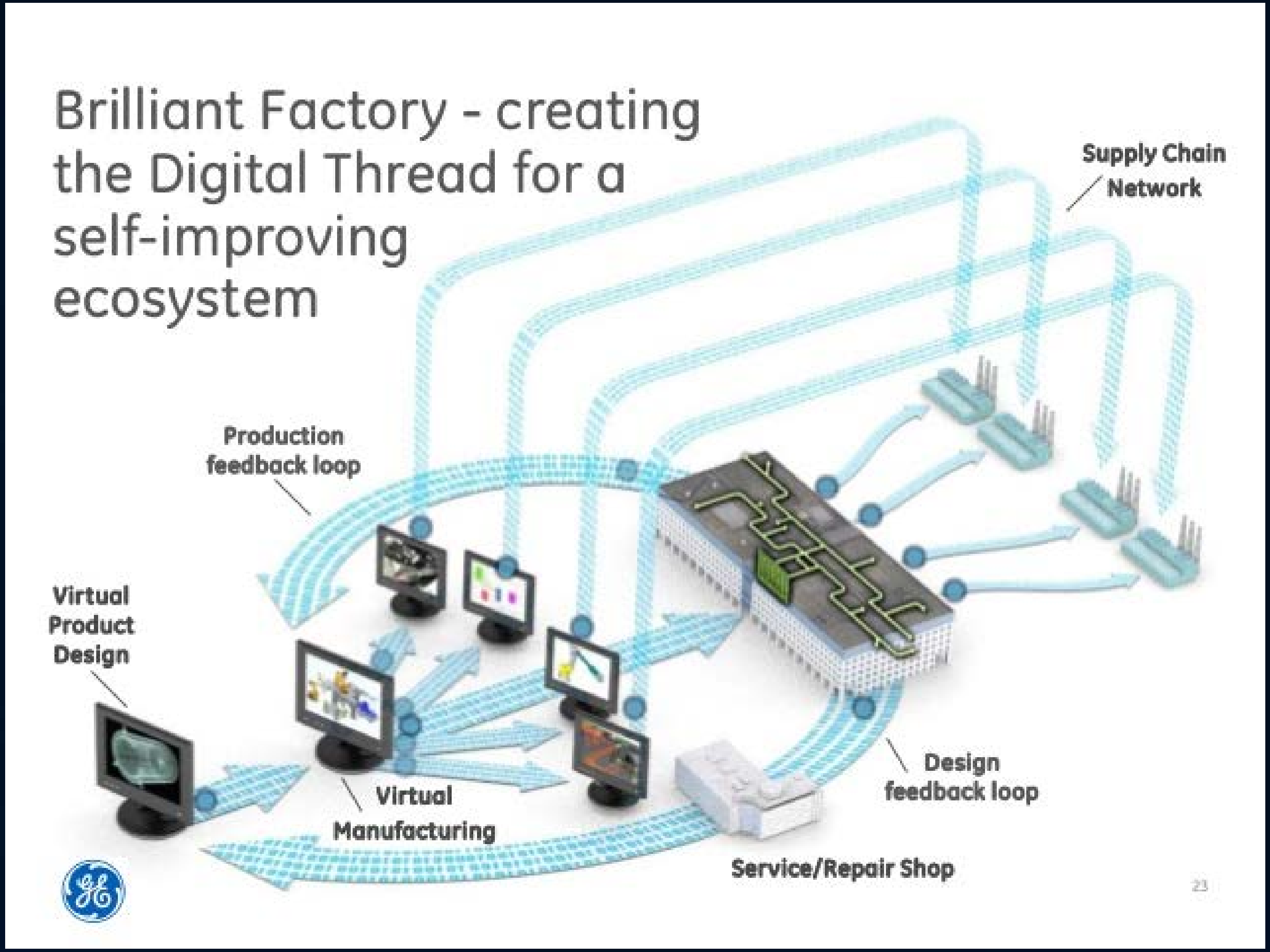
Agenda

- Smart factory context
- Reality check
- It’s all about decision making
- We all use models
- Lessons from device engineering
- The missing piece
- Getting what we need

Smart Factory



https://www.jobshop.com/techinfo/papers/brilliantparts.shtml

Smart Supply Chain

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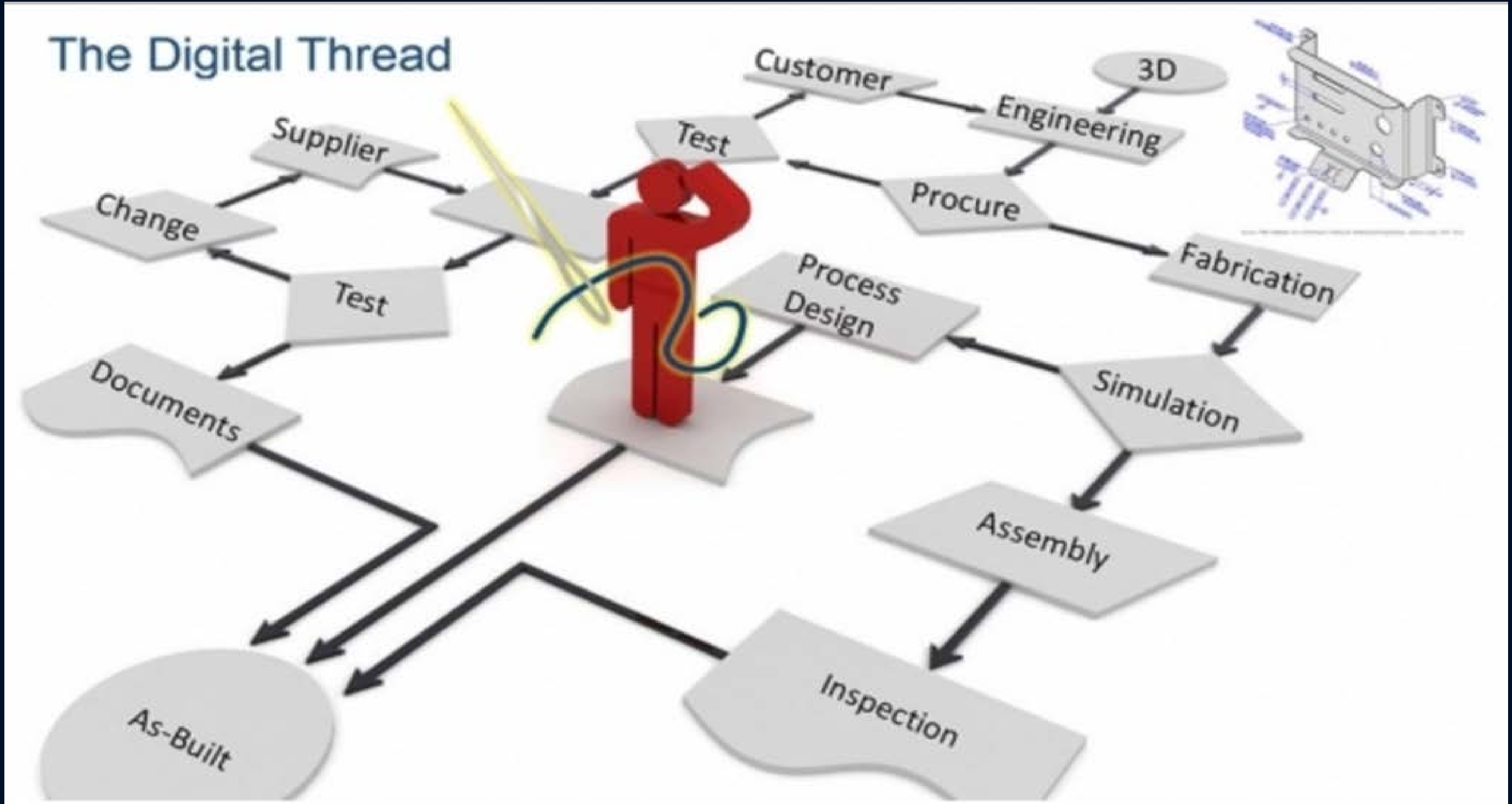
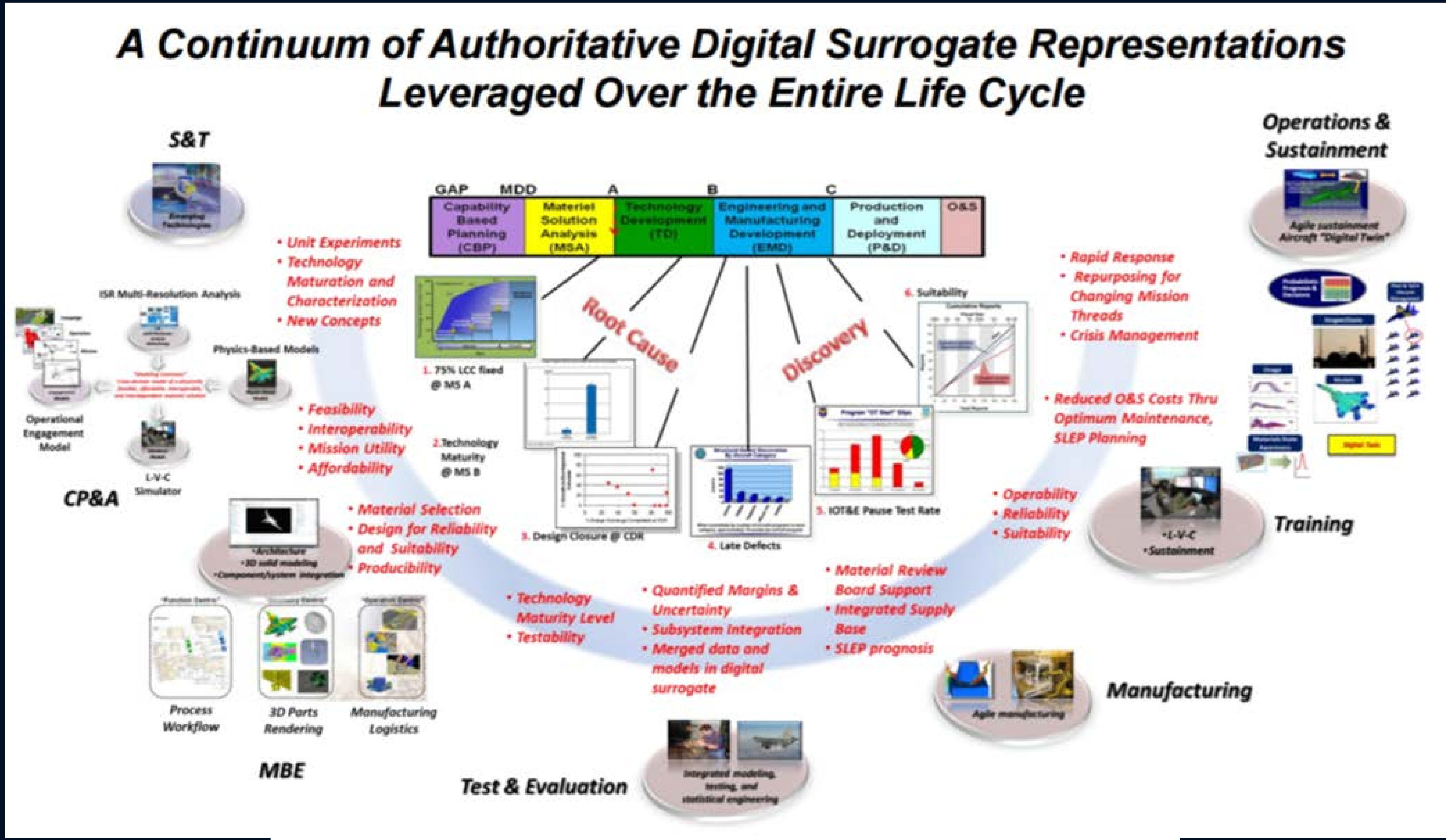


http://www.industryweek.com/systems-integration/demystifying-digital-thread-and-digital-twin-concepts?page=2

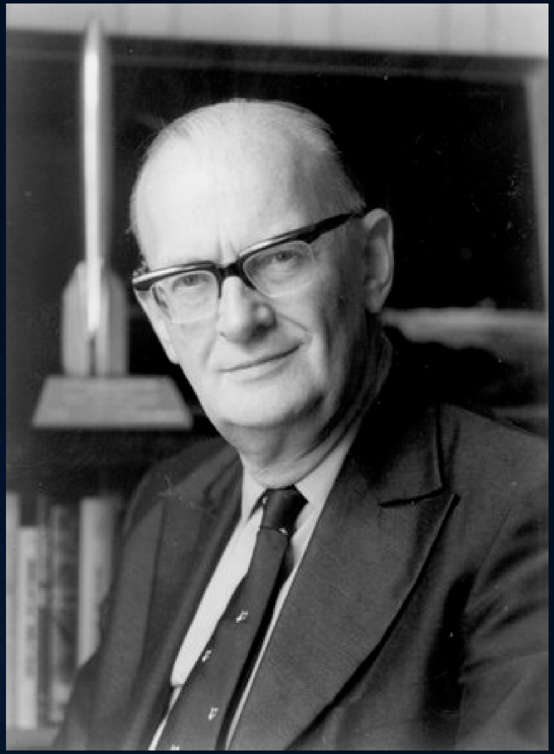


Dr. Ed Kraft, Technical Adviser, Arnold Engineering Development Center

https://www.nist.gov/sites/default/files/documents/el/msid/1Kraft_DigitalThread.pdf

We have the vision!

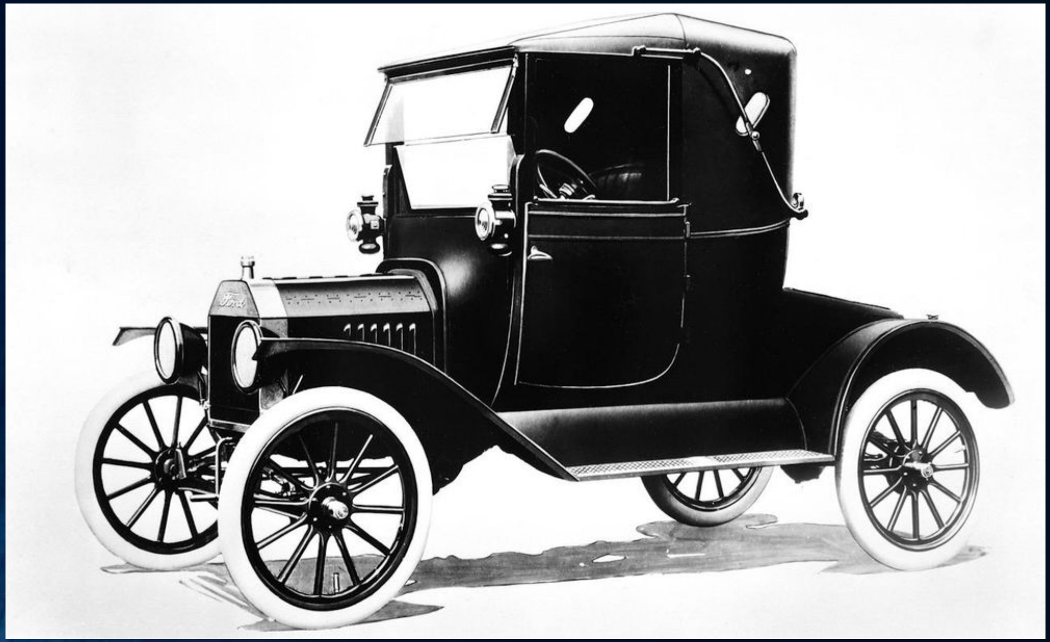
Clarke’s Third Law



https://www.penguinrandomhouse.com/authors/5058/arthur-c-clarke

Any sufficiently advanced technology is indistinguishable from magic.

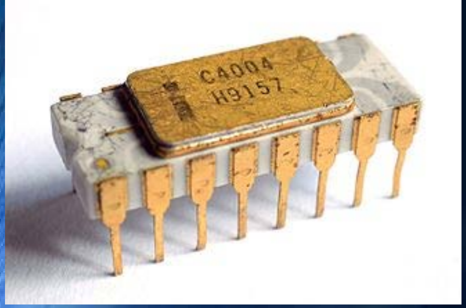
Horses to self-driving in ~100 years

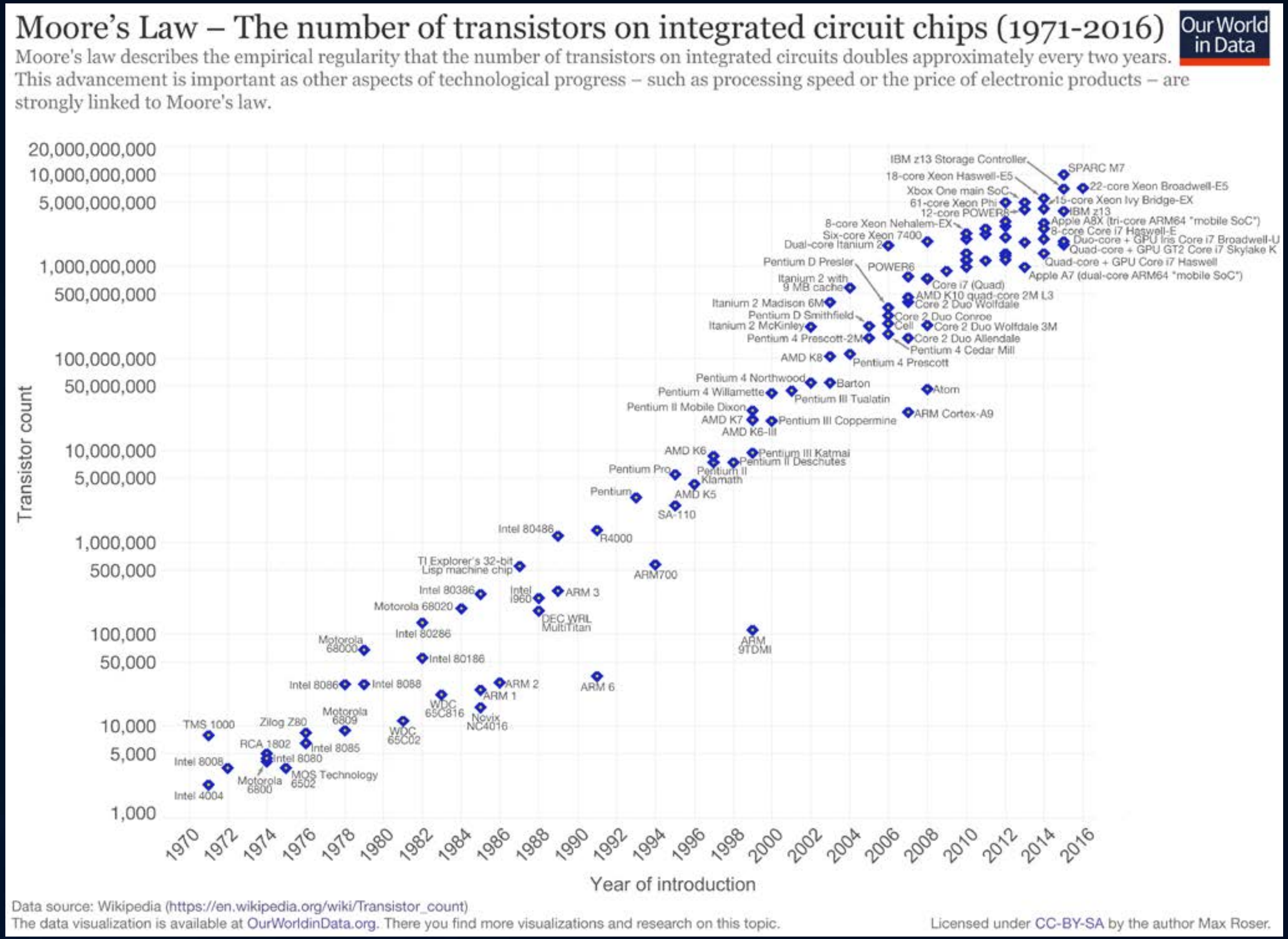


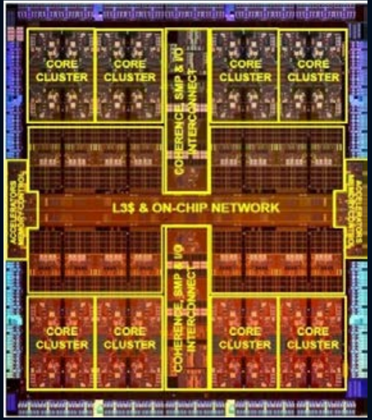
http://blog.dealerrater.com/wp-content/uploads/2016/05/t.jpg

https://c1cleantechnicacom-wpengine.netdna-ssl.com/files/2018/01/GM-Cruise-AV.jpg

10^6 x number of transistors in 40 years!







After 50 years, computer wins Jeopardy!

https://www.npr.org/2011/02/14/133697585/on-jeopardy-its-man-vs-this-machine

Today, it is very easy to take for granted that technology will solve the problem, and smart factories and supply chains really are just around the corner.

What is a “smart machine”?

- Combines Cognitive Computing
  - Intelligent Personal Assistant (Siri)
  - Specialized Applications (meeting scheduler)
  - Intelligent Agent (call center agent)
  - Platform (Watson)
- With hardware (e.g., robot, automobile)
- And “machine-to-machine” technology

Self-Driving Truck "Platoon"

https://www.theverge.com/2016/4/7/11383392/self-driving-truck-platooning-europe


42
culvercityfirefighters
Culver City, California
Follow
culvercityfirefighters A Tesla plowed into the rear of Engine 42 earlier this morning while crews were on the 405 freeway for a motorcycle down. Amazingly there were no injuries! Please stay alert while driving!
#ccfd #culvercityfire
#culvercityfiredepartment
#culvercityfirefighters #culvercity
#heartofscreenland #abc7eyewitness
#fox11news #ktla5news
View all 32 comments
kurt_c86 That just happened to our E4 a few months ago, hit by a Tesla on the 10 fwy
310 likes
1 DAY AGO
Log in to like or comment.

Schneider Electric Says:

Existing smart technologies include:

- Ethernet-based networking
- Enhanced SCADA systems
- Web-enabled PLCs
- Advanced motion controllers
- Intelligent AC drives

Top 5 Automotive Robotic Applications*

- Vision: aligning parts for assembly
- Collaborating robots : handling and welding
- Robotic hand: exoskeleton devices
- Collaborating with humans: final assembly of doors
- Painting

*https://blog.robotiq.com/bid/69722/Top-5-Robotic-Applications-in-the-Automotive-Industry

Contemporary “Smart Machines”

- Highly structured environments
- Narrowly defined tasks
- Ability to report diagnostics
- Task-related decision making
- Limited ability to interact

How do we create smart factories and smart supply chains from smart machines?

What is a “smart factory”?

Which was the "smarter" team?

Rk '17	Team	2017 Payroll
1	Dodgers	$225,553,087
2	Tigers	$199,750,600
3	Yankees	$195,282,058
4	Giants	$181,514,431
5	Red Sox	$178,818,052
18	Indians	$125,808,029
19	Astros	$122,407,233
20	Marlins	$120,191,297

Decision-Making Drives Results

HOW DO WE GET TO (EVEN) BETTER DECISION MAKING?

In The Fab, Smarter Is:

- Better operations management decisions
  - Shorter cycle times
  - More throughput
  - Less WIP
  - Lower costs
  - Higher quality

  Without sacrificing profitability!

- Better systems design decisions
  - Lower system costs
  - Faster ramp
  - Greater flexibility
  - Greater adaptability

  Without sacrificing capability!

In The Supply Chain, Smarter Is:

- Better operations management decisions
  - More on time delivery
  - Better asset utilization
  - Less inventory
  - Lower costs
  - Higher quality

Without sacrificing profitability!

- Better systems design decisions
  - Lower system costs
  - Faster ramp
  - Greater flexibility
  - Greater adaptability

Without sacrificing capability!

“Smarter” is not defined by input (investment), it’s defined by output (results).

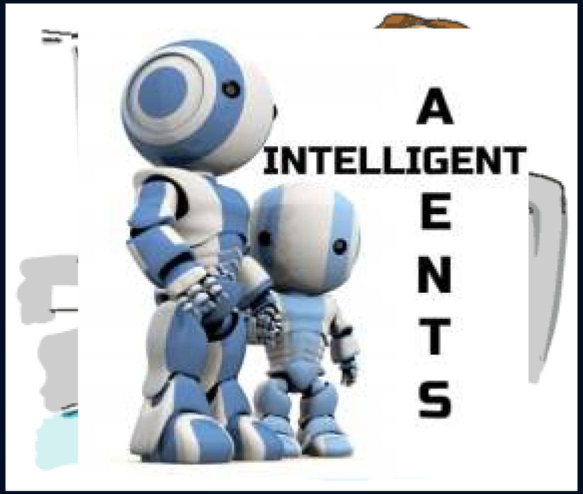
It’s achieved by using resources wisely—both investment resources and operational resources.

It requires good decision-making!

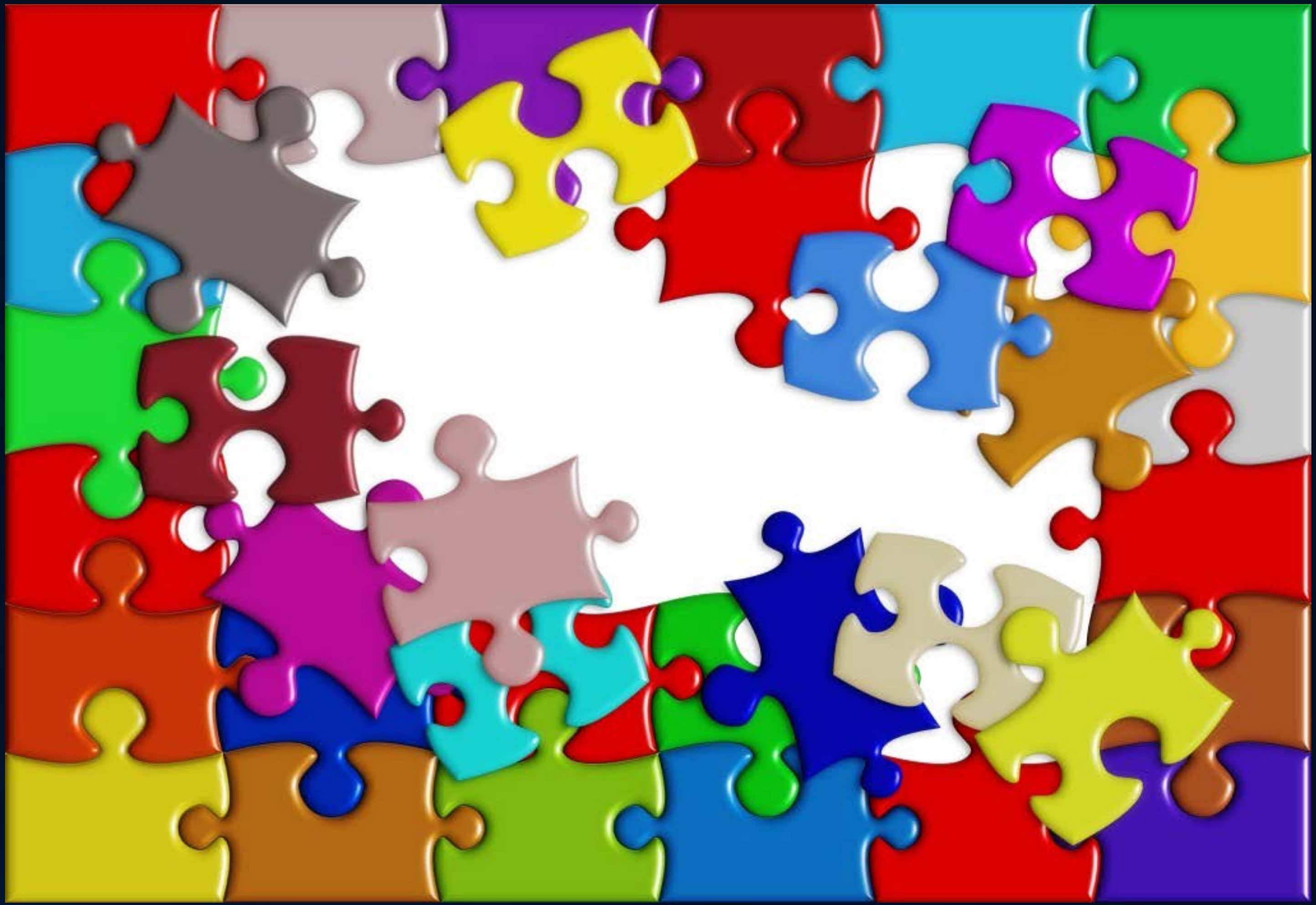
All decisions are based on models

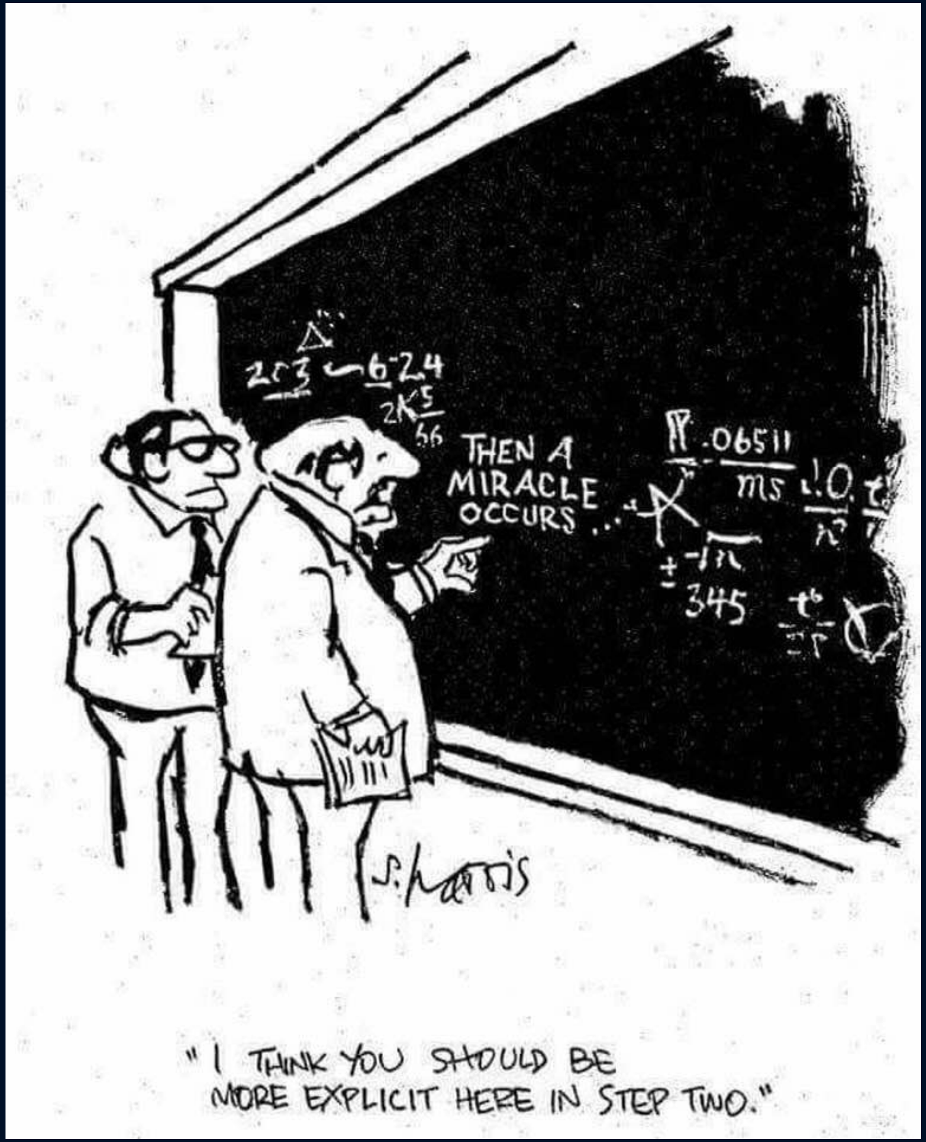
https://asia.nikkei.com/Business/AC/TSMC-ARM-team-up-to-fight-Intel-in-data-center-chips

What kinds of models are decision makers using?

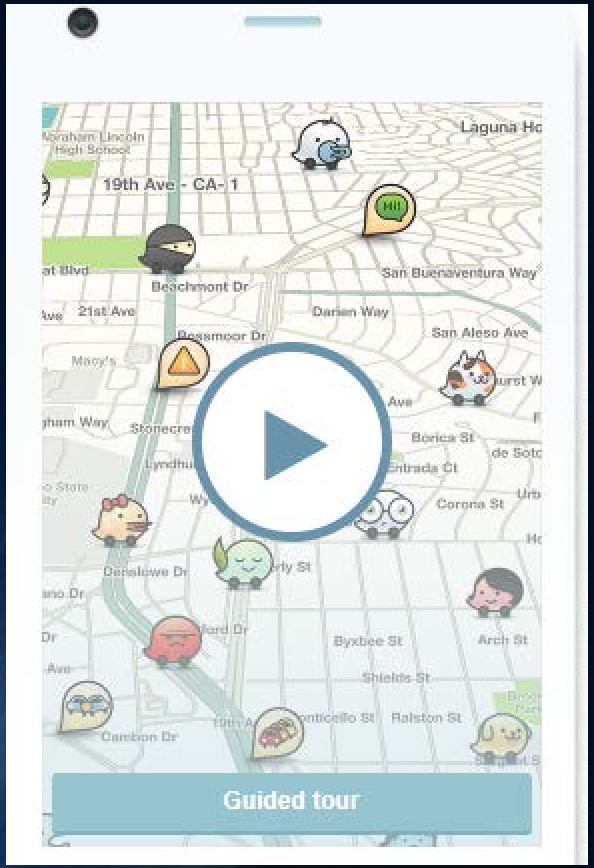


Missing Puzzle Pieces – The System Model



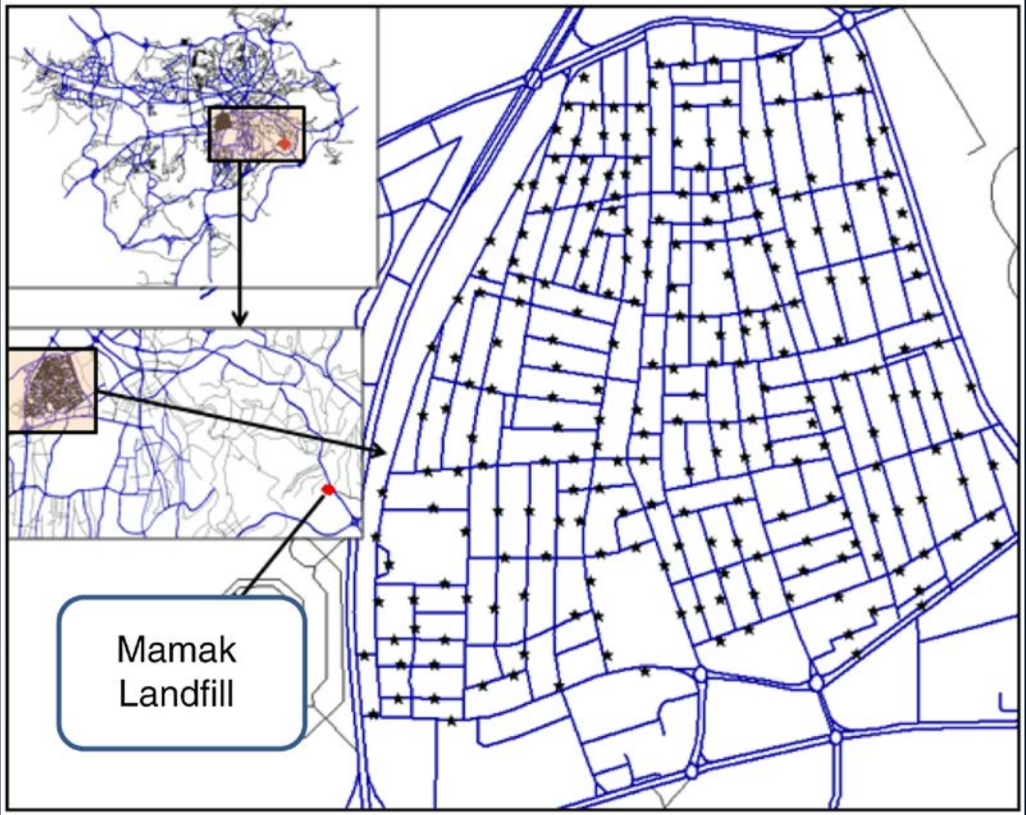

THEN A MIRACLE OCCURS
"I THINK YOU SHOULD BE MORE EXPLICIT HERE IN STEP TWO."

Example: Operational Decision Support



Waze: combination of map data ("static" data about the system) and real-time speed data (collected from Waze users) to compute the "optimal" route for you.

Underlying Formal Model

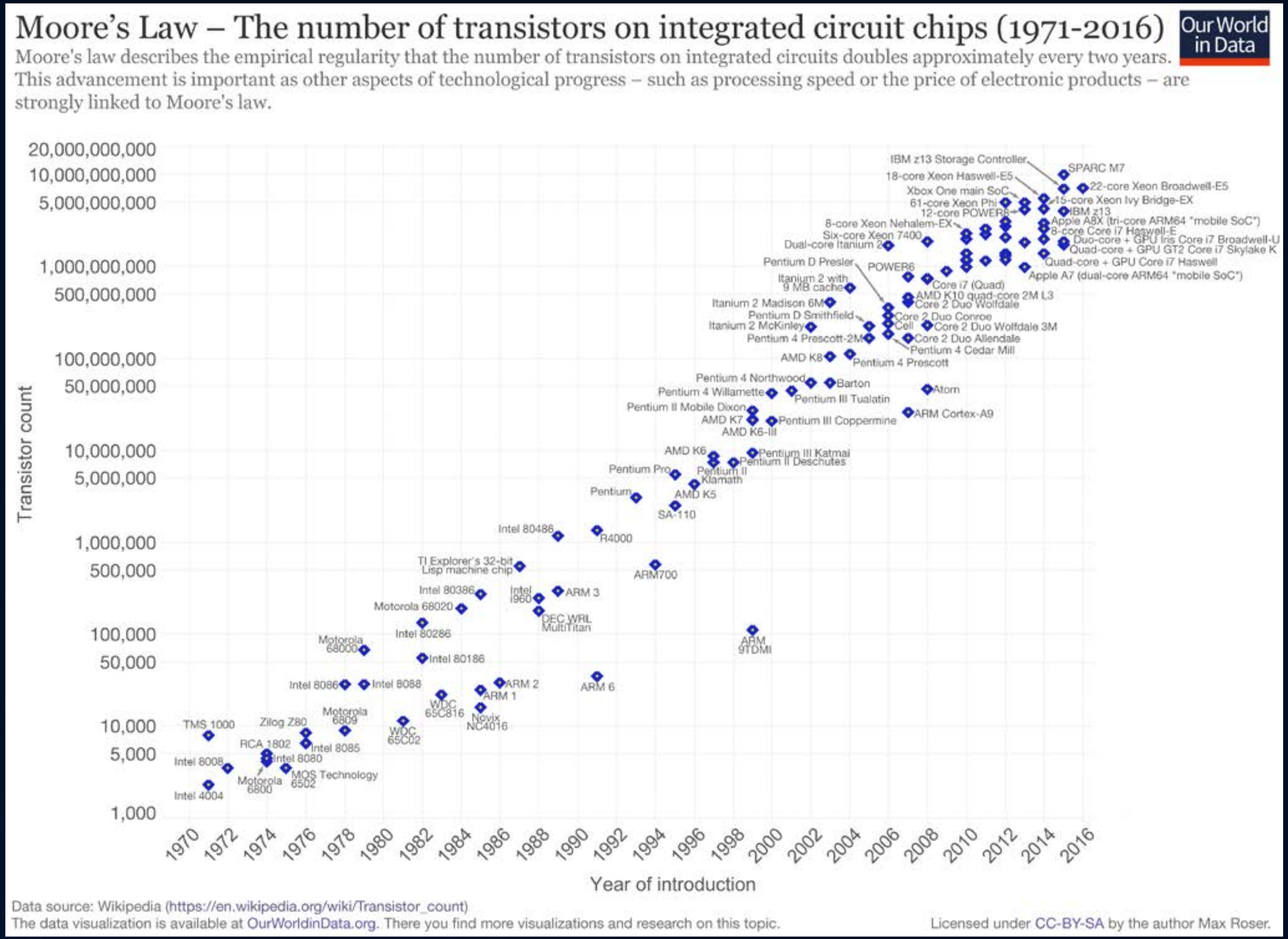


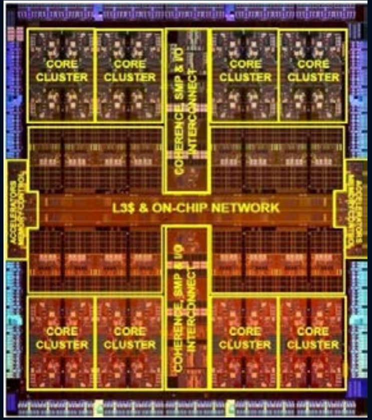
https://ascelibrary.org/doi/abs/10.1061/(ASCE)CP.1943-5487.0000502

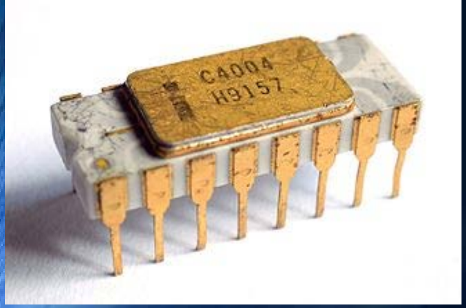
Directed network ("graph") with edge distance representing travel times; use shortest path algorithm to determine best route between two points on the network

No route-finding app can be successful without this underlying formal representation of the transportation system!

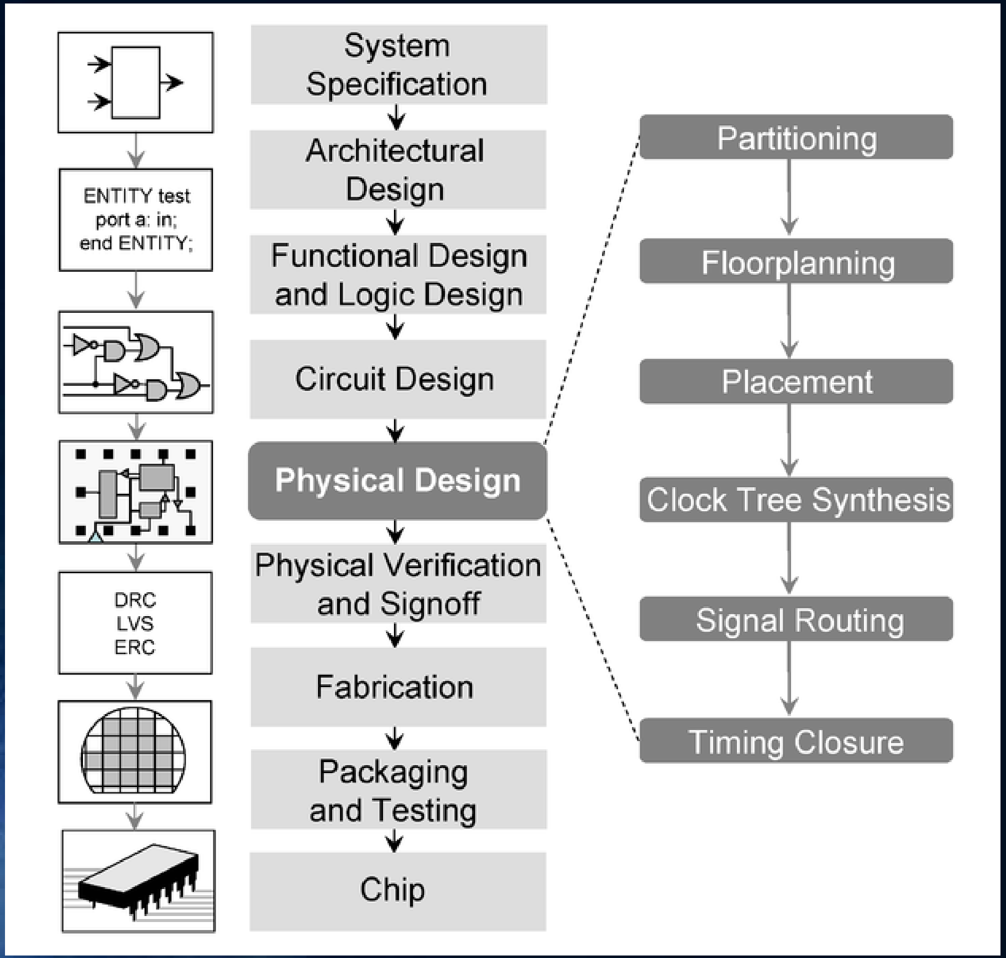
10^6 x number of transistors in 40 years!







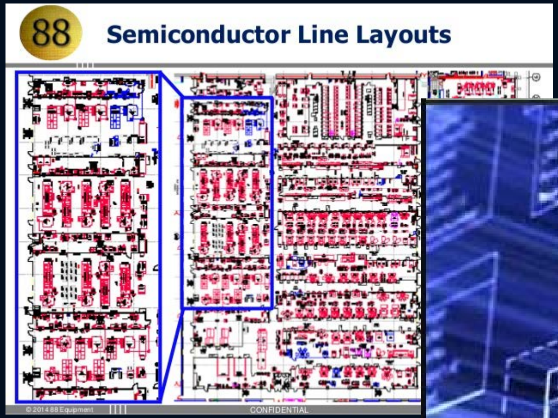
Designing IC's with 10^7 transistors



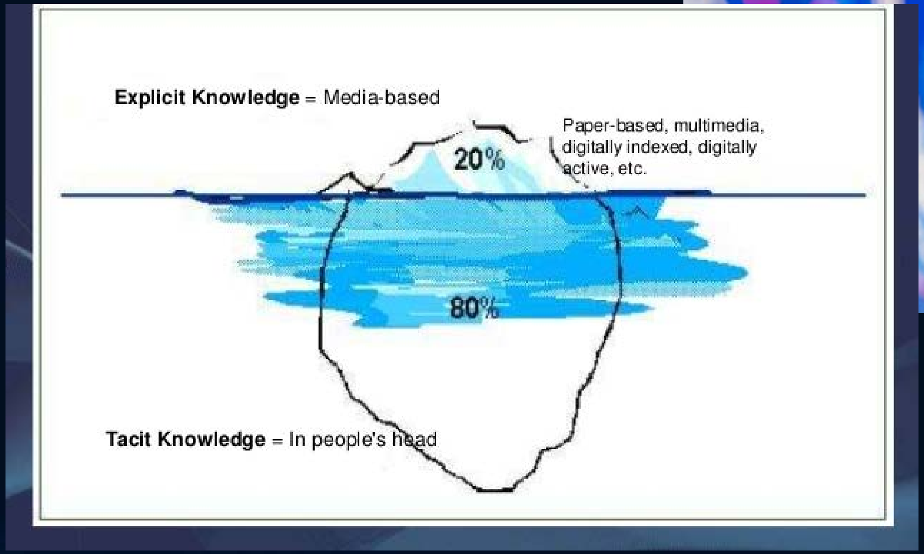
https://commons.wikimedia.org/wiki/File:PhysicalDesign.png

Is only possible because of computational tool chains that enable both specification and analysis at every level from system architecture and function all the way down to the physical layout of the device.

This tool chain is only possible because of formal—computable—system models at each of these levels of abstraction and VHDL was the key.

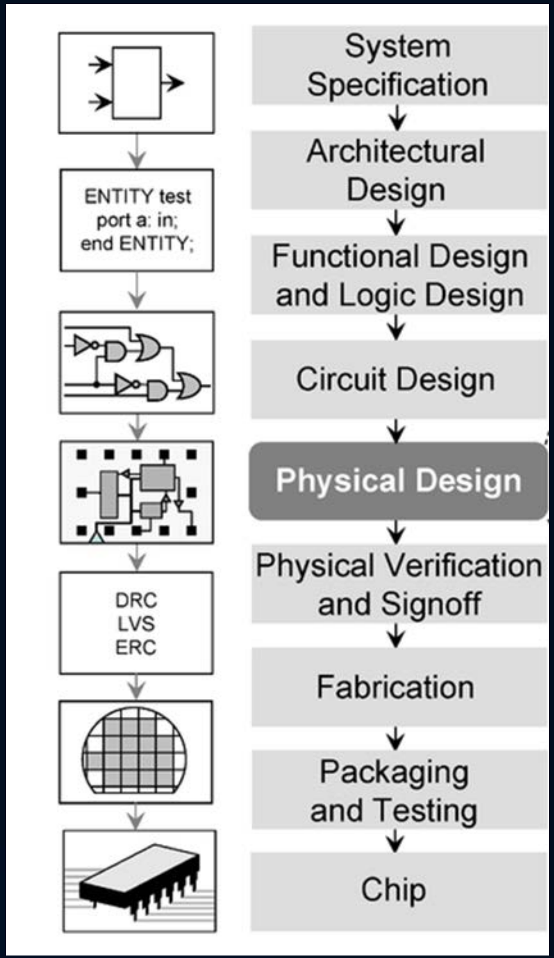

88
Semiconductor Line Layouts
CONFIDENTIAL


TimeKey
CustomerKey
ShipperKey
ShipperID
ShipperName
ProductKey
ProductID
City
Region
PCode
Country


Explicit Knowledge = Media-based
Paper-based, multimedia, digitally indexed, digitally active, etc.
20%
80%
Tacit Knowledge = In people's head

Fab Formal Model Requirements

- Elements of the fab
  - Tools, material handling, foups, people, consumables, …
- Connections
  - Supporting product flow; control flow; information flow; …
- Behavior of resources
  - Resource states and transitions; processes; …
- Products
  - Process plans; production rates; lot sizes; variations; …
- Performance prediction
- ***At multiple levels of abstraction***



Predictions Answer Questions

- Capability
  - Can this fab produce this product?
- Capacity
  - Can this fa
- Cycle time
  - Under this
- Work in pro
  - Under this load, what will be the amount and distribution of WIP?
- And many more questions supporting fab design decisions

Resource portfolio
Resource configuration (layout)
Control policies and algorithms
Production plan

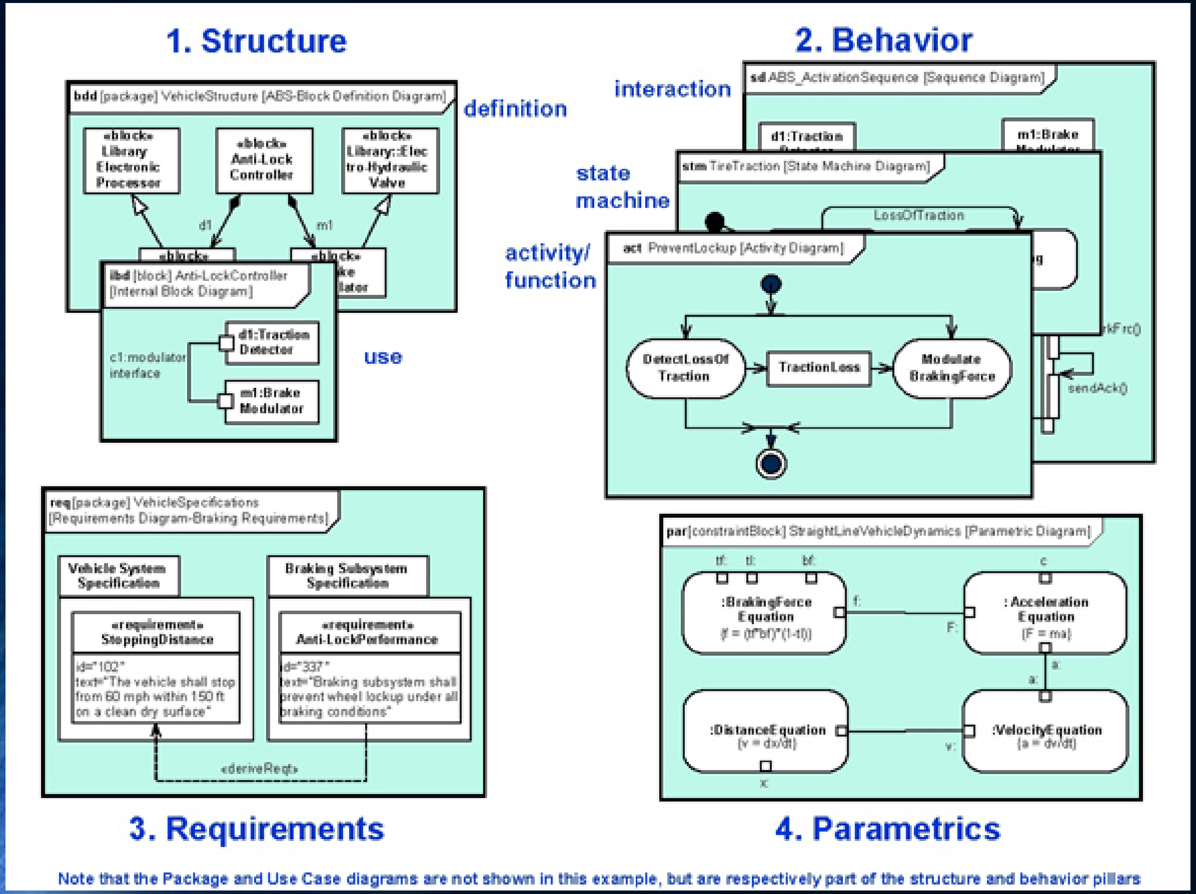
We already know how to construct models to support answering these questions!

Can we do for fabs what has been accomplished for devices?

I THINK THE ANSWER IS <u>YES</u>! THE KEY IS SYSTEM MODELS…

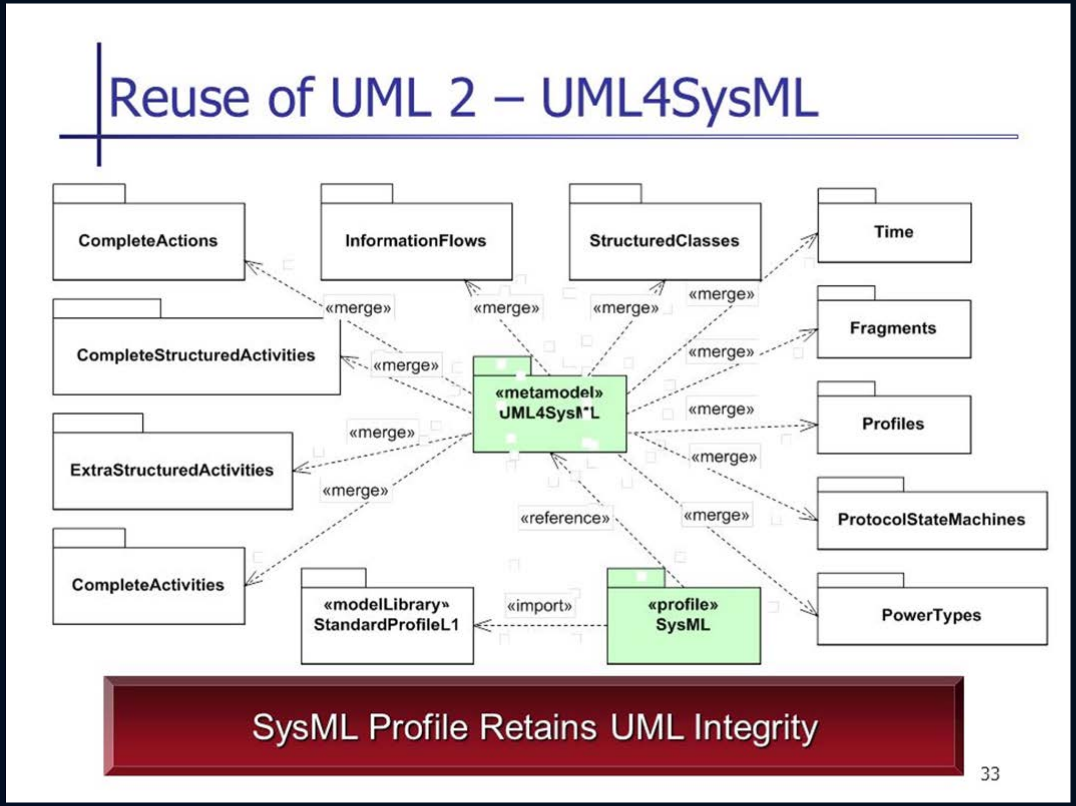
OMG SysML™

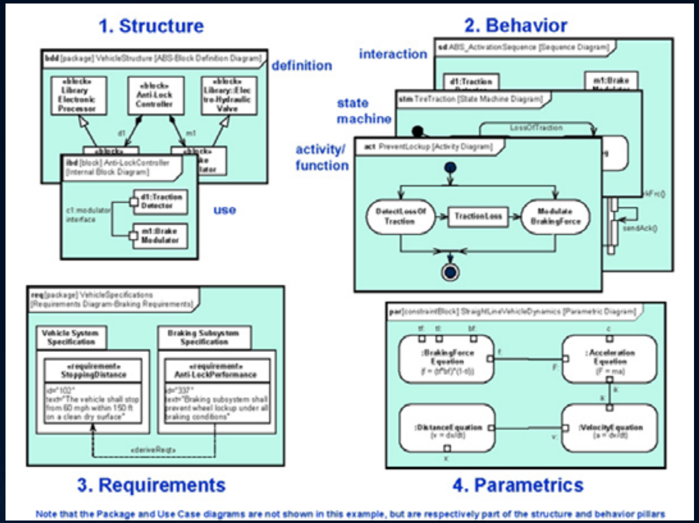
Graphic Presentation



http://www.omgsysml.org/what-is-sysml.htm

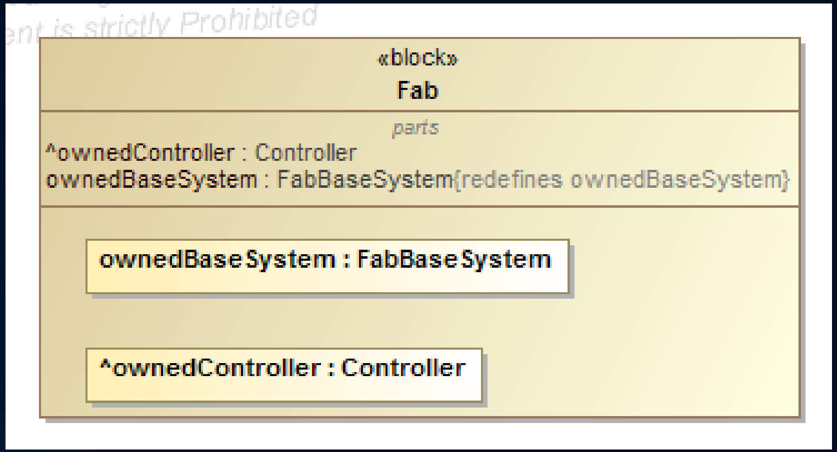
Underlying formal semantics and syntax

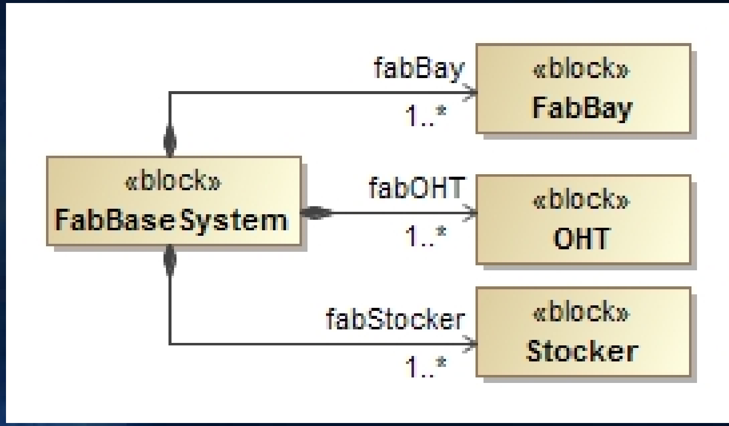


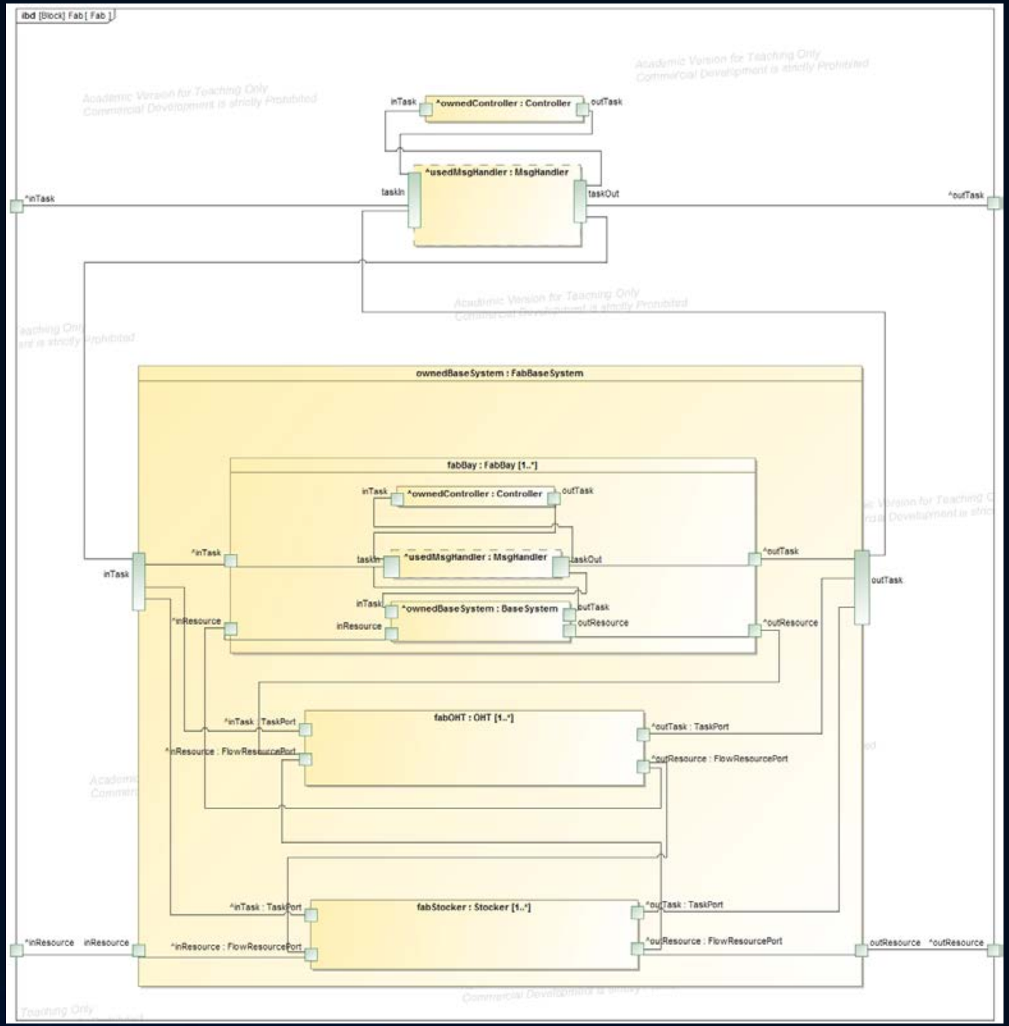


Domain-Specific "Fab Description Language" or *FDL*

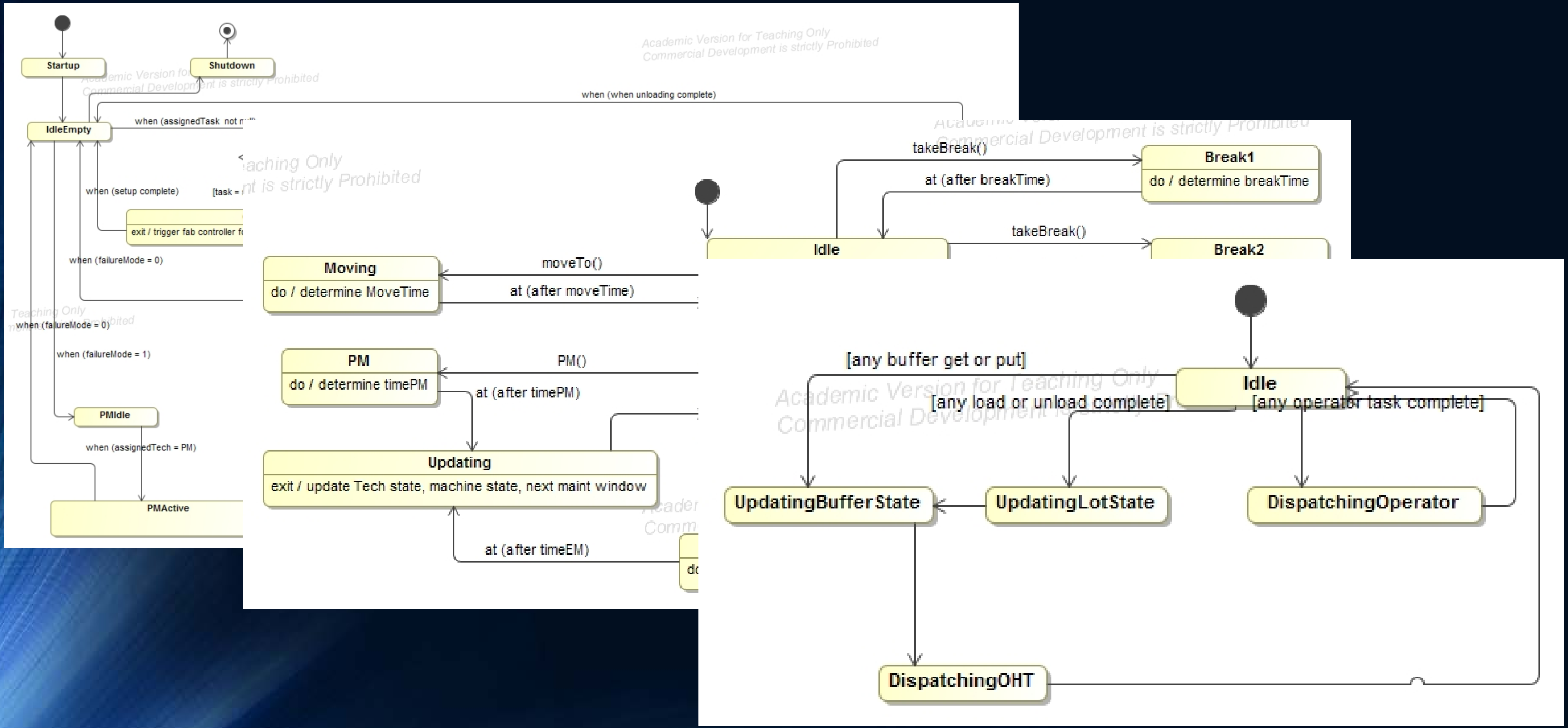
Fab Structure



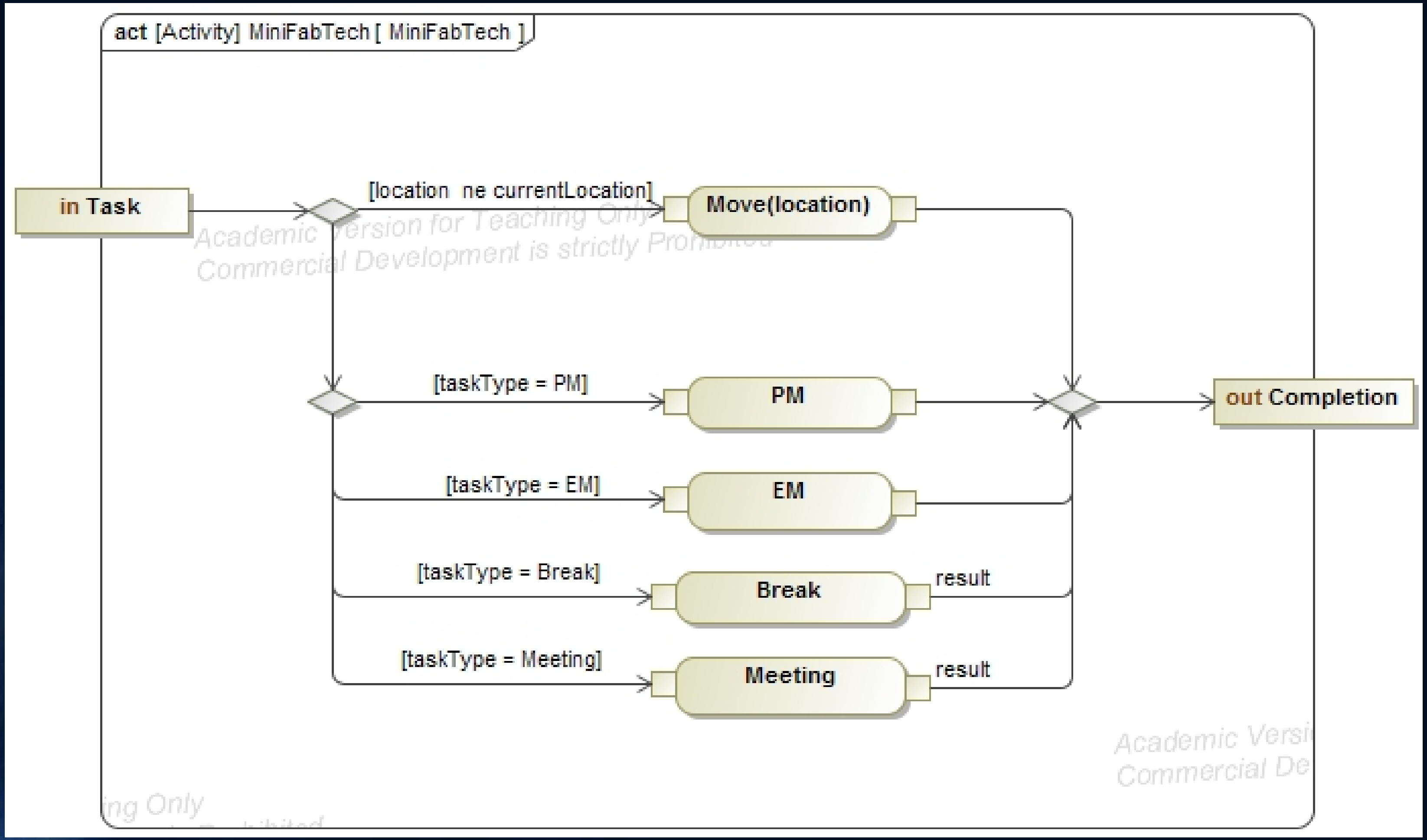




Fab Behavior: State Machines



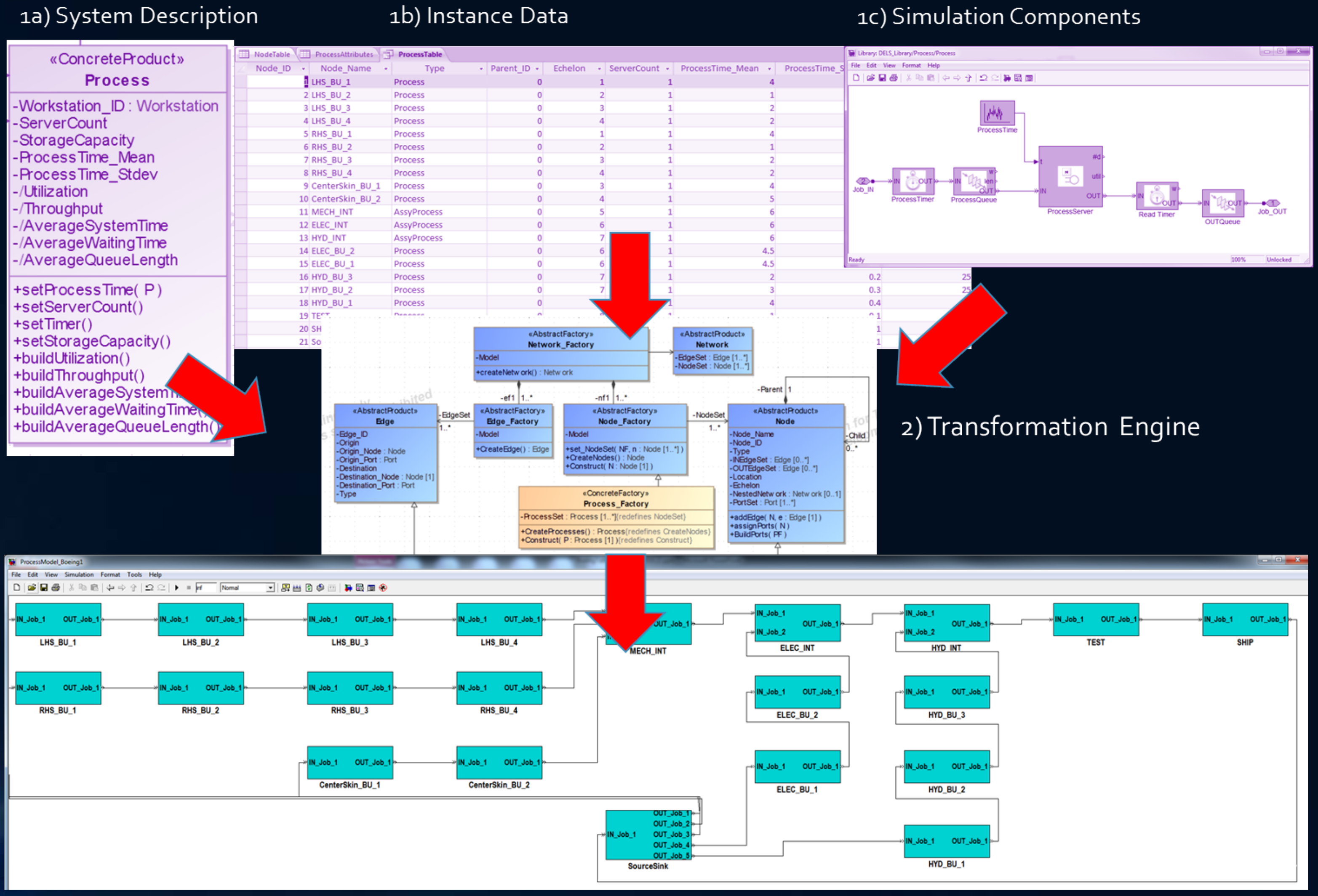
Task Behavior: Activity



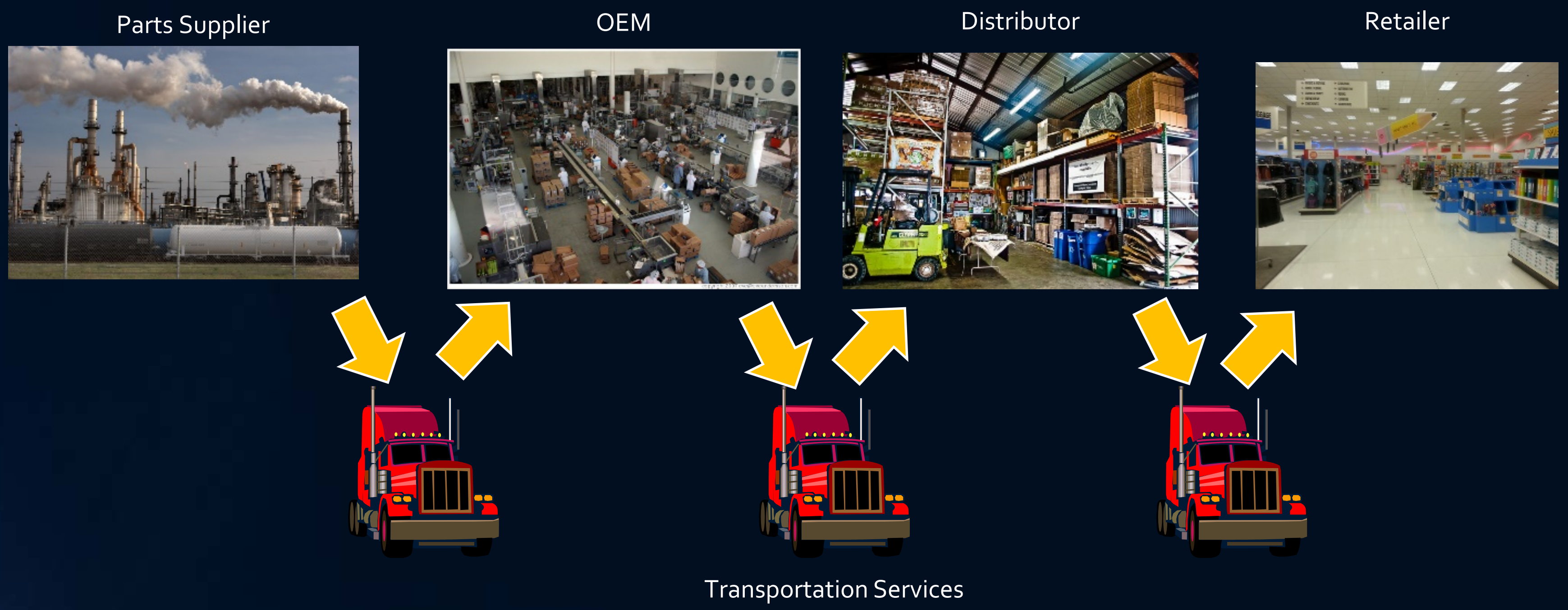
System Modeling Benefits

- System specified at multiple levels of abstraction/fidelity
  - Essential to support design
- Graphical models are easy to understand
  - Essential for capturing knowledge and achieving "buy-in"
- Basis for agreement among subject matter experts
  - Essential for large-scale complex multi-disciplinary systems
- Foundation for analysis model development
  - Essential for enabling the emergence of tool chains
- Foundation for analysis model automation
  - Essential for deployment to practice

Analysis model automation



Supply Chain System Modeling



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**.

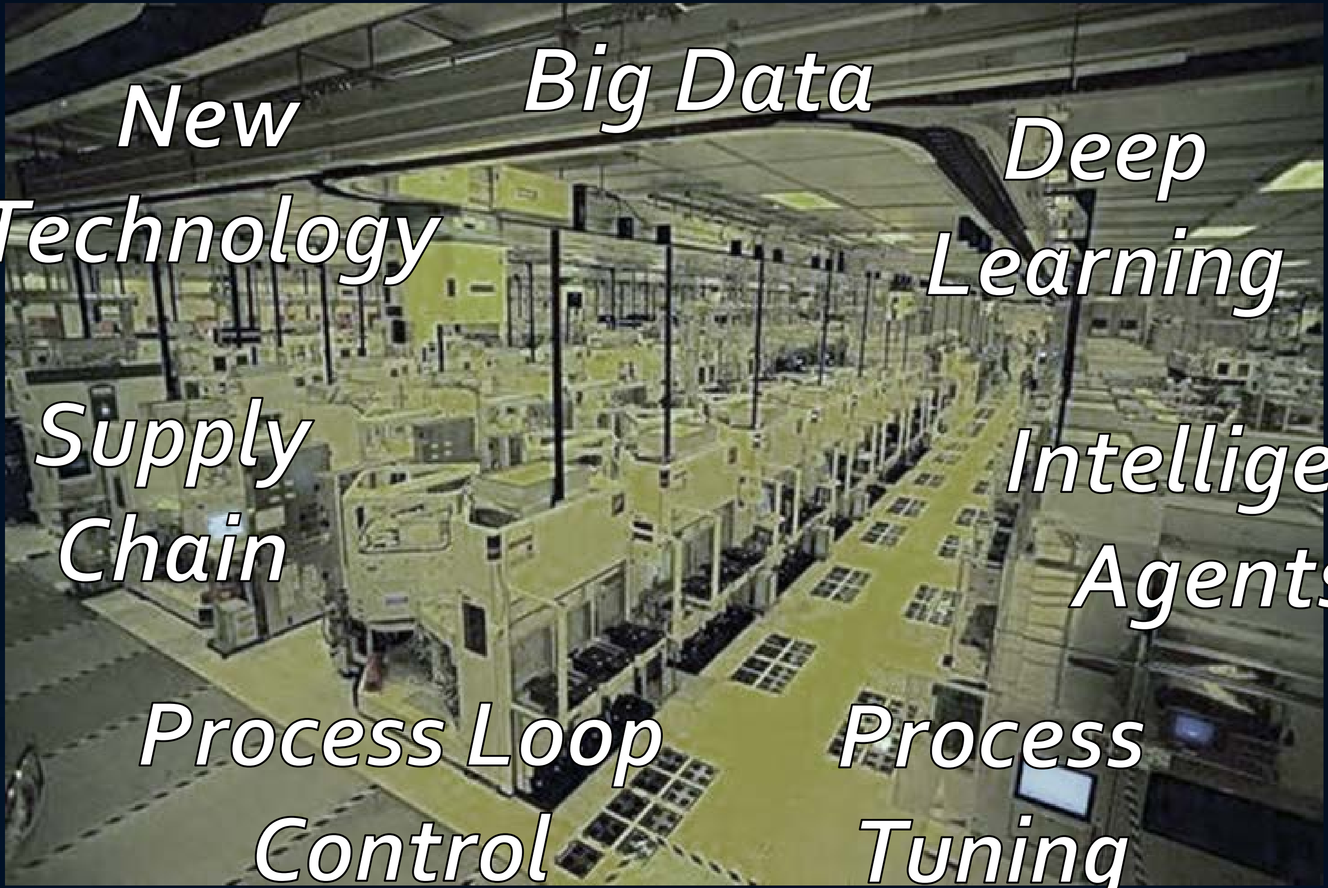
Transformations can be adequately described by their start and end events, and by the summary description of the state change accomplished.

Some typical questions

- Do we have sufficient capacity to add a new program in our final assembly and
- Should we use … logistics network, and if so, what … om each point?
- How much inv … nsure a 99% on-time custome
- For a new product, which parts should we outsource and which should we produce in-house?

We already know how to construct models to support answering these questions!

New Questions/Answers?



Formal system models will give us the means to better organize, synthesize, communicate and share the new knowledge that is being created ***about the system***.

SysML is the key

- Based on a formal meta-model
- Formal semantics and syntax
- Extensible through generalization and redefinition
- API provides computational access to the model => build apps

How will we get there?

- Research and development
- Demonstration projects
  - NIST: Smart Manufacturing Operations Management
  - Industry: Production System Reference Model
- Industry-university collaboration
  - INCOSE Challenge Team: Production and Logistics System Modeling http://www.omgwiki.org/MBSE/doku.php?id=mbse:prodlog

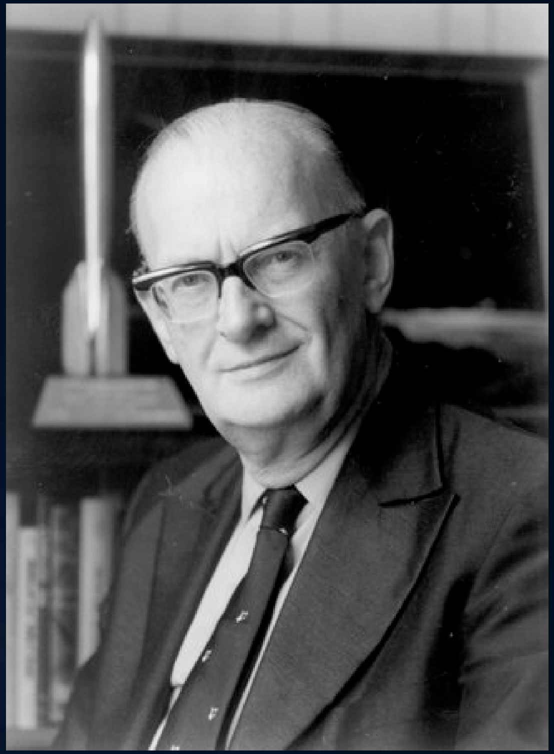
Why should we do it?

- Factories and supply chains are under stress
  - Speed
  - Cost
  - Adaptability
- They are complex systems with many interacting parts
- We need virtual systems ("digital twins"):
  - To develop/demonstrate innovations in design and control
  - To train "intelligent agents"

Why is this so much harder than VHDL?

- Because the US Department of Defense funded the development of a device specification language and standard to document the devices being purchased for weapons systems—money was no object
- There is not (at this time) any government agency or program requiring the documentation of factories or supply chains, and so a "DELSDL" must be created by the owners of factories and supply chains, in a large scale collaborative effort.
- But the required technologies are at hand. All that is needed in addition is the will and the commitment of resources.

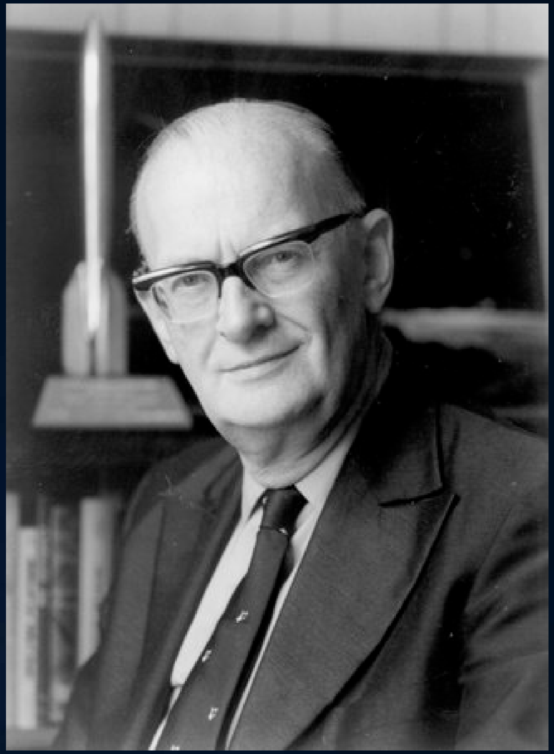
Clarke's First Law



https://www.penguinrandomhouse.com/authors/5058/arthur-c-clarke

When a distinguished but elderly scientist plenary speaker states that something is possible, they are almost certainly right. When they state that something is impossible, they are very probably wrong.

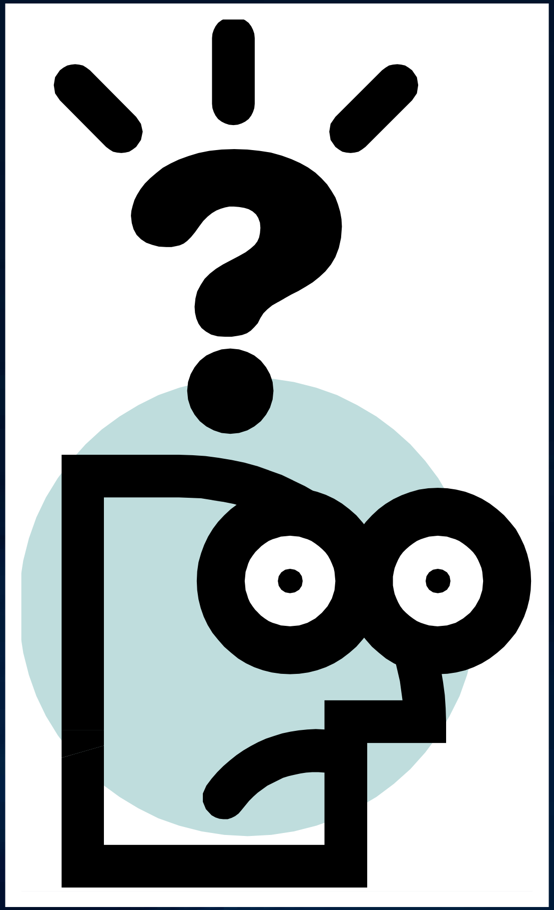
Clarke's First Law (modified)



https://www.penguinrandomhouse.com/authors/5058/arthur-c-clarke

When a ~~distinguished but elderly scientist~~ plenary speaker from far away states that something is possible, they are almost certainly right. When they state that something is impossible, they are very probably wrong.

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/

leon.mcginnis@gatech.edu