So I’ve Modeled... What’s Next?

Extending the use of Systems Models in an Engineering Enterprise

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Why Model?

• Drive a consistent specification

• Analyze & Interrogate the System Design

• Automate, Automate, Automate!
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 & specification generation.

As modeling teams mature, many teams begin extending the functionality through homegrown scripts, tools, and reports.

Script Extensions

Systems Architecture Model

SysML + Requirements

Requirement Analysis & Traceability

Document & Specification Generation

Technical Budget Management (Cost, Mass, Power, etc...)

System, Design & Context Understanding

Interface Management
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 **
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.
Extending The Systems Model
A Use Case Analysis

Leverage Investment in Systems Modeling

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Implement Model-based Program Execution

Incorporate Production & the Supply Chain

Adopt Model-based Test
Make the *model* truly the program’s technical baseline

*Model in this case is really more likely “models”*
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
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
Integration Clusters (Technical “How”)

System Analysis Model
Firmware / Elect. Model
Software Model
System Architecture Model
System Test Model

3D CAD Model

Mech. Analysis Model
Reliability Model
Bill of Materials

Production & Deployment

Operations & Sustainment

Integration of Major Hubs
Achieved through Integrated Data Management Layer

Lifecycle Cost Model

Reliability Model

ConOps Model

ConOps Requirements

System Requirements

Concept Refinement

Concept Development

Technology Development

Engineering & Manufacturing Development

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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
Model-based Program Execution in Action

Use Cases
Sequence Diagrams
Activity Diagrams
Parametric Diagrams

Define Mission
Generate Timeline
Perform Simulations/Scenarios
Generate Outputs

Analysis Outputs
Feedback to Mission Scenario

Power Collect, Storage
Link Margins
Thermal Balance, Heater Usage
dV, duty cycles
Data Storage
Pointing Control, Actuator Usage

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
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
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
Include Production Views & Your Supply Chains!
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
• 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
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
Leverage the UTP Standard
Conclusion:

How is Lockheed Martin Going Beyond the Systems Model?
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.