DESIGN TECHNOLOGY FOR THE TRILLION-DEVICE FUTURE

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The Emerging IT Scene!

Infrastructural core

Sensory swarm

Mobile access

Courtesy: J. Rabaey

Computers and mobiles to disappear!

Predictions: 7 trillions devices servicing 7 billion people!
1,000 devices per person by 2025

The Immersed Human

Real-life interaction between humans and cyberspace, enabled by enriched input and output devices on and in the body and in the surrounding environment

Courtesy: J. Rabaey

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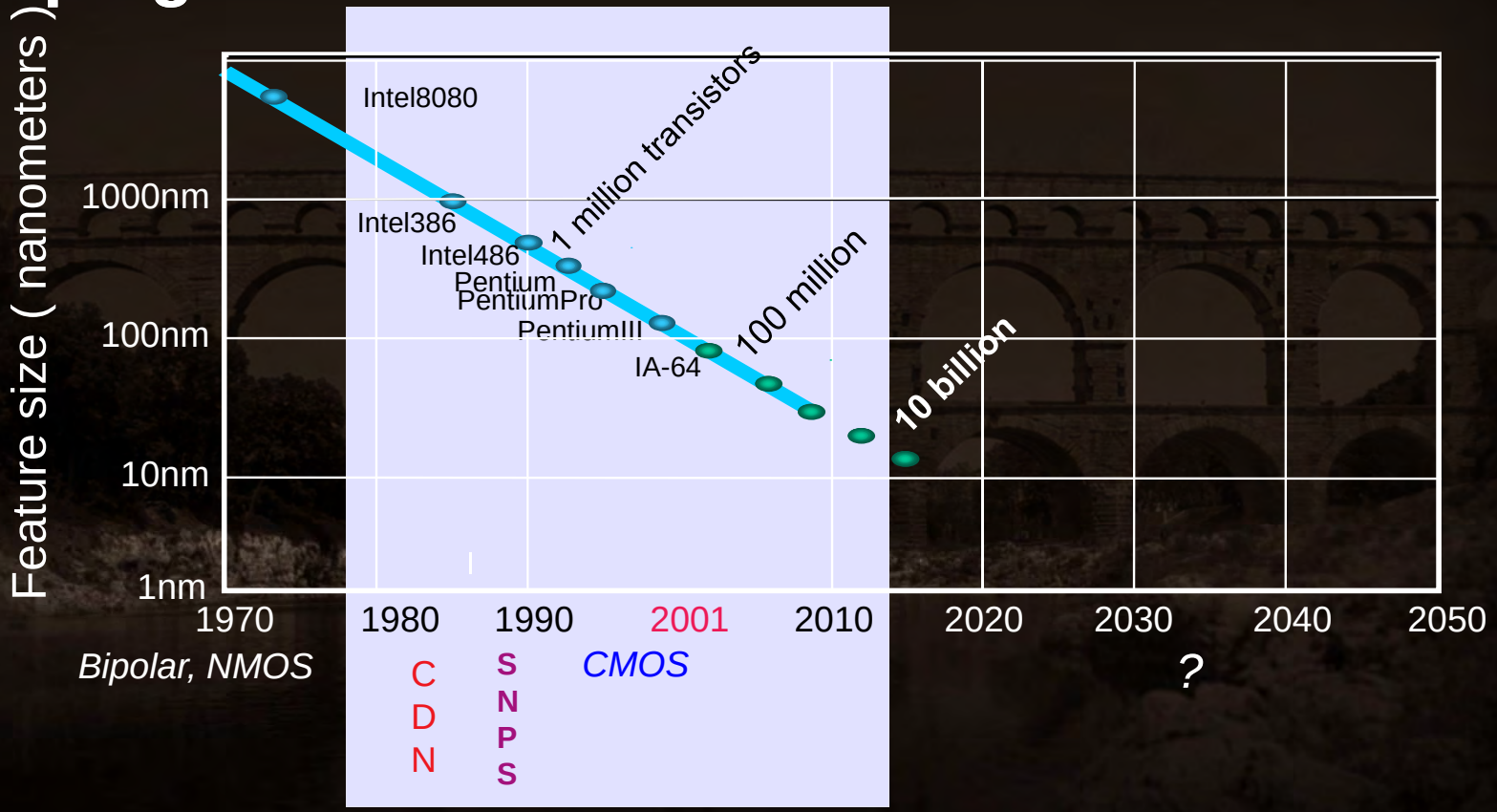
Managing Complexity: Coping with Moore's Law



How Did we Cope with Complexity?

(ASV, Corsi e Ricorsi: The EDA Story, IEEE Solid State Circuits Magazine, 2010)

Method
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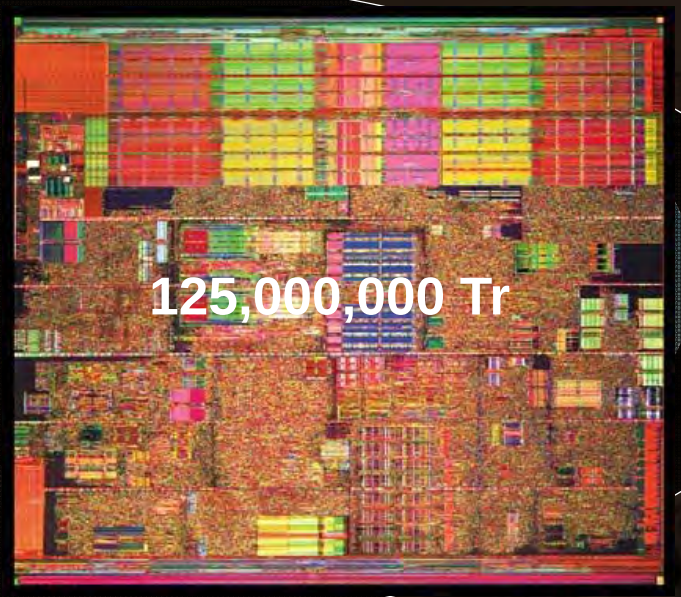


Formalization, Rigor, Discipline

General principles

Verification complexity is managed by:

- **Abstraction**: reduce the number of items by aggregating objects and by eliminating unnecessary details with respect to the goal at hand
- **Decomposition**: reduce the number of items to consider by breaking the design object into semi-independent parts (*divide et impera)*

Design Complexity is managed by “construction” (e.g., automatic layout and logic synthesis):

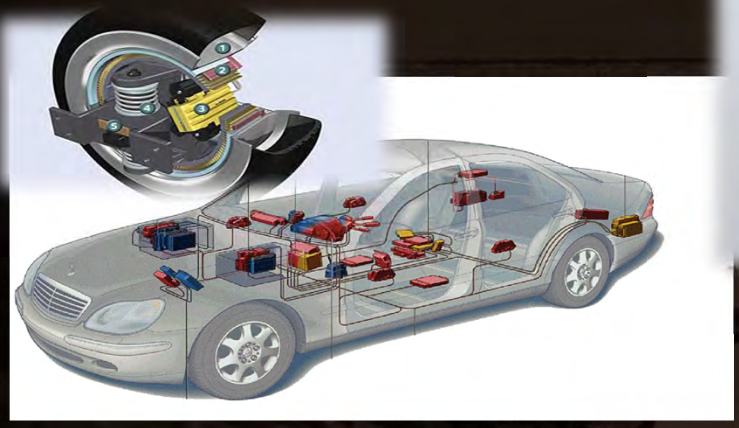
- **Refinement:** Start high in the abstraction layers and define a number of refinement steps that go from the initial description to the final implementation
- **Composition:** Assemble designs by composing existing parts

Cyber-Physical Systems (CPS)

Avionics

Transportation
(Air traffic control)

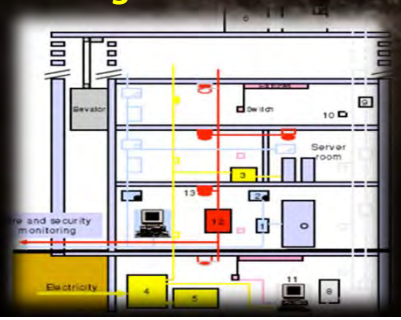
Automotive



Telecommunications

Factory automation

Buildings



Power generation and distribution

The core of the problem today: CyberPhysical Systems (CPS)

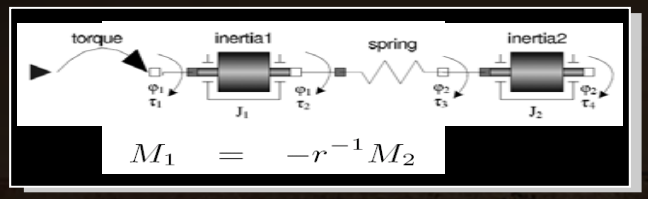
- Computation and networking integrated with physical processes.
- The technical problem is managing dynamics, time, and concurrency in networked, distributed computational + physical systems.

In the year 2054, the entire defense budget will purchase just one aircraft. ***Norman Augustine***

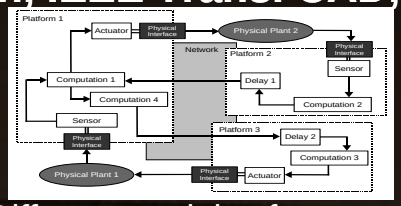
Modeling Cyber-Physical Systems

(Lee, ASV: A framework for comparing models of computation, IEEE Trans. CAD, 1998)

Model



Equation-based model



Different models of computation

Abstraction
"physical modeling"

Concept of Time

C-code

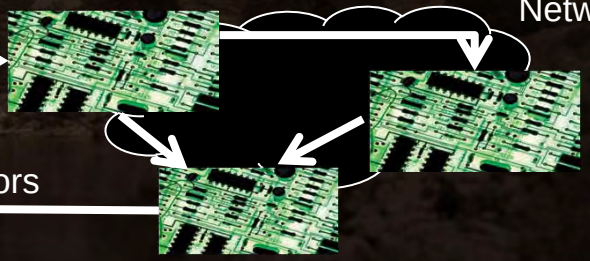
System

Physical system (the plant)

Sensors

Actuators

Networking



Embedded systems (computation)

Courtesy: D. Broman

Status Quo:
There are several areas where change is needed

MIL-STD-499A (1969) systems engineering process: as employed today

MILD

Planning
Constrain: N/A
Optimize: Cost

Programming
Constrain: Performance
Optimize: Cost

Budgeting
Constrain: Cost
Optimize: N/A

Execution

Source Selection
Constrain: Performance
Optimize: Cost

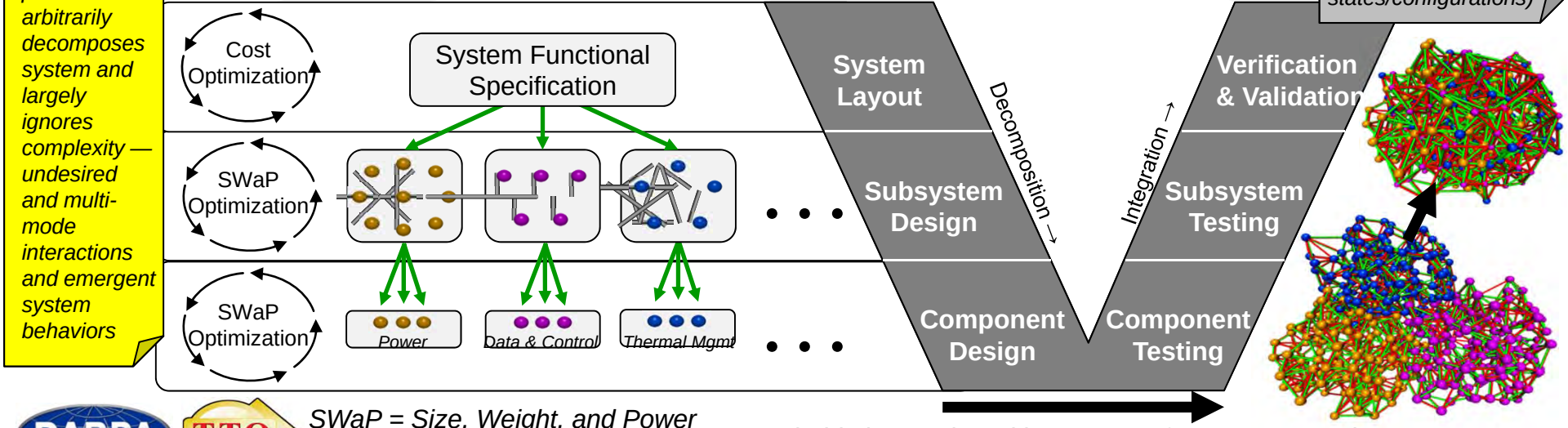
Systems Engineering
Constrain: Performance
Optimize: SWaP

Verification & Validation
Constrain: Performance
Optimize: N/A

Cost-centric acquisition process provides dis-incentives to incorporation of flexibility and adaptability into system designs

Conventional V&V techniques do not scale to highly complex or adaptable systems (i.e., those with large or infinite numbers of possible states/configurations)

Design process arbitrarily decomposes system and largely ignores complexity — undesired and multi-mode interactions and emergent system behaviors



DARPA TTO Tactical Technology Office

SWaP = Size, Weight, and Power

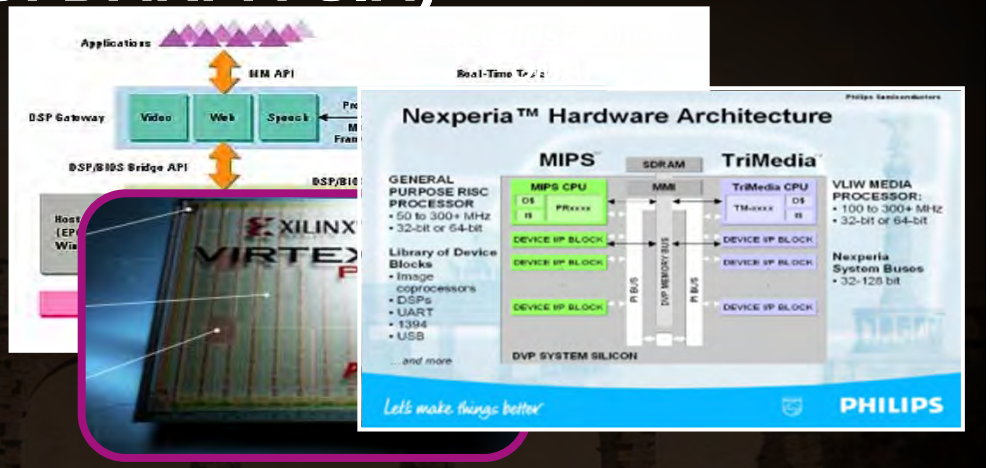
Desirable interactions (data, power, forces & torques)
Undesirable interactions (thermal, vibrations, EMI)

Integration Challenges: Plug and Play?

Plug and Pray!

The Platform Concept (GSRC: DARPA-SIA)

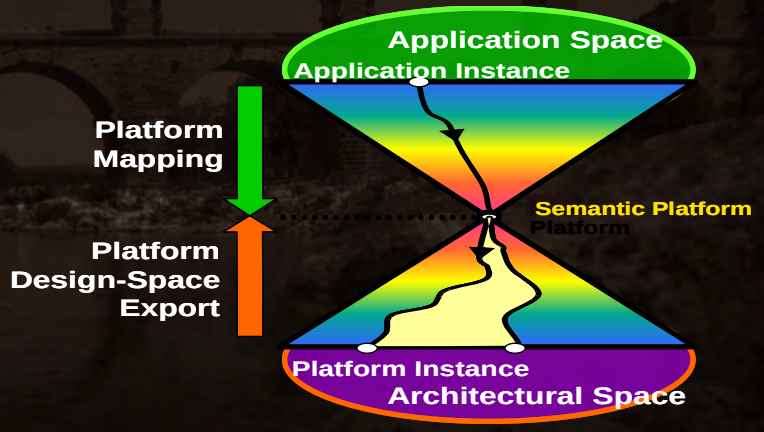
ASV, Quo Vadis, SLD? Reasoning About the Trends and Challenges of System Level Design, Proc. of the IEEE, 2007.



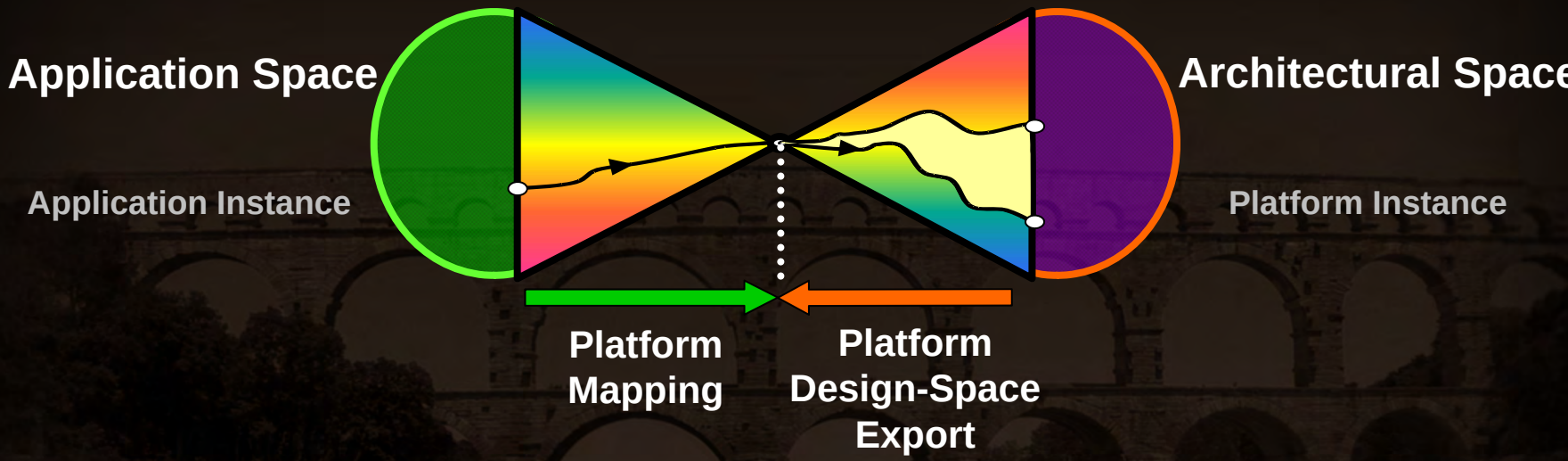
- Meet-in-the-Middle Structured methodology that limits the space of exploration, yet achieves good results in limited time
- A formal mechanism for identifying the most critical hand-off points in the design chain
- A method for design re-use at all abstraction levels

An intellectual framework for the complete electronic design process!

See AUTOSAR, Intel, National Instruments, Cadence, Synopsys, UTC, GM, Magneti Marelli, ELT, Xilinx,....



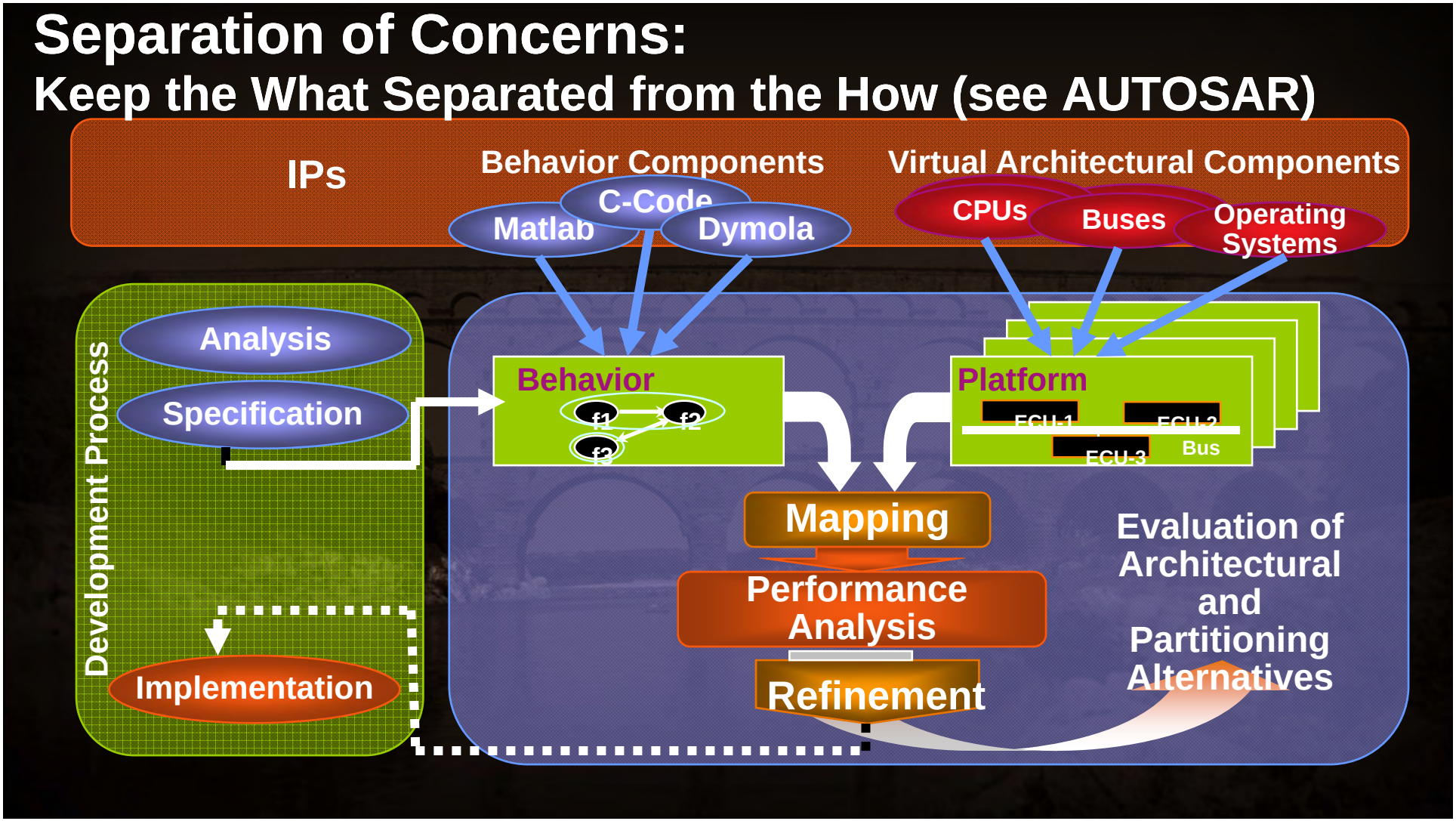
Platform-Based Design



Platform: library of resources defining an abstraction layer **with interfaces that identify legal connections**

- Resources do contain virtual components i.e., placeholders that will be customized in the implementation phase to meet constraints
- Very important resources are **interconnections and communication protocols**

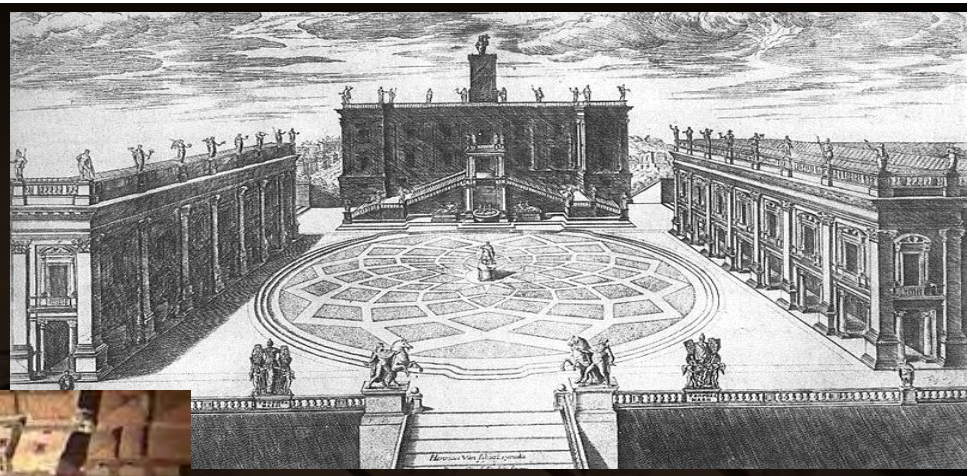
Separation of Concerns:
Keep the What Separated from the How (see AUTOSAR)

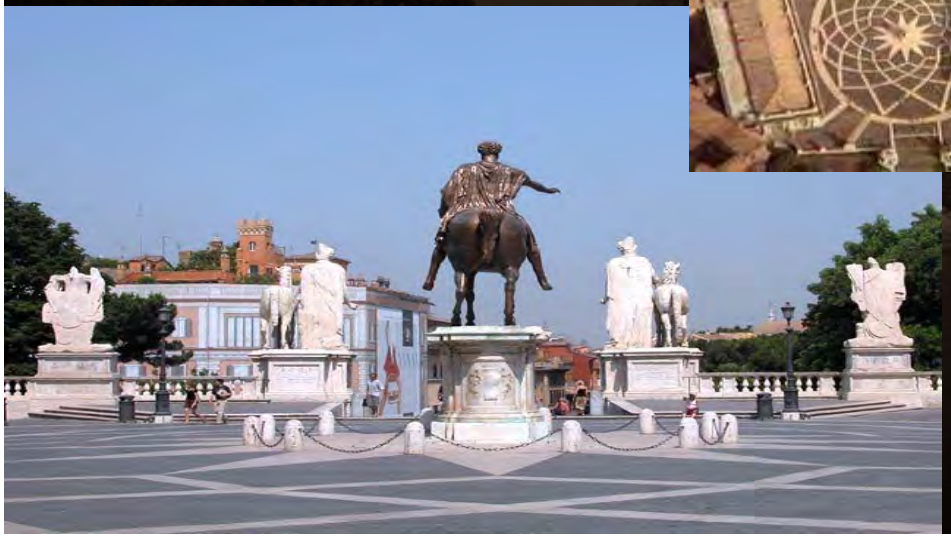


Virtual Design and Refinement

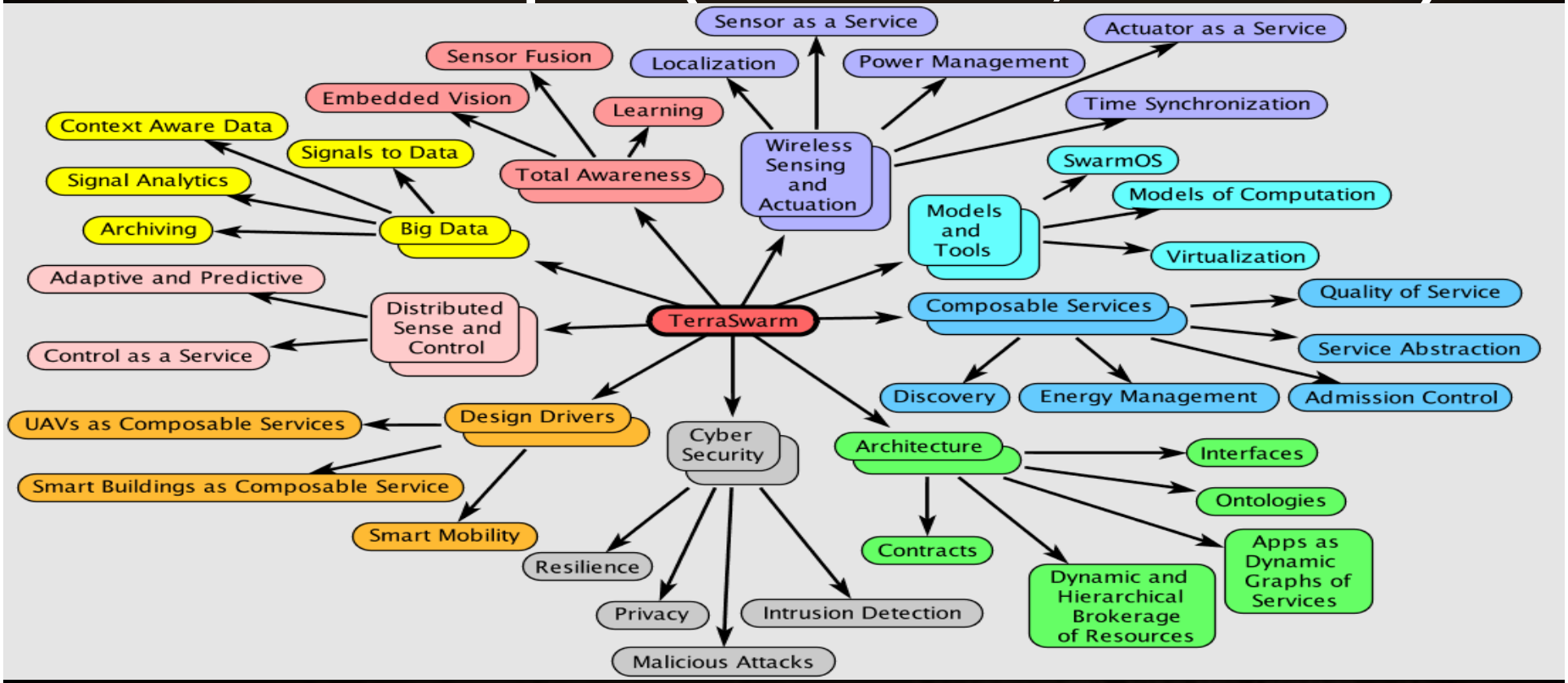
Design Re-Use

- Re-use Library
- Imported IPs

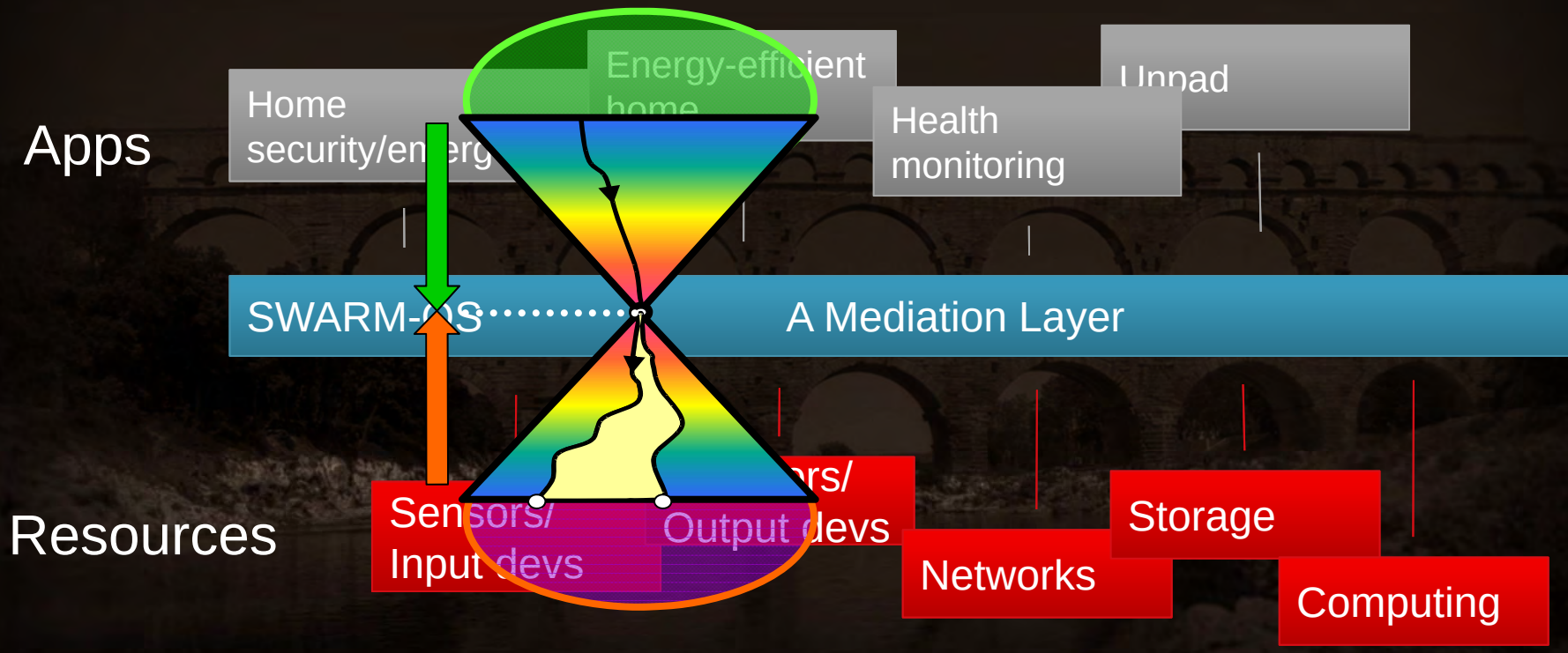




Designing a Swarm System: The Problem Space (TerraSwarm, DARPA-SIA)



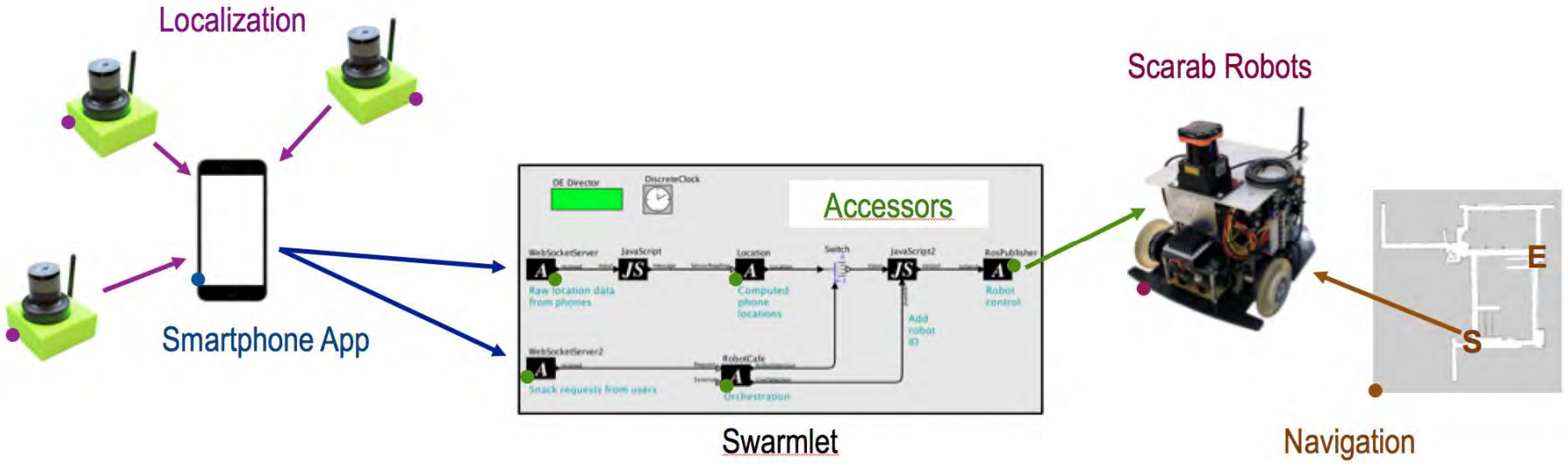
The Swarm as a Platform



Presenting a uniform API to Apps Developers (similar to trends in the Cloud)

[J. Rabaey, VLSI '11]

SwarmBox Delivery Service (STARnet Arena, Area A1)

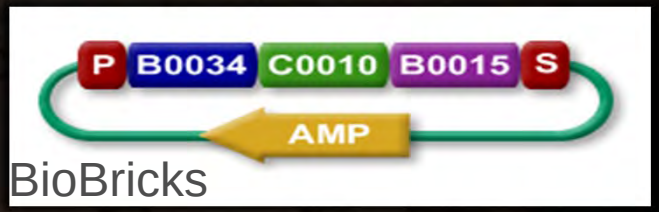


Platform-based Design Environment for Synthetic Biological Systems

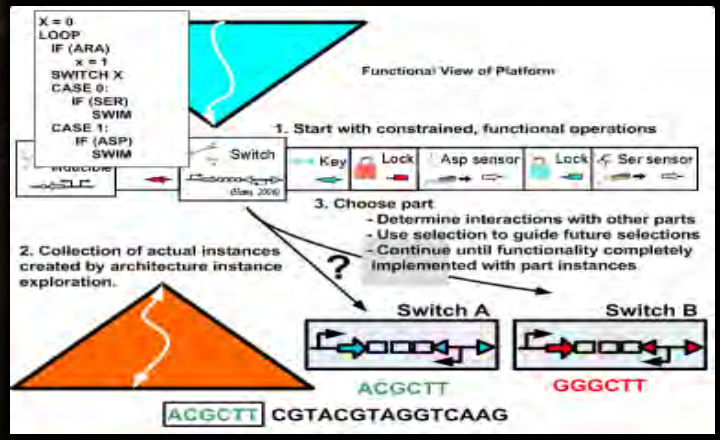
(D. Densmore, Boston University)

Synthetic Biology:

The creation of novel biological functions and tools by modifying or integrating well-characterized biological components into higher-order systems using mathematical modeling to direct the construction towards the desired end product.



Building life from the ground up **(Jay Keasling, UCB)**



Development of foundational technologies:

- **Tools for hiding information and managing complexity**
- **Core components that can be used in combination reliably**

Final Words of Wisdom

Essential Ingredients

- **Library of re-usable components**
  - Verified, tested, parametrized
  - Interfaces defined and standardized
  - MODELS!!! For verification, testing, analysis
  - Organized hierarchically with clear relationships established
- **Methodology**
  - To develop additional components
  - To define architectures for product families
  - To derive models
  - To assemble components
  - To verify
- **Organization**
  - Rigor in adding components and verifying compliance for library insertion
  - Standard work to encode and enforce methodology
- **Education and Training**

The Way Forward

- *Everything is Connected:*
  - Society, Electronic and System Industry facing an array of complex problems from design to manufacturing involving complexity, power, reliability, re-configurability, integration….
- Complexity is growing more rapidly than ever seen
- Interactions among subsystems increasingly more difficult to predict
- Pre-existing systems put to work to provide new services
- *Need work at all levels: Methodology, Modeling, Tools, Algorithms*

- Deep collaboration among

  - Governments, industry, and research centers
  - Different Disciplines : Control, Communication, Computer Science, Electrical Engineering , Mechanical Engineering, Civil Engineering, Chemistry, Biology.....