

Advancing Systems Engineering Practice using Model Based Systems Development (MBSD)

Systems & Software Technology Conference

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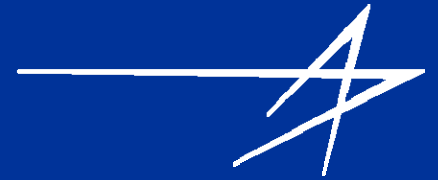
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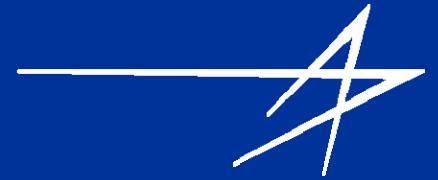
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Topics

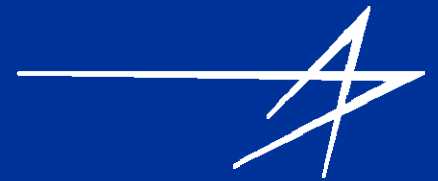


- **Model-based Systems Development (MBSD)
Motivation and Scope**
- **System Modeling Using SysML**
- **System Model as an Integration Framework**
- **Deploying MBSD into your Organization**
- **Summary**



MBSD Motivation and Scope

Practices for Describing Systems

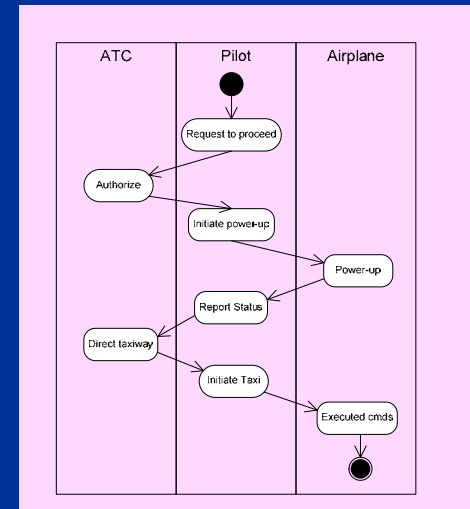


Past



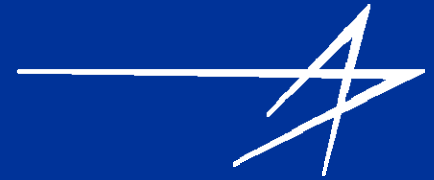
- Specifications
- Interface requirements
- System design
- Analysis & Trade-off
- Test plans

Future



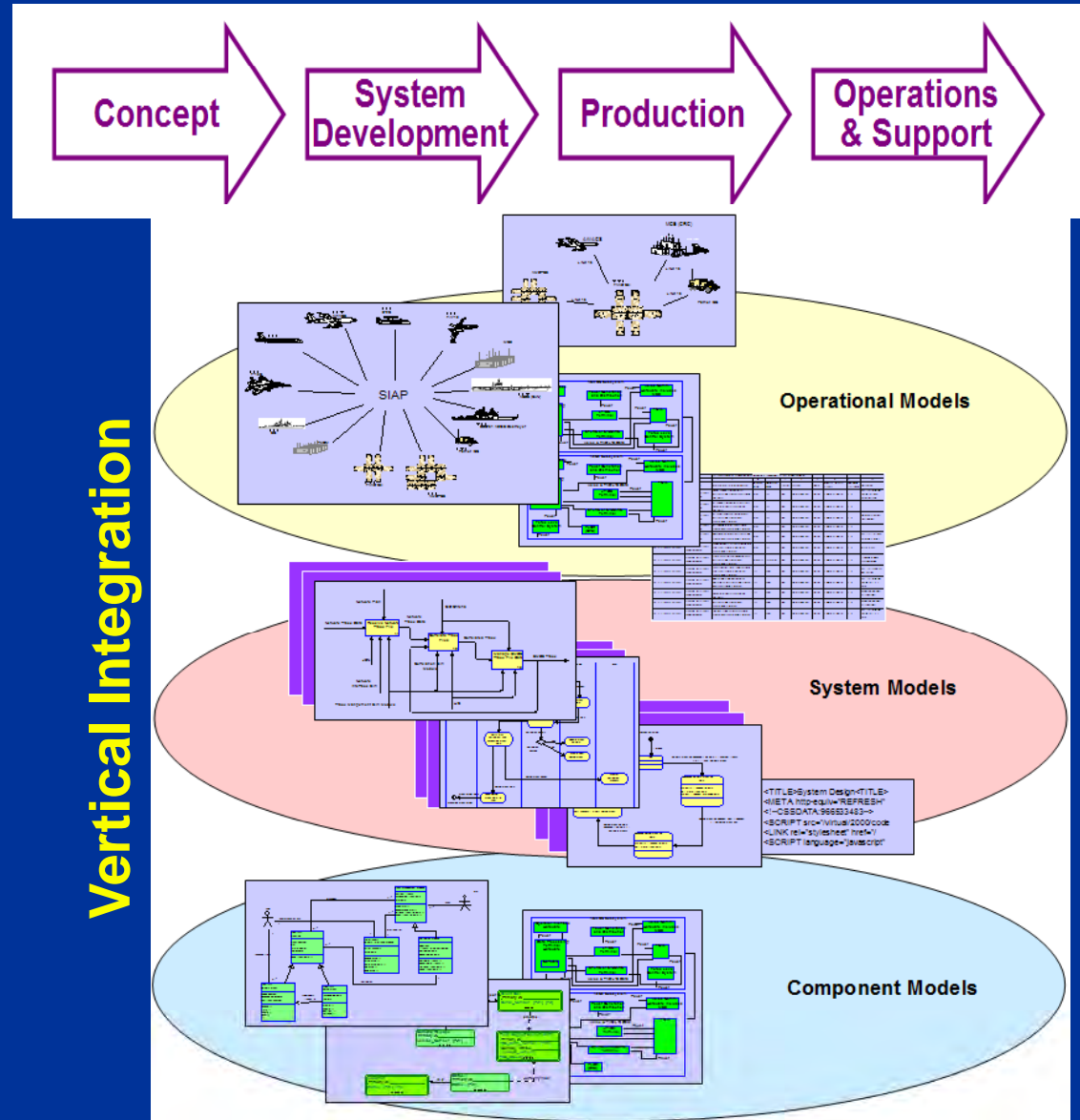
Moving from Document centric to Model centric

Model-based Systems Development (MBSD)

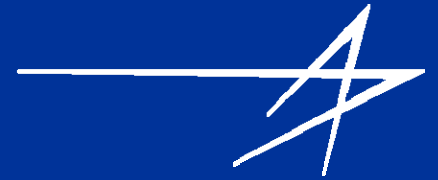


- Formalizes the practice of systems development through use of models
- Broad in scope
 - Integrates with multiple modeling domains across life cycle from system of systems to component
- Results in quality/productivity improvements & lower risk
 - Rigor and precision
 - Communications among system/project stakeholders
 - Management of complexity

Life Cycle Support

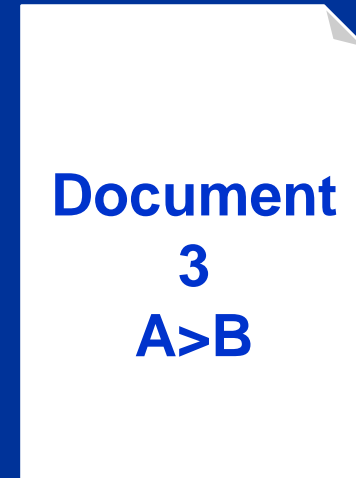
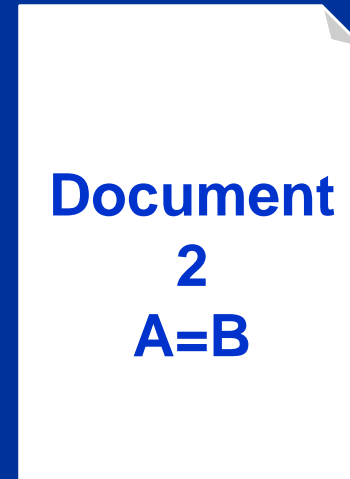
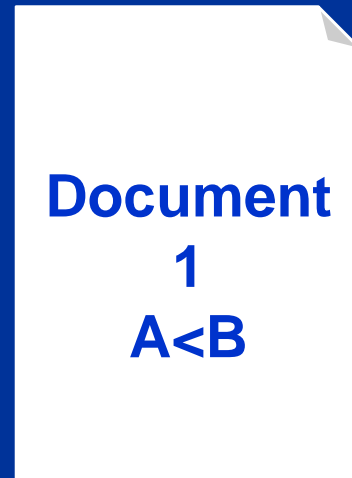


System Description



- *Document-Based System Engineering:*

Where is truth?

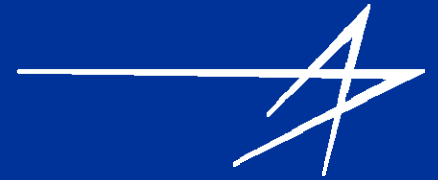


Inconsistencies within and among documents

- *Model-Based System Engineering:*

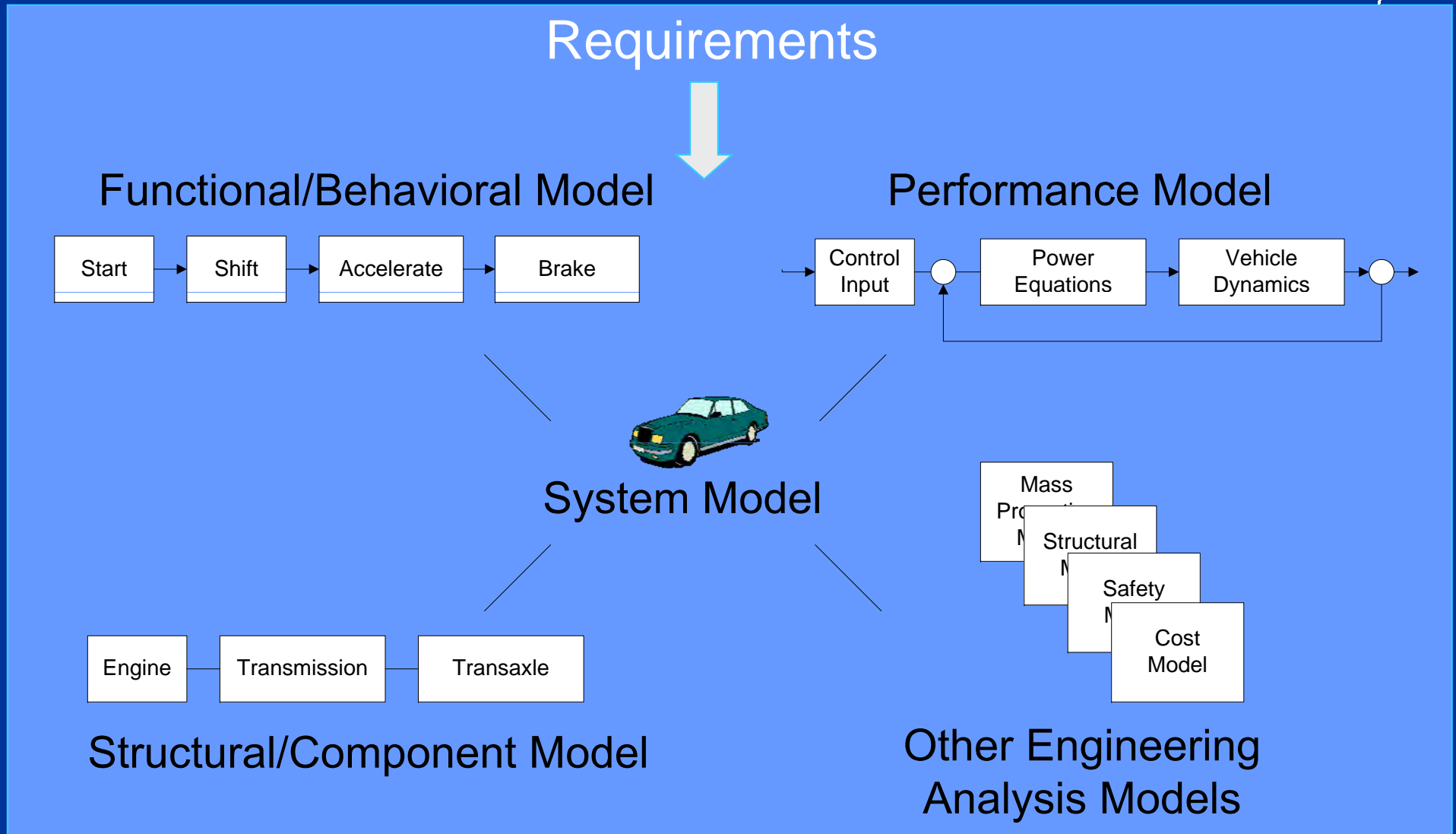


Model enforces consistency



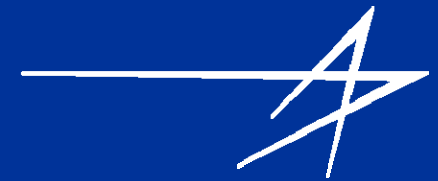
System Modeling Using SysML

System Modeling



Integrated System Model Must Address Multiple Aspects of a System

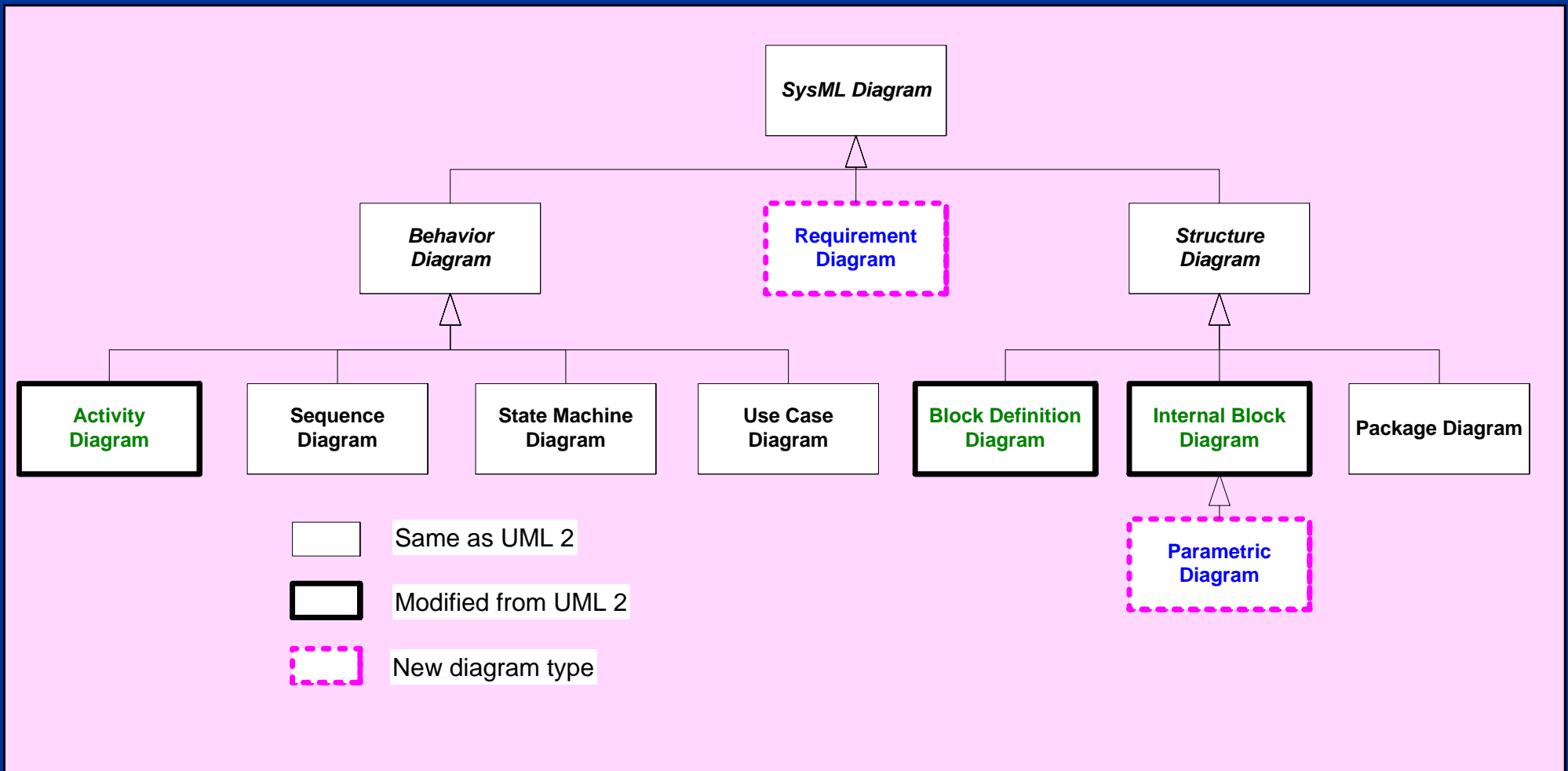
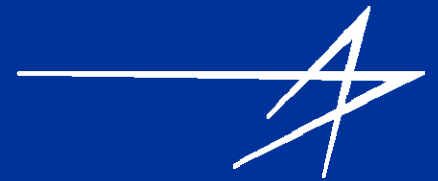
What is SysML?



- **A graphical modeling language in response to the UML for Systems Engineering RFP developed by the OMG, INCOSE, and AP233**
 - a UML Profile that represents a subset of UML 2 with extensions
- **Supports the specification, analysis, design, verification, and validation of systems that include hardware, software, data, personnel, procedures, and facilities**
- **Supports model and data interchange via XML Metadata Interchange (XMI®) and the evolving AP233 standard (in-process)**

SysML is Critical Enabler for MBSE

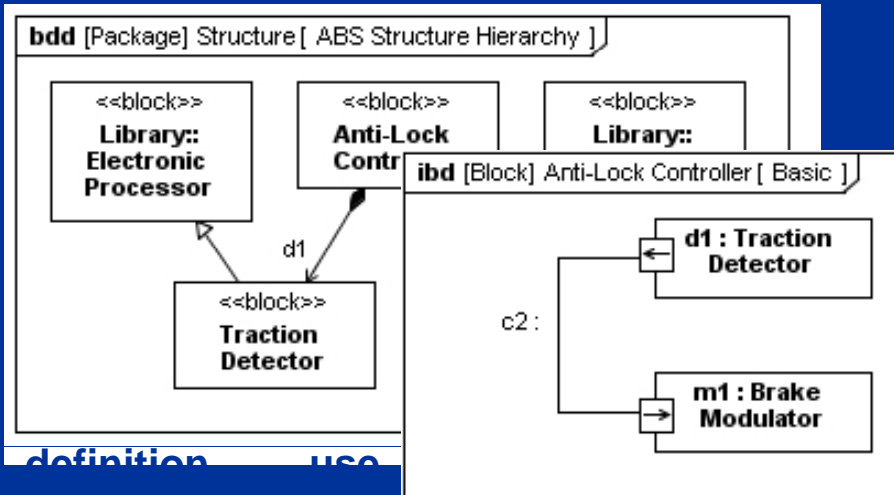
SysML Diagram Taxonomy



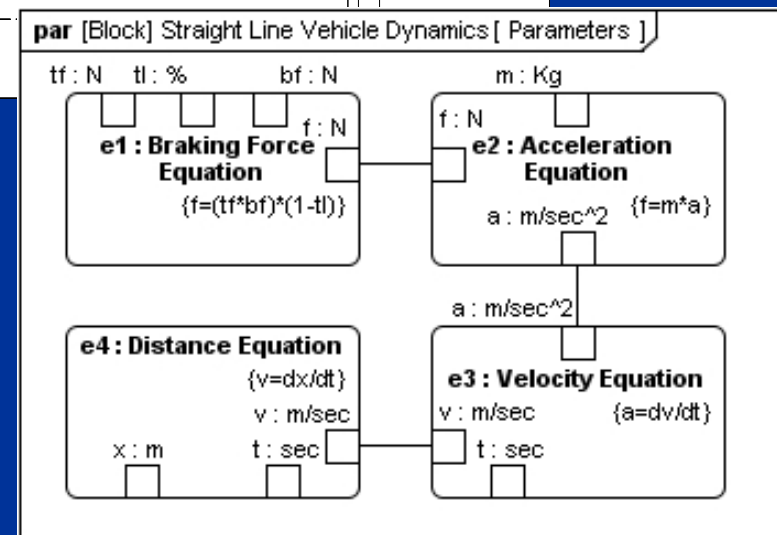
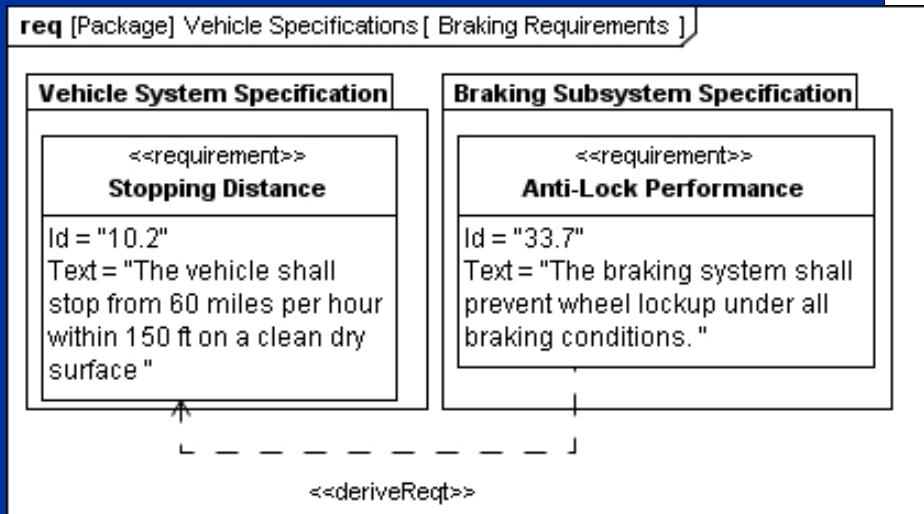
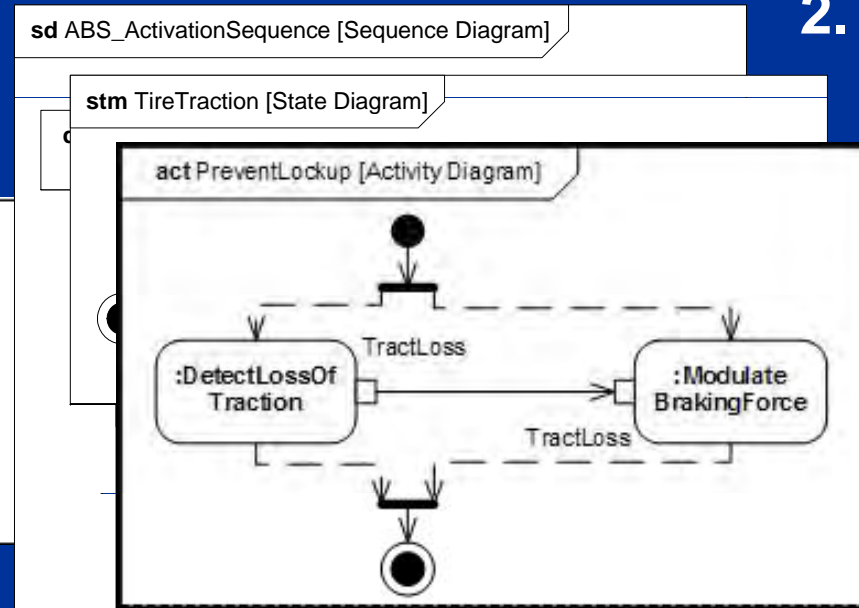
4 Pillars of SysML – ABS Example



1. Structure

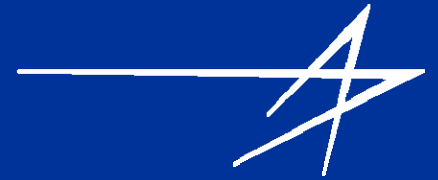


2. Behavior



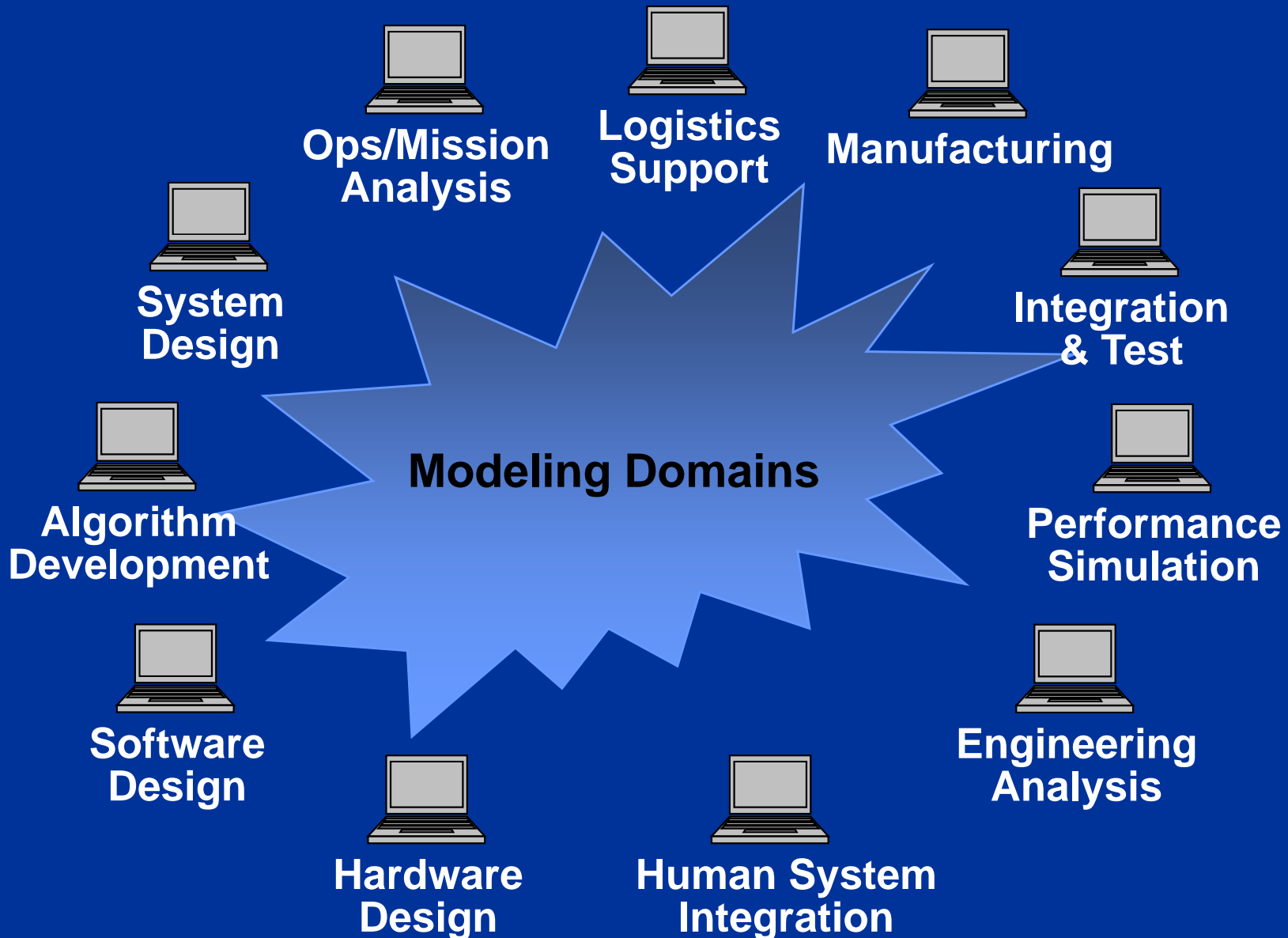
3. Requirements

4. Parametrics

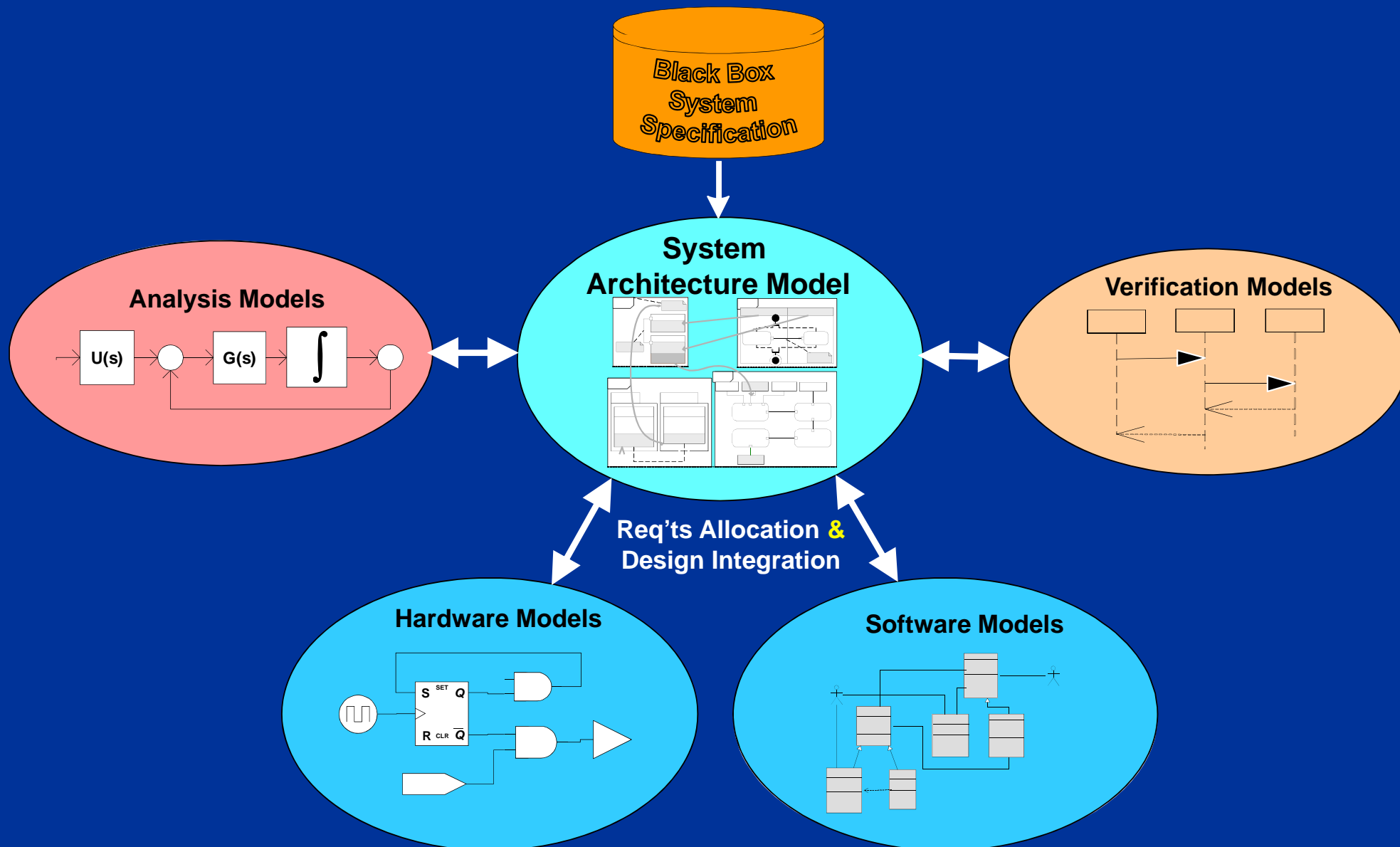
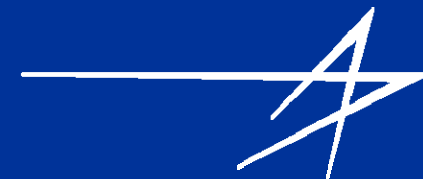


System Model as an Integration Framework

MBSD Must Integrate across Modeling Domains



Using System Architecture Model as an Integration Framework



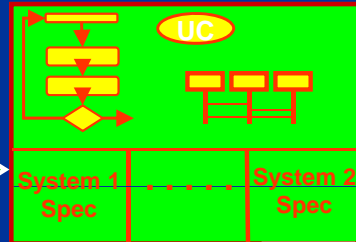
Using the System Architecture Model to Flowdown Requirements



System-of-System Level

- 1st Level Of Decompositions
- How Our System Contributes to the Overall Mission

Mission Concept of Operations



Trade Studies, Simulation, Specification Reviews, etc.

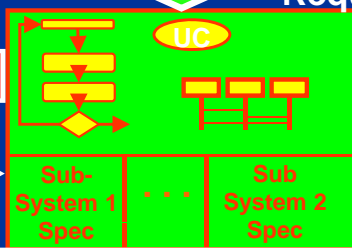
System Level

- Derives Subsystems
- Allocates Requirements to Subsystems



A-Spec

Subsystems



Behavior, Structure & Requirements

Trade Studies, Simulation, Specification Reviews, etc.

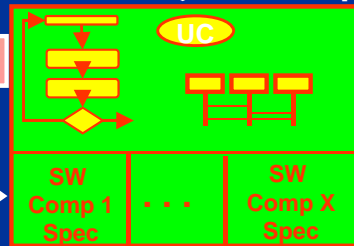
Element Level

- Derives Hardware and Software Components
- Allocates Requirements to Components



B-Spec

Components

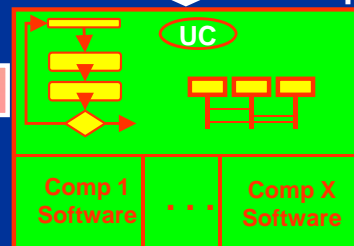


Behavior, Structure & Requirements

Trade Studies, Simulation, Specification Reviews, etc.

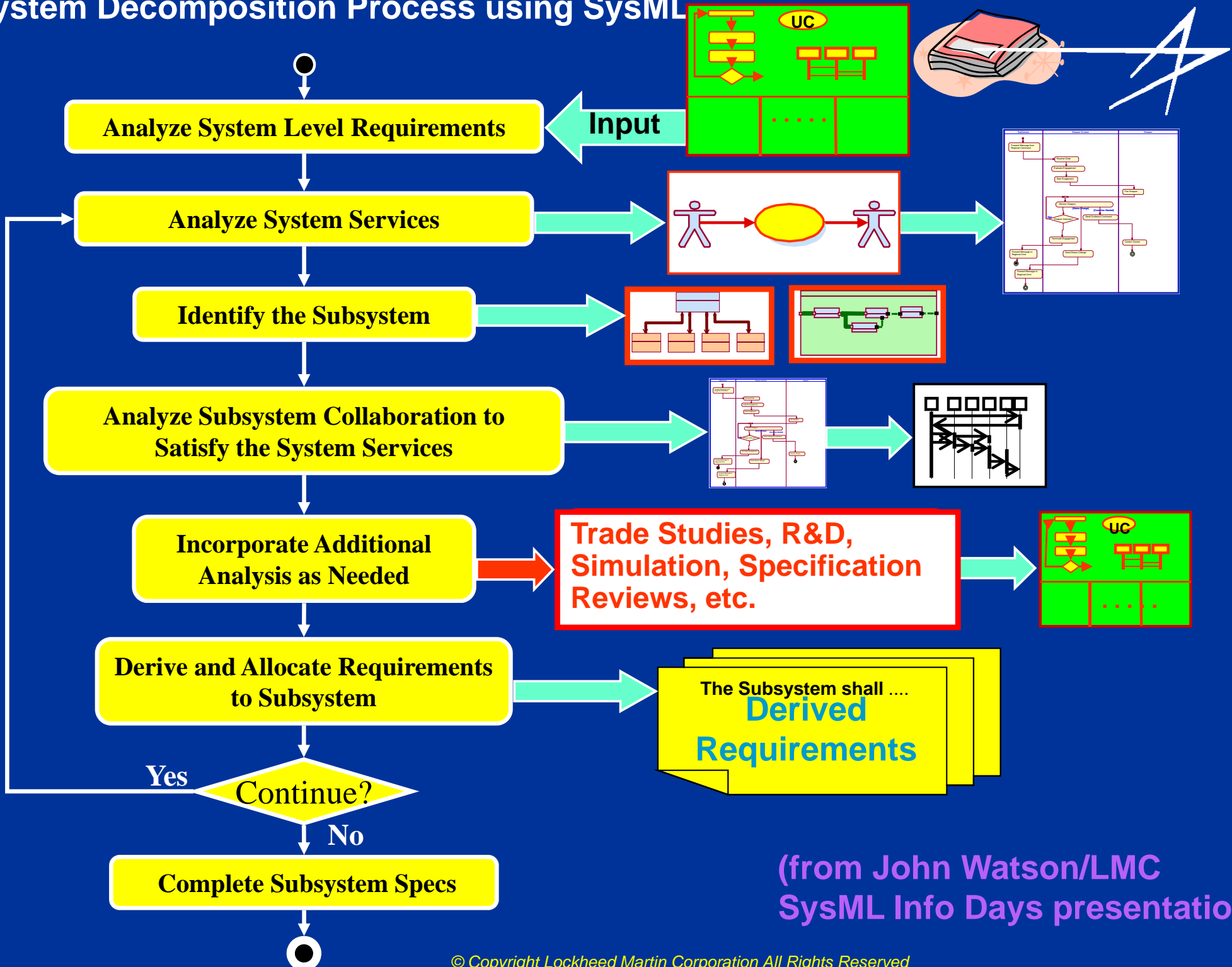
Component Design & Implementation Level

(from John Watson/LMC SysML Info Days presentation)



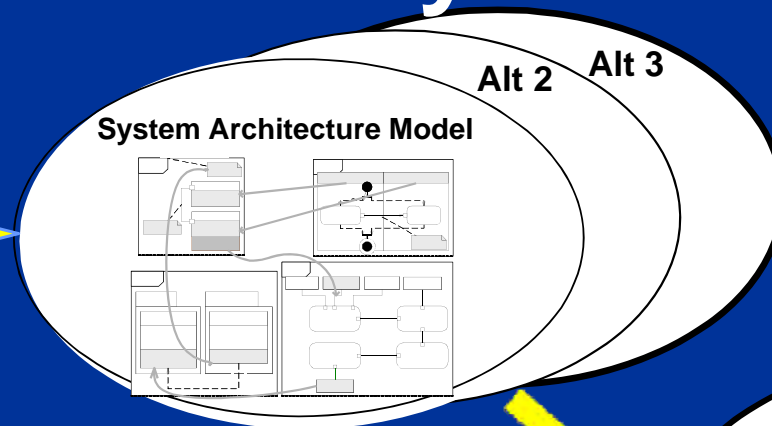
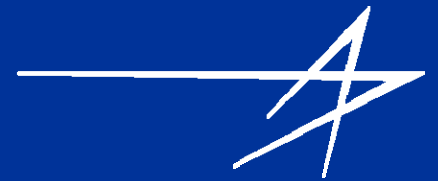
Behavior, Structure & Requirements

System Decomposition Process using SysML



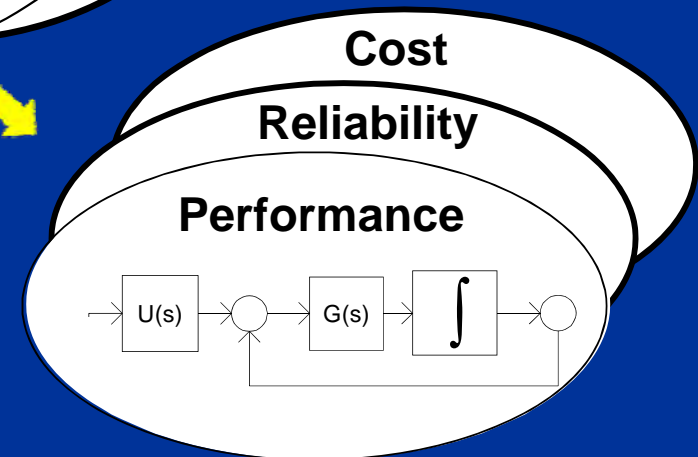
(from John Watson/LMC SysML Info Days presentation)

System Architecture Model to Support Tradeoff Analysis

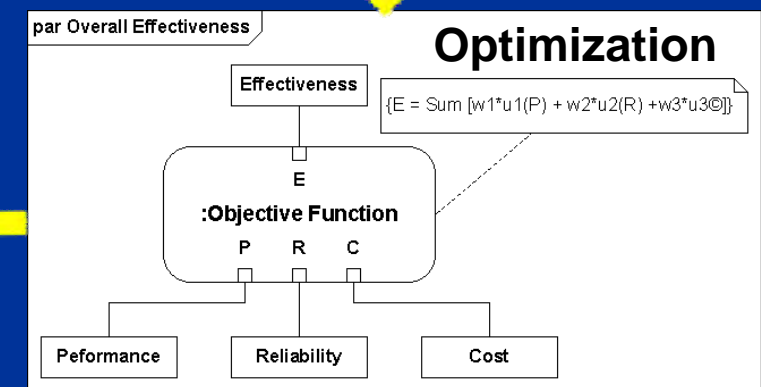


Analysis Results

Subsystem	Alternative1	Alternative2	Alternative3
Sensor	Sensor1	Sensor2	Sensor3
Processor	Processor1	Processor2	Processor3
Control	Control1	Control2	Control3



Criteria	Weight	Alt 1	Alt 2	Alt 3
Performance	0.5	7	5	5
Reliability	0.2	4	6	5
Cost	0.3	3	5	8
Effectiveness		5.2	4.2	<u>5.9</u>



Integrating SysML with Simulation GIT* Project

Modelica

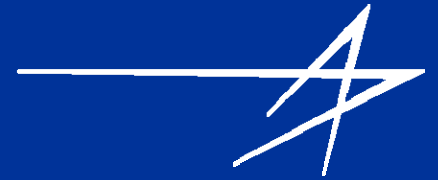
Lexical Representation

(auto-generated from SysML)

```
*ExcavatorExample.mo
package ExcavatorExample
...
class ExcavatorDigCycle
  Modelica.Mechanics.MultiBody.World world;
  ExcavatorExample.Components.Hydraulics hydraulics(redeclare
  ExcavatorModel.SubSystems.DigCycleSeq command(startTime=0.1)
  ExcavatorModel.SubSystems.MechanicsBody body(swing_phi_start
  ExcavatorExample.Interfaces.Nodes.TransNode2 node;
equation
  connect(hydraulics.boomCylBaseL, body.cylBoomLeftBase);
  connect(hydraulics.boomCylRodR, body.cylBoomRightRod);
  connect(hydraulics.boomCylRodL, body.cylBoomLeftRod);
  connect(hydraulics.armCylRod, body.cylArmRod);
  connect(hydraulics.armCylBase, body.cylArmBase);
  connect(hydraulics.bucketCylRod, body.cylBucketRod);
  connect(hydraulics.bucketCylBase, body.cylBucketBase);
  connect(hydraulics.commandSignal, command.commandSignal);
  connect(world.frame_b, body.baseFrame);
  connect(hydraulics.swingFlange, body.swingFlange);
  connect(hydraulics.boomCylBaseR, node.a);
  connect(node.b, body.cylBoomRightBase);
end ExcavatorDigCycle;
end ExcavatorExample;
```

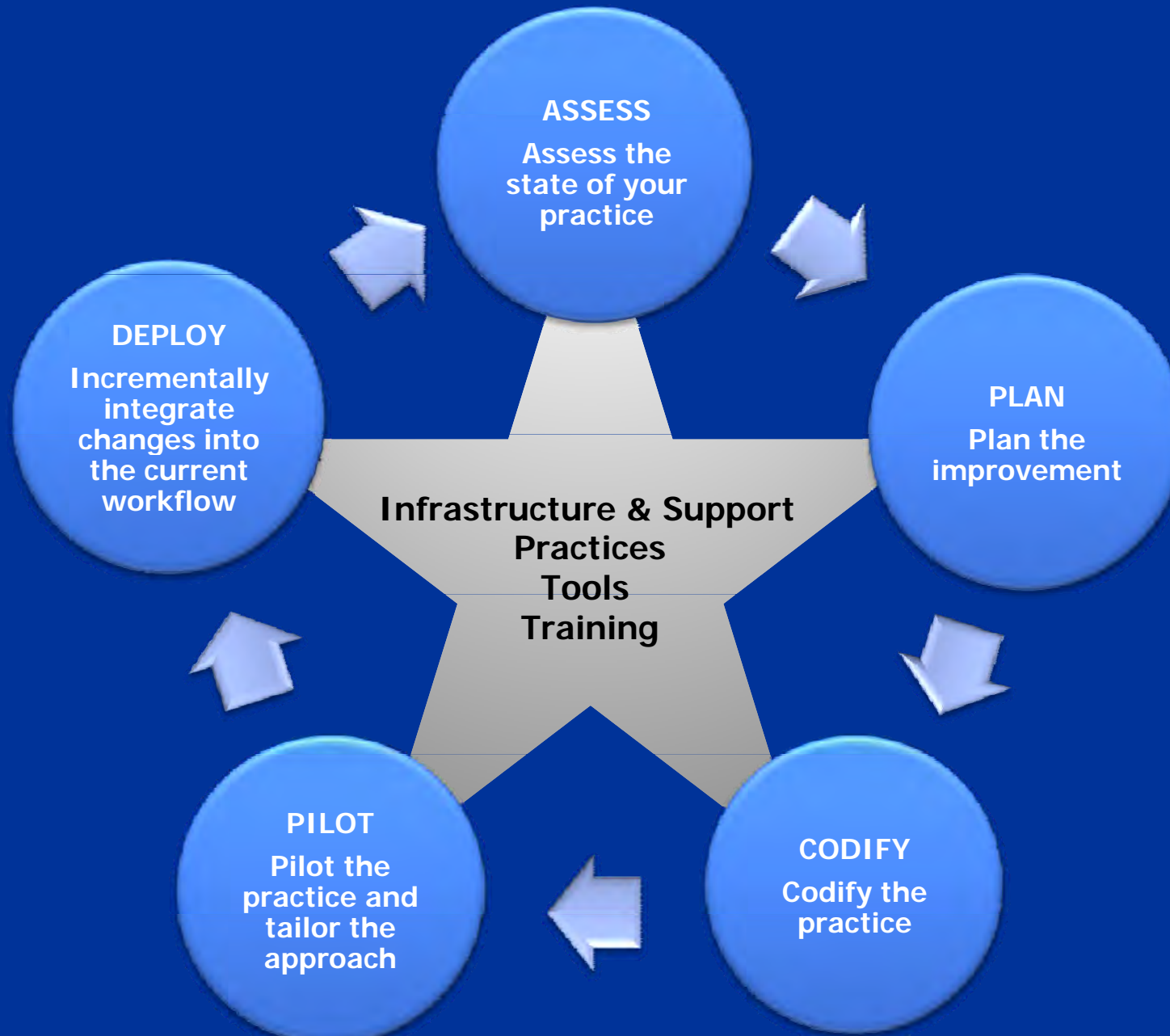
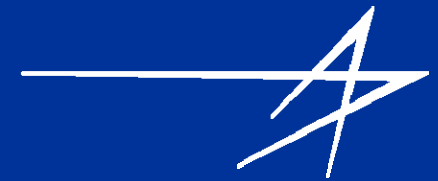
[Johnson, 2008 - Masters Thesis]

* Georgia Institute of Technology

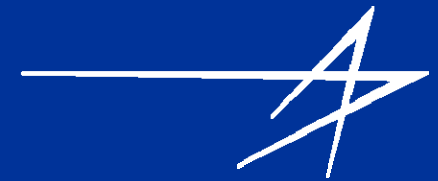


Deploying MBSD into Your Organization

Deploying MBSD as part of Improvement Process

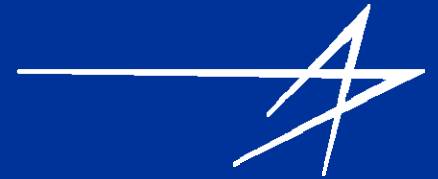


MBSD Observations



- **Transition from document-centric to model-centric is a cultural change**
- **Well defined MBSE method is essential**
- **Multiple tool vendors provide a range of price point, capability, and standards conformance**
- **MBSE training should include language, method, and tools**
- **Employ pilots to validate your MBSE approach**
- **Need buy-in from program and customer on MBSE benefits, approach and deliverables**
- **Scope model to support program objectives and within program constraints**
- ***A lot has been learned, but much more remains***

Summary



- **MBSD is a key practice to advance complex systems development**
- **Standards such as SysML and UML are critical enablers of MBSD**
- **Multiple tool vendors implementing SysML**
- **System architecture model and standards based approach facilitate integration across modeling domains**
- **Growing interest and application of MBSD**

Acronyms

- **MBSD – Model-based Systems Development**
- **MBSE – Model-based Systems Engineering**
- **OMG – Object Management Group**
- **SysML – Systems Modeling Language**
- **UML – Unified Modeling Language**