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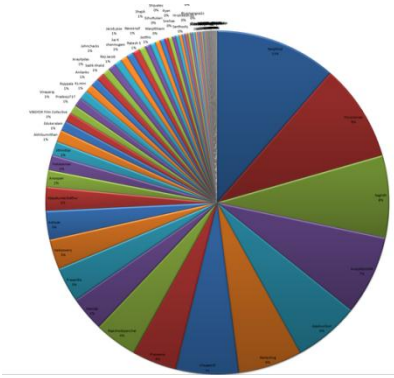
So I've Modeled… What's Next?

Extending the use of Systems Models in an Engineering Enterprise

Christopher Oster
Lockheed Martin Corporation

Why Model?



- **Drive a consistent specification**
- **Analyze & Interrogate the System Design**
- **Automate, Automate, Automate!**

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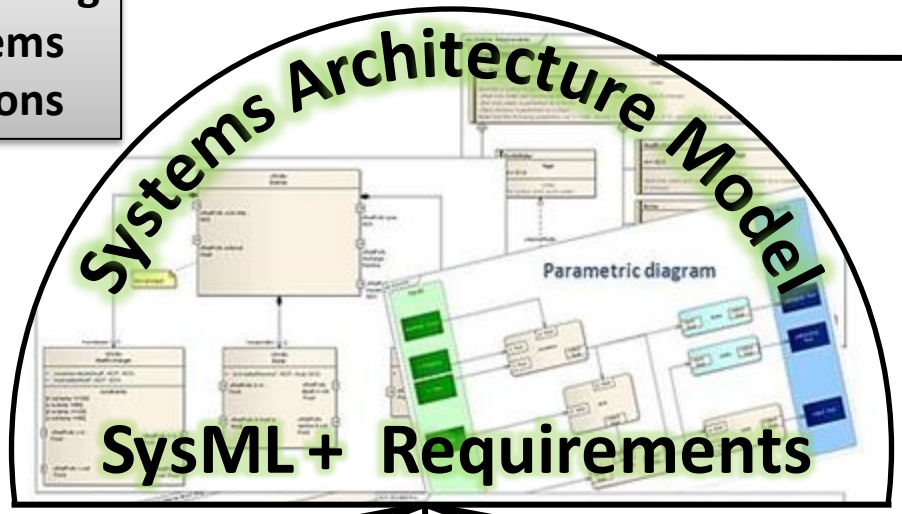
Typical Applications of Systems Modeling

System Modeling Is Becoming More Common in Systems Engineering Organizations

Most Teams Start Modeling To Address Traditional SE Responsibilities such as Requirements Management & Spec Generation



Script Extensions

As Modeling Teams Mature, Many Teams Begin Extending the Functionality through Homegrown Scripts, Tools and Reports.

- Requirement Analysis & Traceability
- Document & Specification Generation
- Technical Budget Management (Cost, Mass, Power, etc…)
- System, Design & Context Under-standing
- Interface Management

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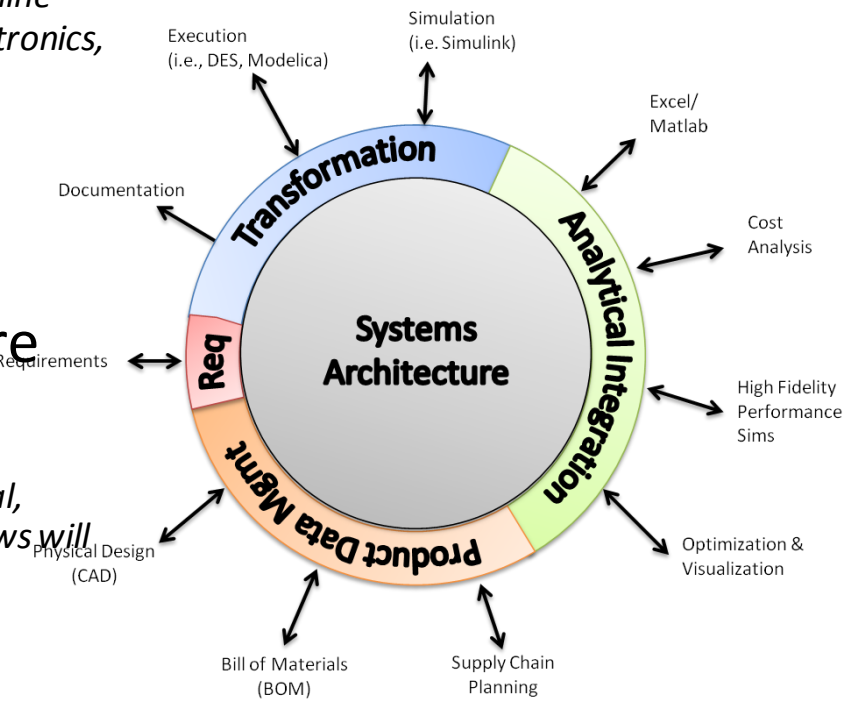
What Will Be The Role of Systems Models?

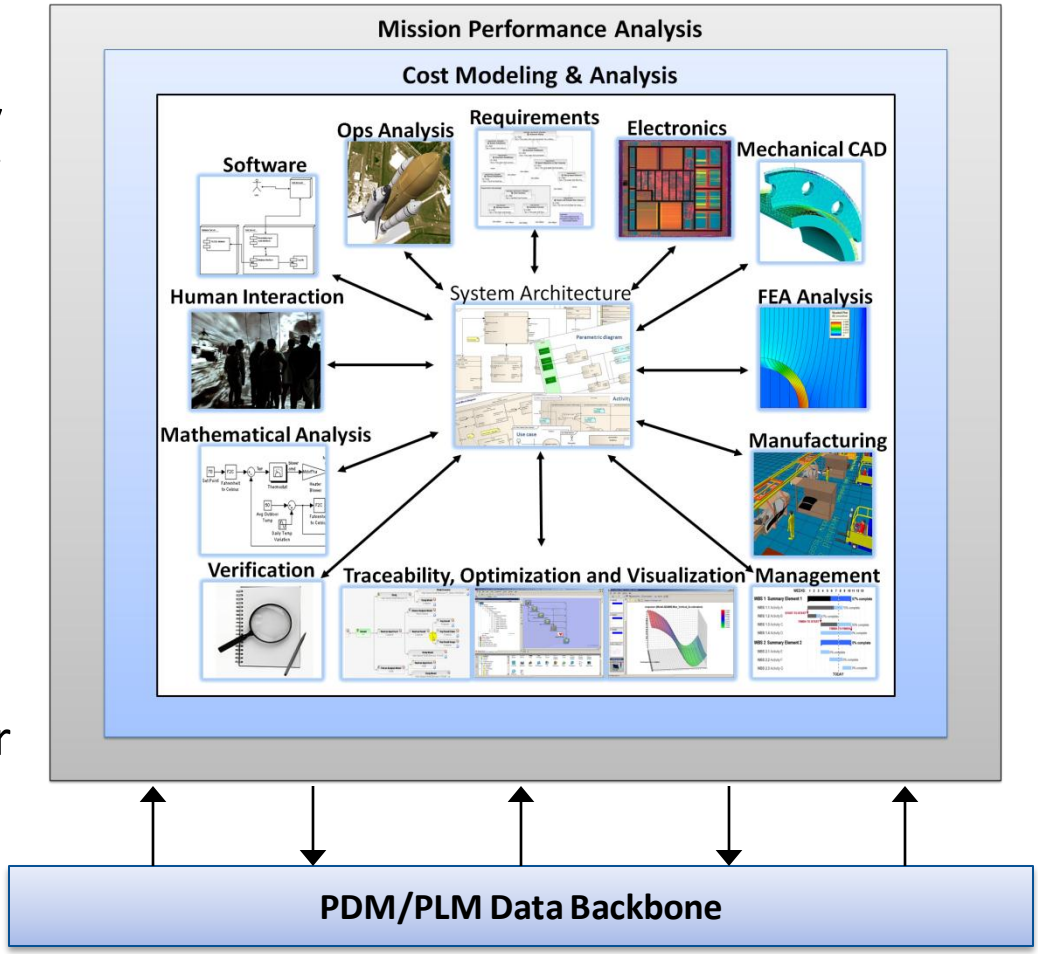
- Systems Engineering will increasingly become an integrating function across systems development and design functions throughout the program lifecycle
  - *Systems engineering will drive logical and physical product structure and will draw in appropriate fidelity analytics to address producibility, assembly, fielding and support*
  - *Systems level models will be integrated with discipline specific models including software, firmware, electronics, mechanical CAD, manufacturing, supply chain, associated analysis models, and more*
- Systems engineering models will become more integrated with product BOMs and PDM structure
  - *Architecture will drive design throughout the program lifecycle including into sustainment*
  - *The multiple "views" of the system including logical, physical, geometric and sourcing/supply chain views will be consistent through integrated tools and models*



** Credit: INCOSE SE Vision 2025 Team **

SysML & PLM: Enabling the Vision

- A well defined System Architecture Model (SAM) is a key enabler for integrating and linking our engineering enterprise
- The SAM helps link requirements to logical and behavioral design
- Requirements can be fed into increasingly detailed levels of domain specific modeling
- Integration between Systems Engineering and the PDM/PLM backbone opens up a new frontier for integrated model-centric engineering



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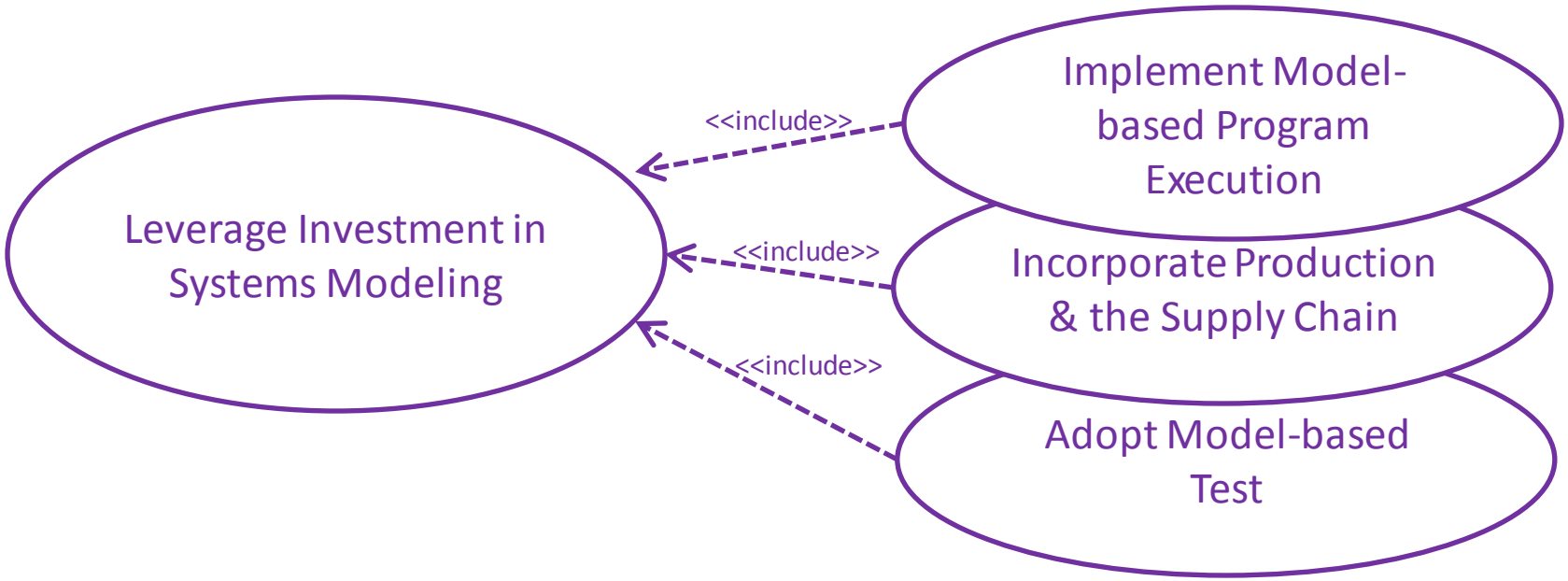
Extending The Systems Model
A Use Case Analysis



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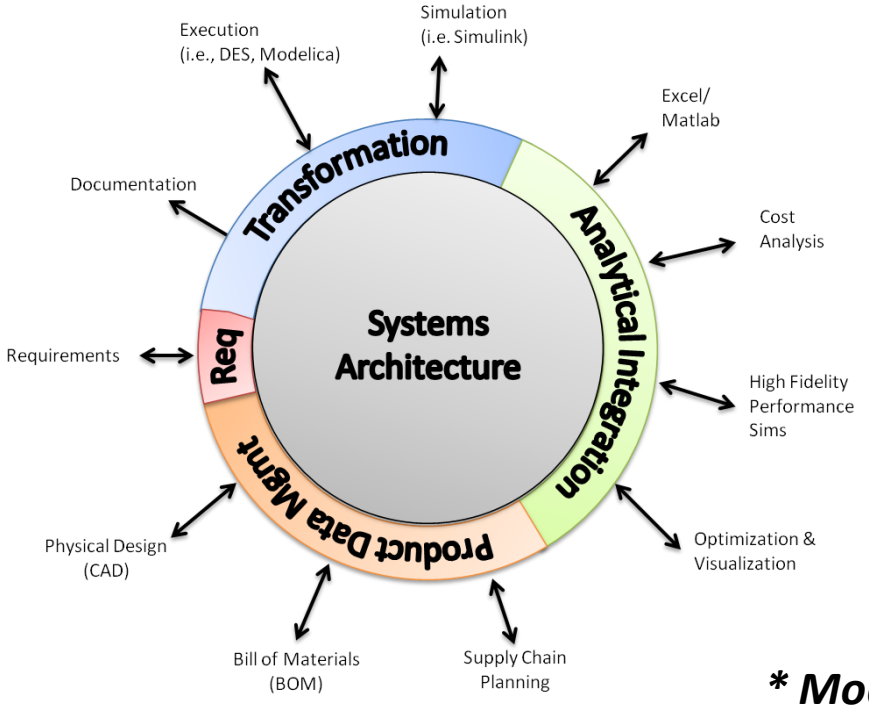
Make the *model** truly the program's technical baseline



** Model in this case is really more likely "models"*

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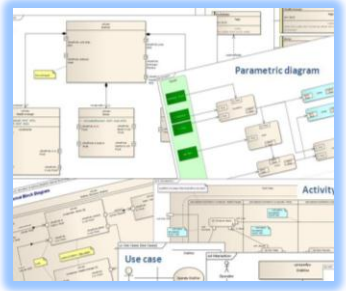
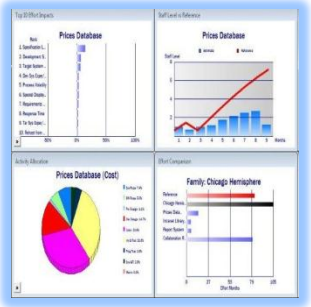
Connect Existing Modeling Activities

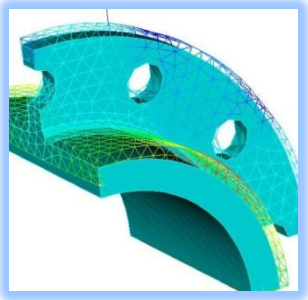
- Most engineers leverage *focused* modeling activities across various disciplines.
- Capability to support integration across discipline lines has been historically limited or missing.
- Move beyond traditional “point to point” integrations

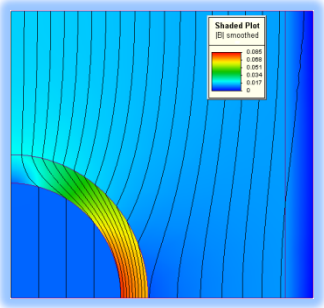


Architecture

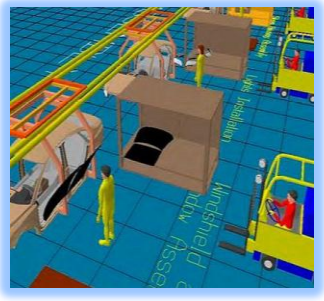


Cost


CAD



Performance


Manufacturing

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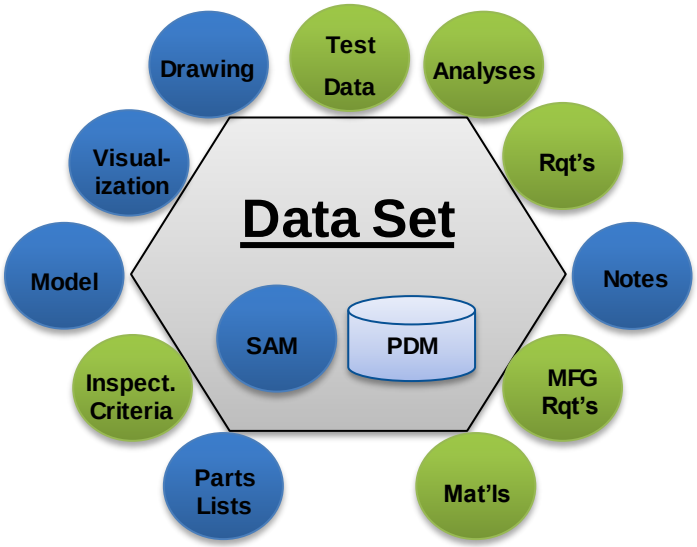
Not Just a Model but a Product Data Set

A Product Data Set Contains Artifacts That Define A Product…

- Systems Architecture Model
- 3D Model
- Specifications
- Notes
- Metadata or Attributes
- Bill Of Material
- Design Requirements
- Other Product Descriptive Info



The Entire Data Set Must Be Managed

- Creation & Control
- Association To Design

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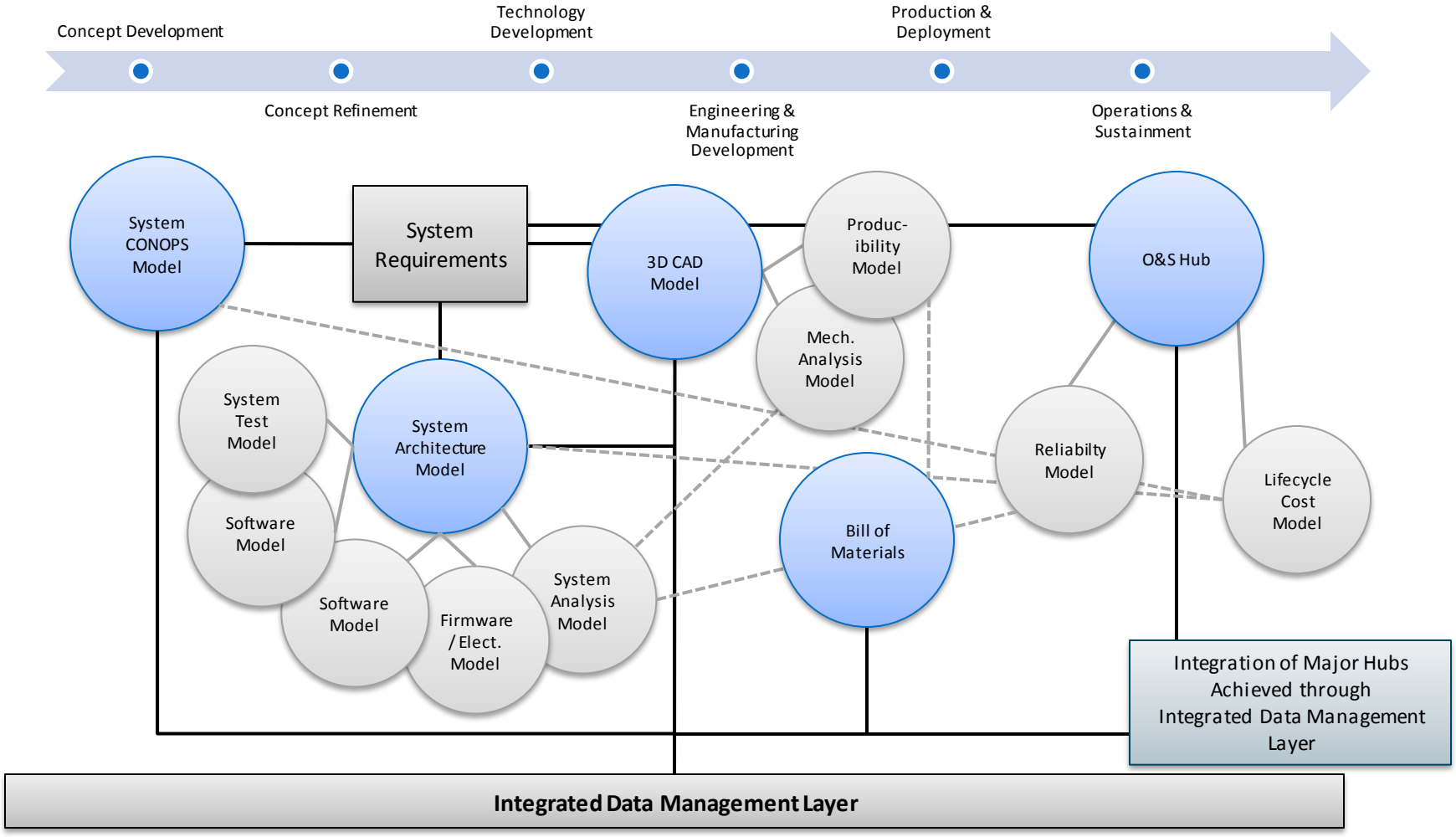
Integration Clusters (Technical "How")



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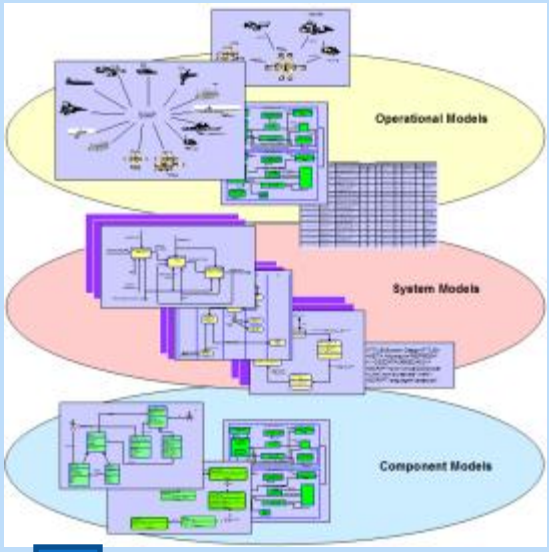
Make a Shift to Model-based Program Execution

Model-based Program Execution

- Requirements Flowdown
- Architecture Definition
- Interface Definition
- Document Generation
- Analysis Tools Integration (ModelCenter, Matlab, …)
- PDM/BOM Consistency (Windchill)

- Enterprise Modeling
- System Modeling
- Component Modeling



- CAD Modeling
- Firmware Modeling
- SW Modeling
- V&V Modeling

- HW Implementation
- SW Implementation

- Product Integration

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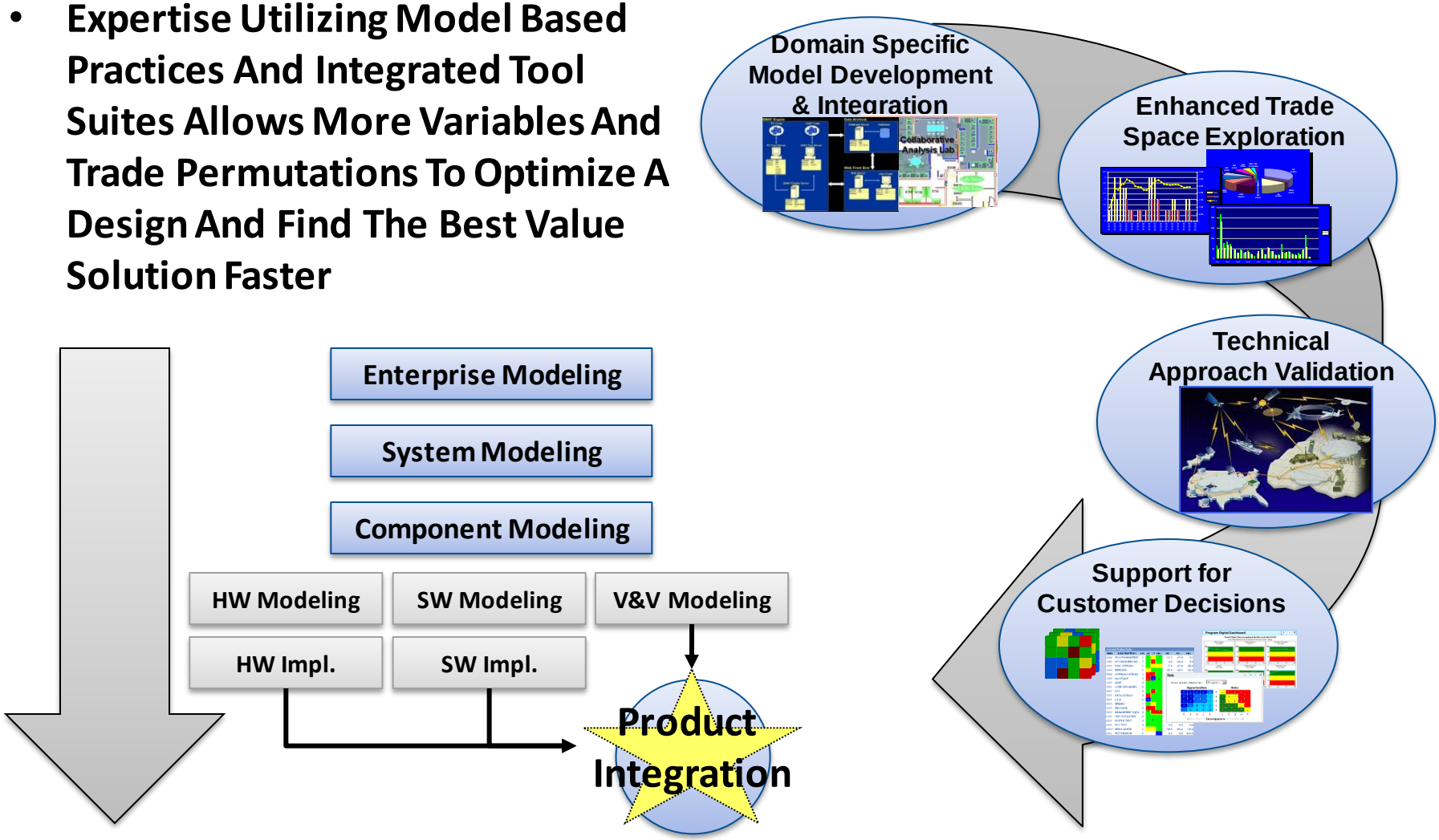
Enabling our Engineers

- **Expertise Utilizing Model Based Practices And Integrated Tool Suites Allows More Variables And Trade Permutations To Optimize A Design And Find The Best Value Solution Faster**



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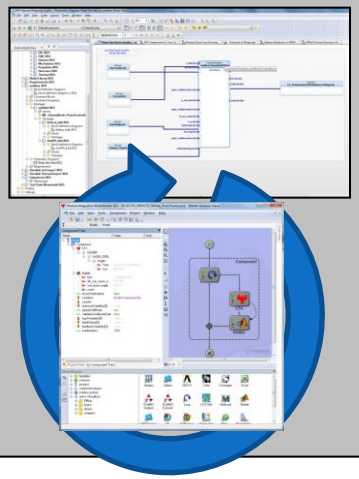
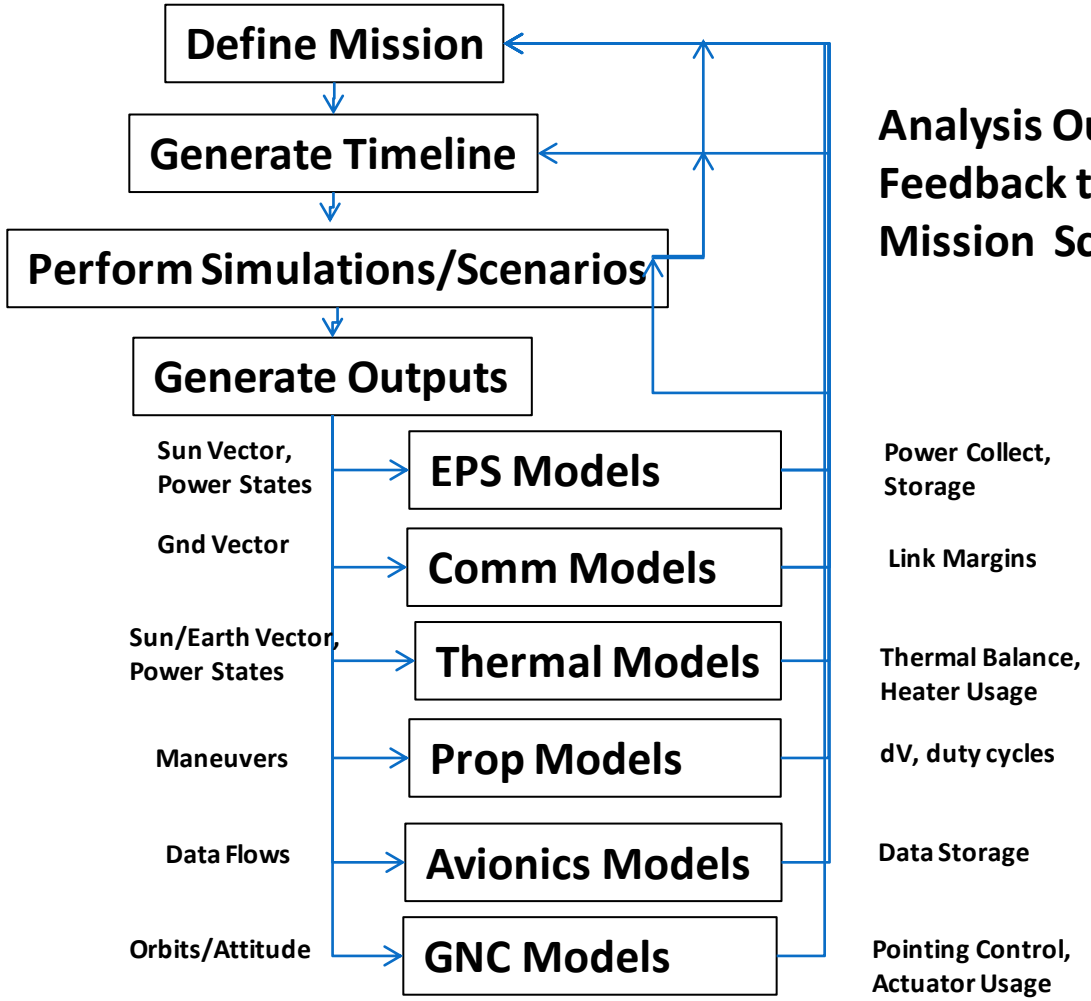
Model-based Program Execution in Action

Use Cases
Sequence Diagrams
Activity Diagrams
Parametric Diagrams



User Models
(Simulink, Excel, etc)

Rhapsody/SysML models operations dynamically linked to analysis tools and models



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Enable Product Family Design Approaches

&

Leverage Reference Architectures for Optimized Solutions

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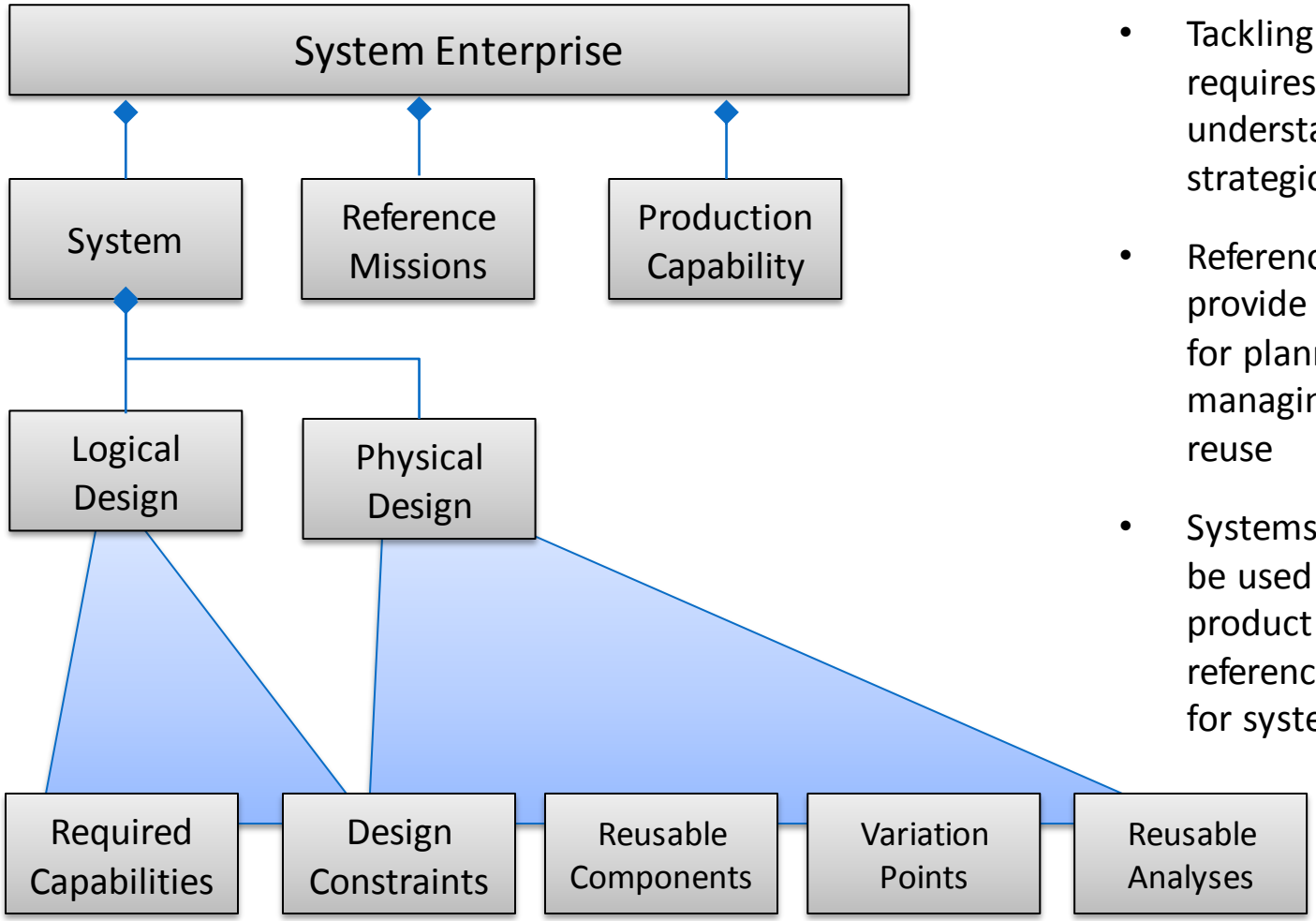
Modeling for Product Families & Reuse



- Tackling affordability requires teams to understand and strategically plan reuse
- Reference Architectures provide a framework for planning and managing system level reuse
- Systems modeling can be used to capture product families and reference architectures for system design reuse

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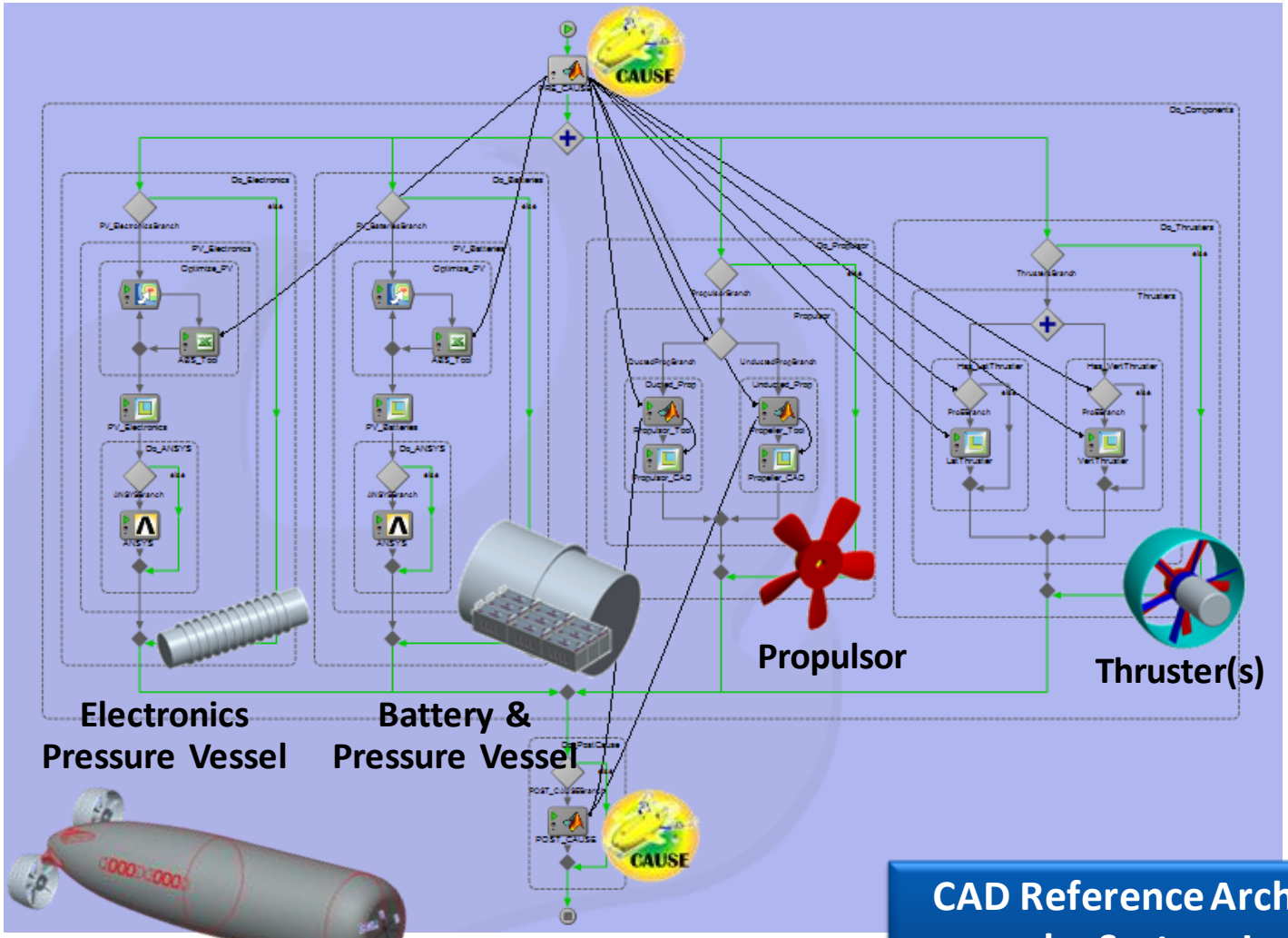
Example: UUV Reference Component Model Suite



Component Requirements Are Based on System-Level Allocation

Component Analysis Models Provide Higher-Fidelity Sizing & Design

Second CAUSE Run Captures Higher Fidelity Estimates & Identifies System-Level Impacts

CAD Reference Architecture is Driven by System-Level Analysis

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Identify Options to Leverage Model-based Auto-generation.

Don't Limit Your View to Code!

Vision: Single Source Generative Practices

- Generating code, interfaces, test cases, documentation, and more from models and higher level languages
- Many programs at LM and across industry leverage generative coding for targeted problems
- Focus must be on extending that paradigm from targeted software to a broader base of artifacts

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Include Production Views
&
Your Supply Chains!

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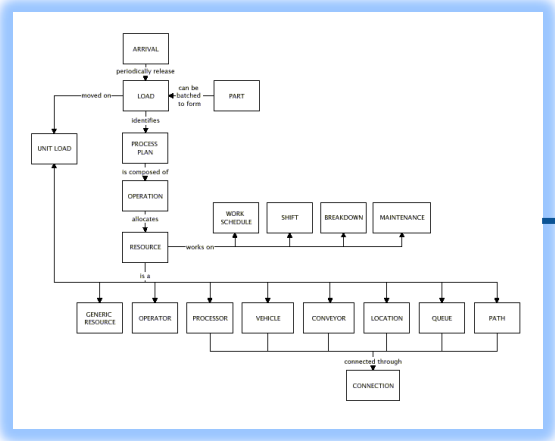
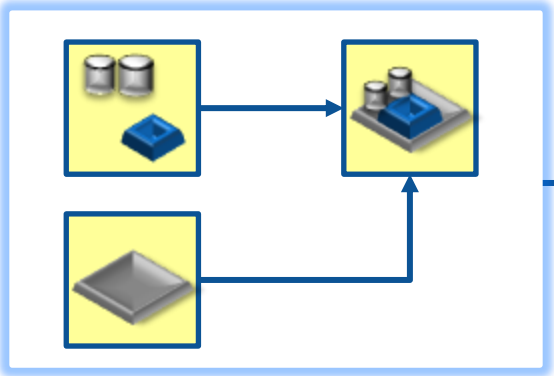
Systems Engineering for Manufacturing: Production Planning Early in the Lifecycle





- Architecture – PDM – BOM Association
- Apply more consistent Discrete Event Simulation to up front planning
- Allocate factory stations and tooling through system architecture

Tie Architecture & Simulation To Production

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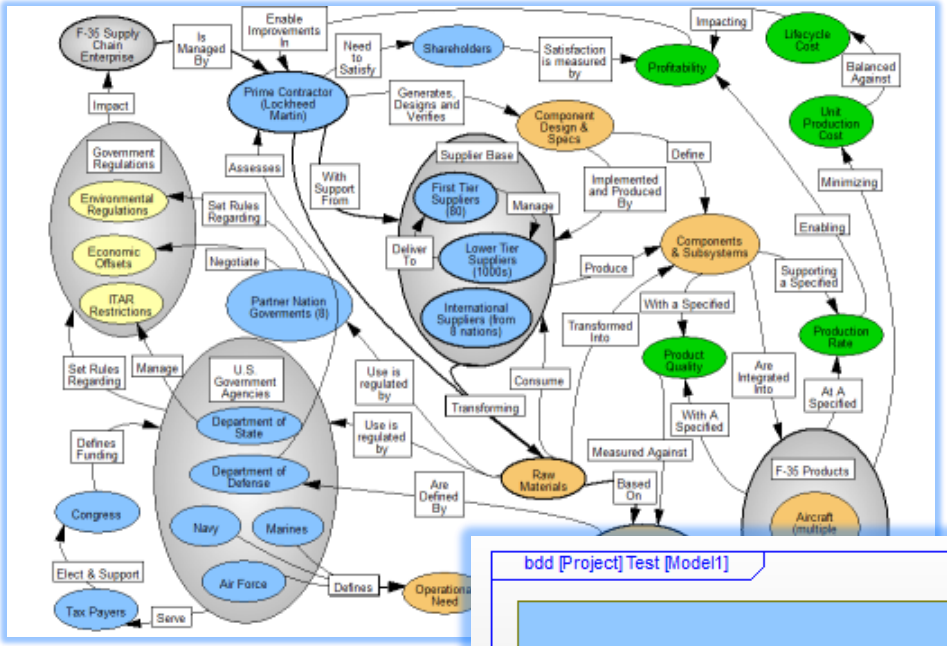
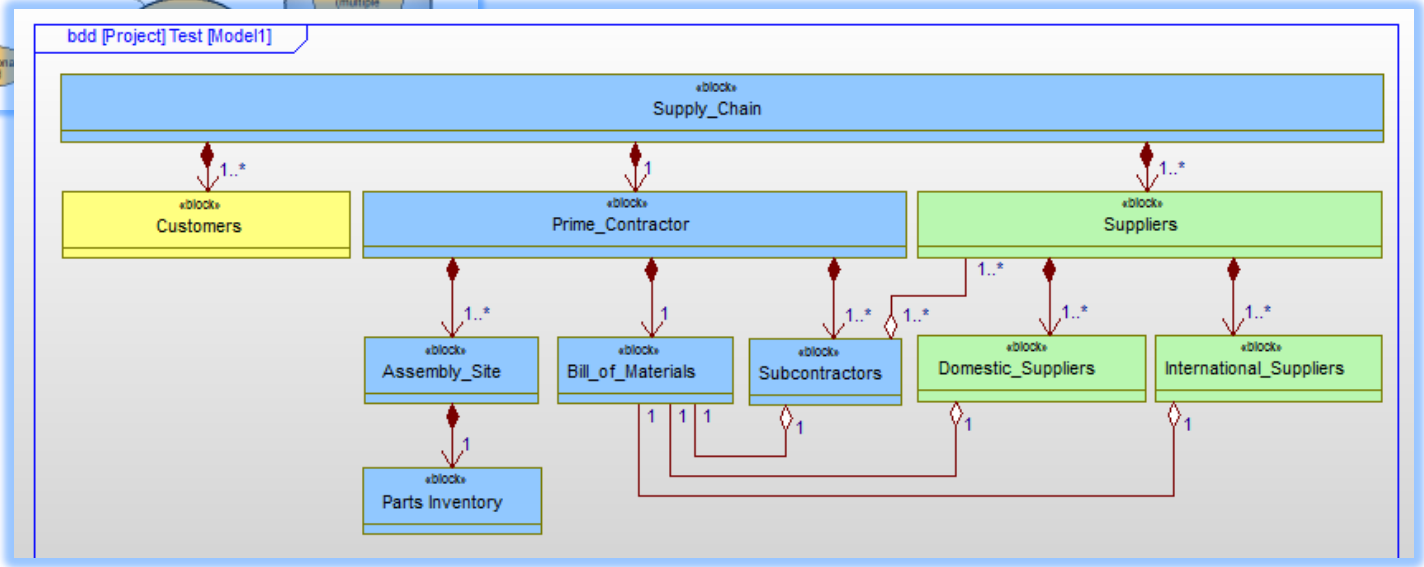
Understanding and Managing the Supply Chain



- Considerations for Production should start in Systems Engineering
- Treating the supply chain as a part of the system allows logical needs to be mapped to both physical architectures and the organizations responsible for them



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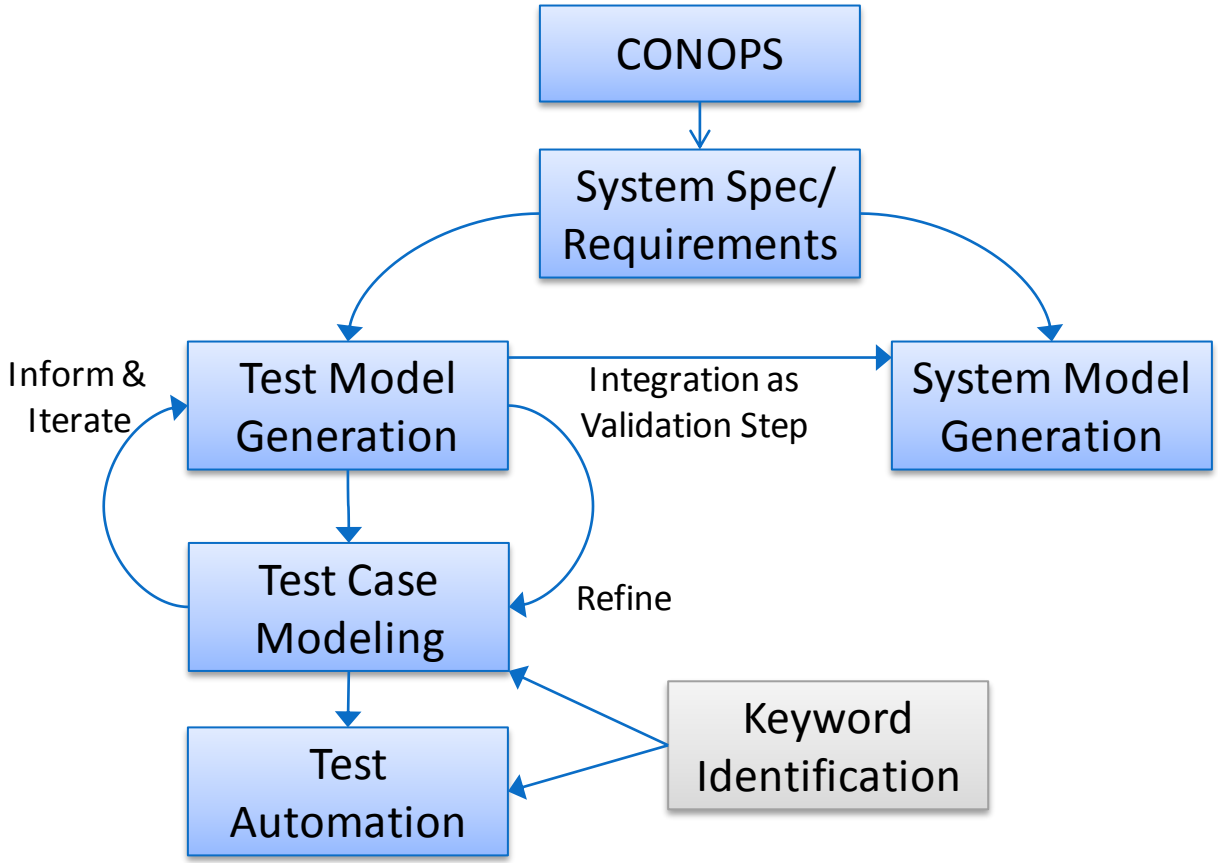
Embrace Model-based Test

Develop a Test Architecture Model



- System Architecture Model & Test Architecture Model Managed as Peers
- Integration of Models can be seen as a validation step
- Both System and Test models driven from common CONOPS, requirements and specifications

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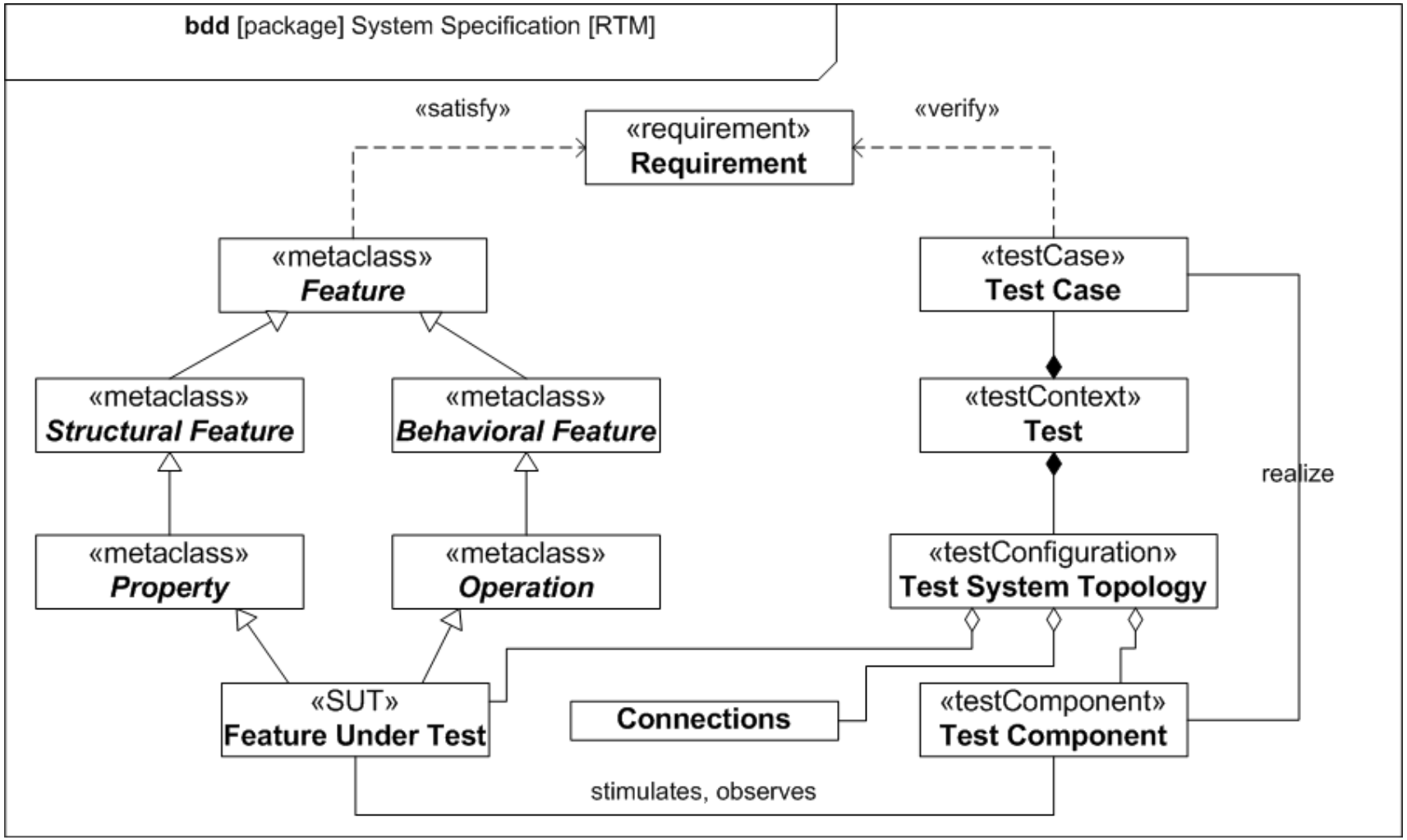
Leverage the UTP Standard



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Conclusion:

How is Lockheed Martin Going Beyond the Systems Model?

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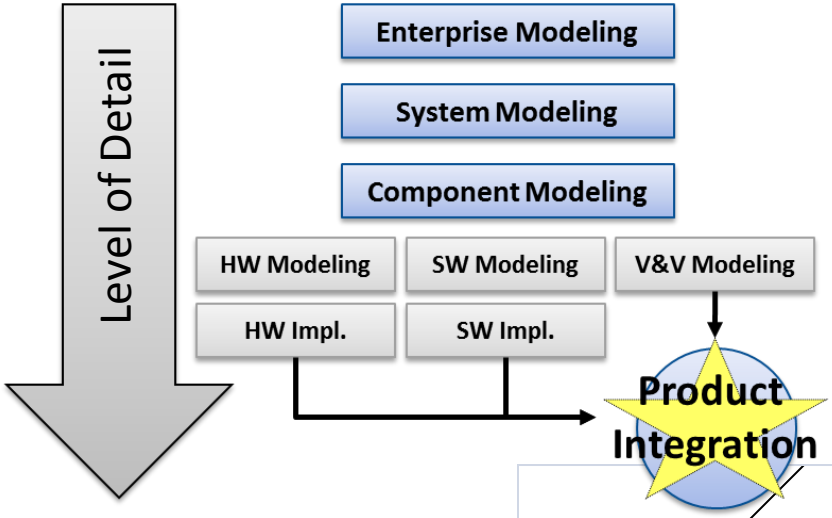
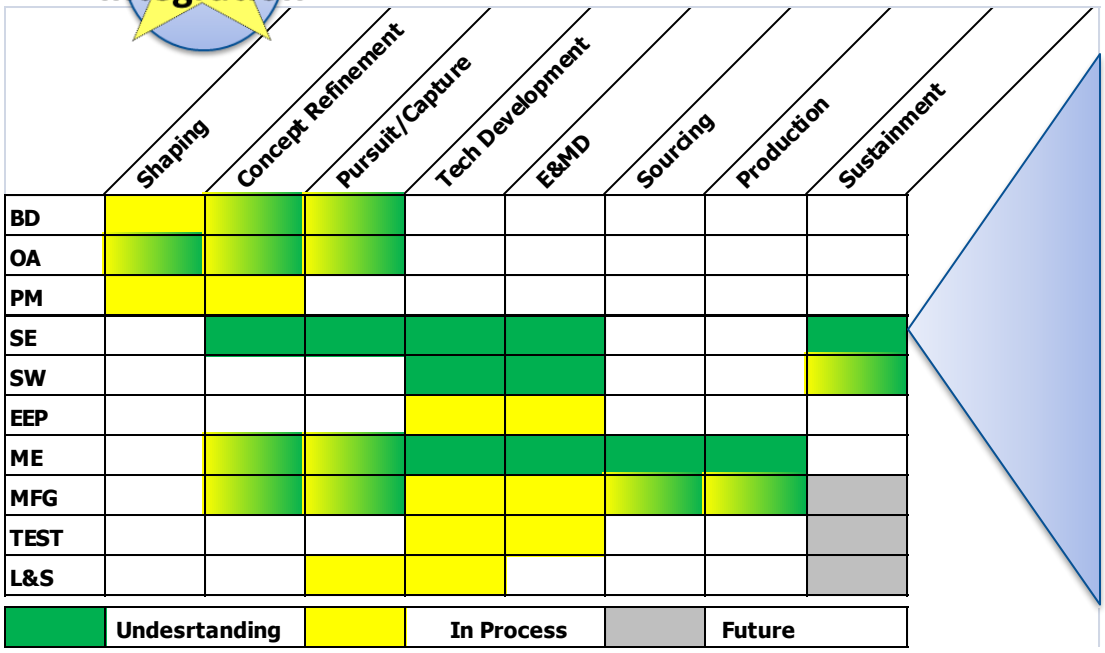
Lockheed Martin Model Based Portfolio



Today's Hard Problems are *System Level* Problems. Therefore Lockheed Martin's Model Based Effort is Grounded with a Solid Model-based Systems Engineering and Architecture Portfolio

LM's Model-based Strategy is Focused on Pulling Model-based Digital Threads from Concept Development through Design to Test, Production and Sustainment



Partitioned Across Multiple Programs and Pilots

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