33rd Annual INCOSE international symposium

hybrid event

Honolulu HI USA

MBSE Model Integration in a Mixed-Fidelity Environment

Mixed Fidelity Model Integration

Authors

Alex Gaspar

Bradley Kukurza

Eric Martens

Problem Statement

Mixed Fidelity MBSE

The Mixed Fidelity System Design Problem Statement

01	New Systems	New systems are not truly clean sheet; integrate existing components
02	System Upgrades	System upgrades are built upon source of truth that may be in a variety of formats
03	New Components	New components can be fully modeled for use in future models

New Models	Source of Truth developed in MBSE environment
Existing Validated Models	Should not modify existing validated models for sake of integrating into a new design
Existing Products without models	Existing products intended for reuse that have no MBSE models
Supplier / Customer Models	Suppliers and customers may have different MBSE frameworks, tools, and skills

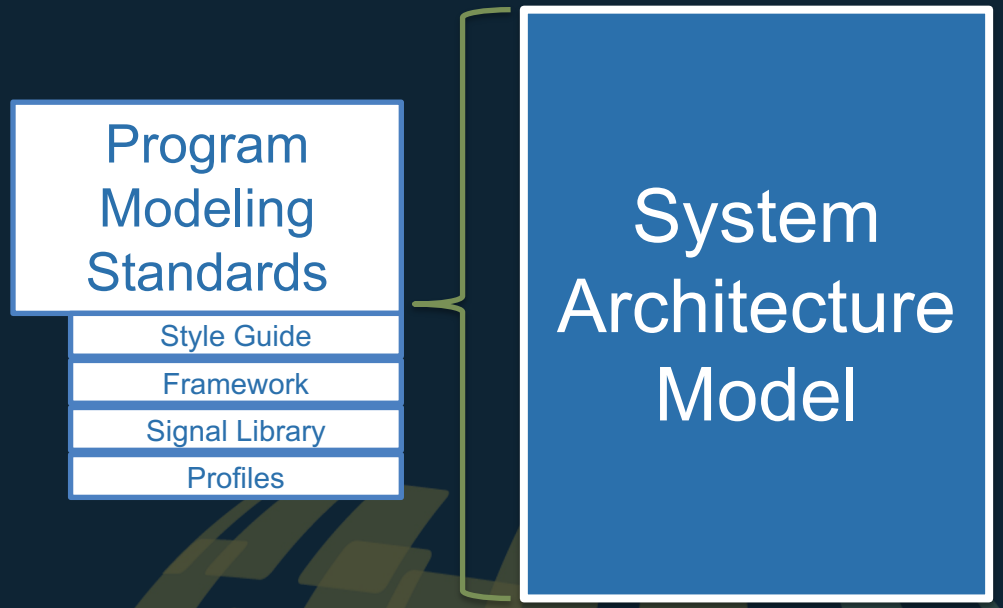
Applying "New Models" thinking to complex mixed fidelity systems adds undue cost, schedule, and source of truth risks


Conversion Cost

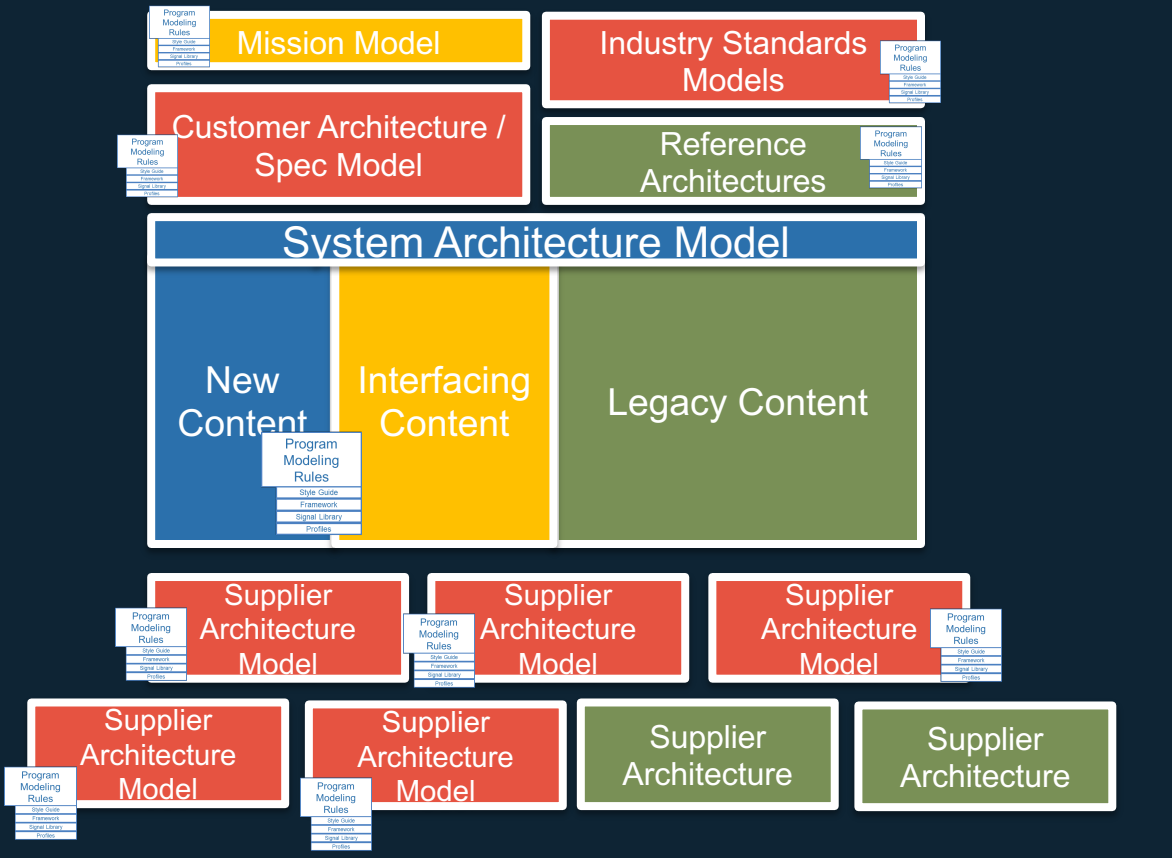

Modeling Scope


What is Truth?

New Model Approach (Theory)

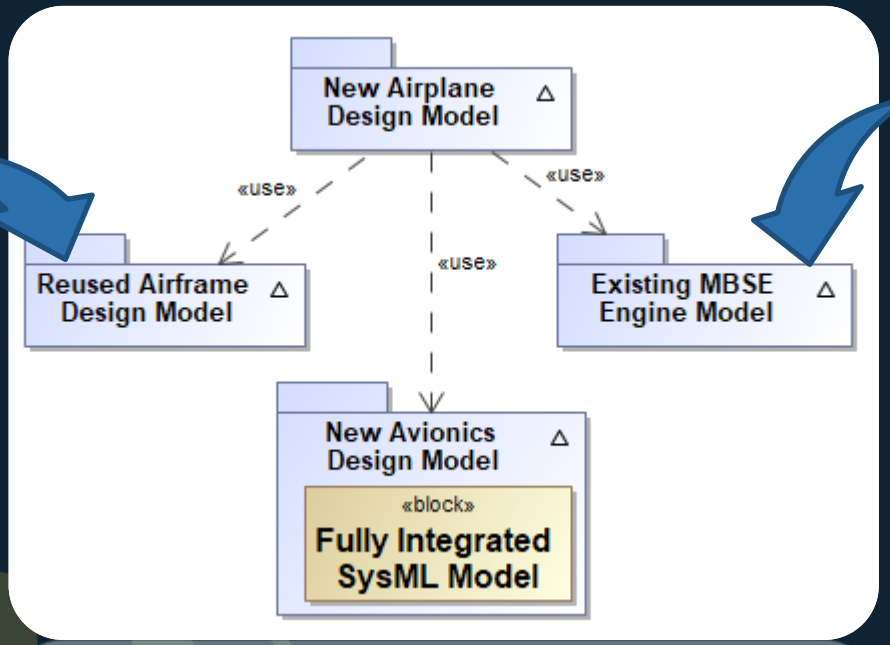


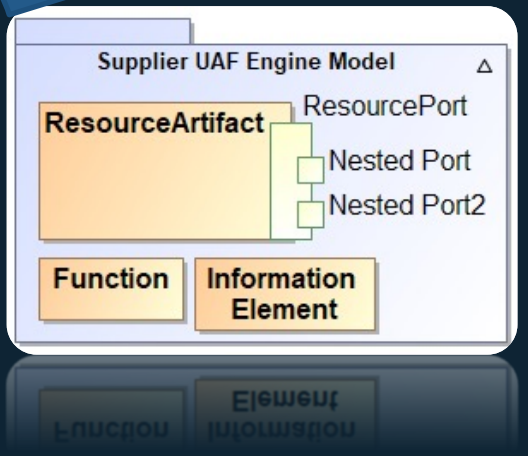
Mixed Fidelity (Reality)



Modeling approaches must accept and accommodate that mixed-fidelity models and variations in modeling standards will exist

Loose Coupling Allows Mixed Fidelity





Loose coupling allows extracting and modeling a minimum set of data from documentation of existing products that lack MBSE

Loose coupling allows "translation layers" between two different models, even models of different techniques and languages

Solution to Problem Statement

Loose Model Coupling Approach

Architecting Loose Coupling in Models

Black Box – White Box – Solution Concept

1. Start with this concept, as explored in MagicGrid® Book of Knowledge

Implement BB-WB at Every Layer of Decomposition

2. At each decomposition, turn each BB into a self-contained WB containing more BBs

Loosely Couple a WB to the BB

3. For structure, behavior, and interfaces effectively duplicate the BB into a WB and trace back to the BB

Develop the System Solution Architecture

4. Realize each logical element into a system solution element, with a focus on HW/SW end items

Loose coupling allows flexibility to model only portions of a system, compare models for early trades, or swap out models for upgrades later in the lifecycle with minimal rework of higher tiers of the model.

Loosely Coupled Modular Modeling Framework

			Pillar				
			Requirements	Structure	Behavior	Parametors	Safety & Reliability
Domain	Problem	Black Box	Stakeholder Needs	System Context	Use Cases	Measures of Effectiveness (MoEs)	Conceptual and Functional Failure Mode & Effects Analysis (FMEA)
		White Box		Conceptual Subsystems	Functional Analysis	MoEs for Subsystems	Conceptual Subsystems FMEA
	Solution		System Requirements	System Structure	System Behavior	System Parameters	System Safety & Reliability (S&R)
			Subsystem Requirements	Subsystem Structure	Subsystem Behavior	Subsystem Parametors	Subsystem S&R
			Component Requirements	Component Structure	Component Behavior	Component Parametors	Component S&R
	Implementation		Implementation Requirements				

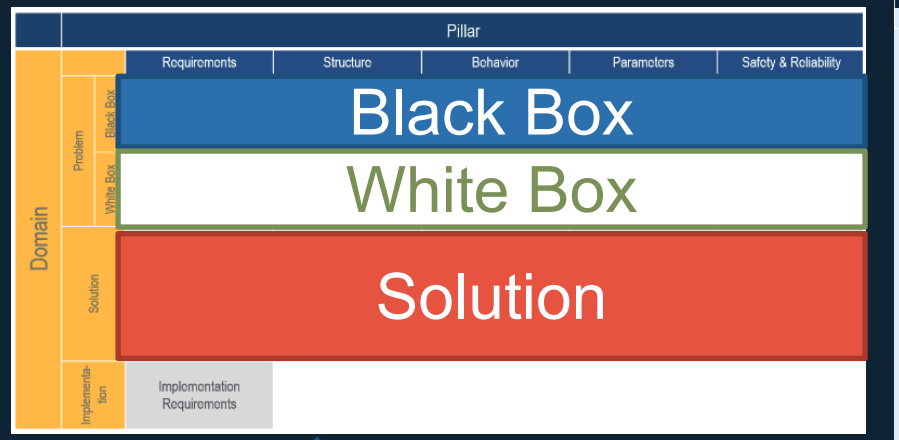
From MagicGrid Book of Knowledge

Compare To

		Architecture	Modules	Pillar					
				Requirements	Structure	Behavior	Interfaces	Parametrics	System Analysis
Domain	Stakeholder Needs	Influencing Architectures	Multiple	Stakeholder Requirements	Reference Architectures		Interface Needs Information Exhange Requirements	KPPs, MOEs/MOPs	-
	Functional/Logical (Needs)	Weapon System Context	WB Weapon System Context	-	Weapon Sys Internal Structure	Use Cases WB Activities	Internal Data Flows	-	-
			BB Weapon System	Weapon System Fn Requirements Verification Requirements	Needed Segments	BB Activities BB States	External Interfaces	Requirement Values	-
		Weapon System WB	WB Weapon System	-	Segment Internal Structure	WB Activities	External Interface Redefinition Internal Data Flows	-	Weapon System Trade Studies
			BB Segments	Segment Fn Requirements Verification Requirements	Needed Segments	BB Activities BB States	Segment Ext Interfaces	Requirement Values	-
		Vehicle (Segment) WB	WB Segments	-	Segment Internal Structure	WB Activities	External Interface Redefinition Internal Data Flows		Segment Trade Studies
			BB Subsystems	Subsystem Fn Requirements Verification Requirements	Needed Subsystems	BB Activities BB States	Subsystem External Interfaces	Requirement Values	-
		Subsystem WB	WB Subsystems	-	Subsystem Internal Structure	WB Activities	External Interface Redefinition Internal Data Flows		Subsystem Trade Studies
			BB Components / Skills	Component / Skill Fn Requirements Verification Requirements	Needed Components	BB Activities BB States	Component External Interfaces	Requirement Values	-
		Skills WB	WB Skills		Skill Internal Structure	WB Activities	External Interface Redefinition Internal Data Flows		Component Trade Studies
			BB Services	Service Fn Requirements Verification Requirements	Needed Services	BB Activities BB States	Services External Interfaces Service Contracts	Requirement Values	-
	Solution	System Solution	Solution Architecture	Non-Fn System Requirements Non-Fn Equipment Requirements Verification Requirements Zone Requirements	Selected Equipment System HW-HW Schematics System SW-SW Schematics SW to HW Allocation	Equipment States	Interface Protocols Message Structure Network Interfaces Service Contracts	Equipment Parameters Predicted/Measured Values TPM Predictions TRL / MRL / IRL Evaluations	Solution Architecture Trades Model Metrics TPM Tracking Readiness Levels SCFTA Modularity Assessments Network Loading
		Equipment Models	BB Equipment	Supplier Fn Requirements Supplier Non-Fn Requirements Verification Requirements	Detailed Equipment	Inherited	Pins Outs Connector Assignments	Interface Parameters TPM Predictions RMS&H Values	
			WB Equipment	SRU Requirements Verification Results	Equipment Internal Structure	SRU Behaviors	Detailed Interfaces SRU-SRU Interfaces	Equipment Parameters Predicted/Measured Values TPM Predictions TRL / MRL / IRL Evaluations RMS&H Equipment Values	SRU Trades
	Analysis & Planning	Specialty Analysis	-						FMEA / FMECA PHA / FHA
		VV&C	-	Links to Verification Requirements Certification Requirements	CVA Plan Dependencies VV&C Facility Elements VV&C Article Configuration	Certification / Verification Activity	Test Facility Interfaces	VV&C Results	-

*Black Box: Represents the external view only of a “thing” where “thing” could be a system, a subsystem, a component and any other type of logical or physical object.
*White Box: Represents the internal view of a corresponding BB “thing”. WB internal structure & behavior must satisfy the “boundary requirements, interfaces, associations and interactions” defined by the BB

Loosely Coupled Modular Modeling Framework



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			BB Subsystems	Black Boxes					
		Subsystem WB	WB Subsystems	White Boxes					
			BB Components / Skills	Black Boxes					
		Skills WB	WB Skills	White Boxes					
			BB Services	Black Boxes					
	Solution	System Solution	Solution Architecture	Solution					
		Equipment Models	BB Equipment	Supplier Black Boxes					
			WB Equipment	Supplier White Boxes					
	Analysis & Planning	Specialty Analysis	-						
		VV&C	-	Verification					

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Pros and Cons

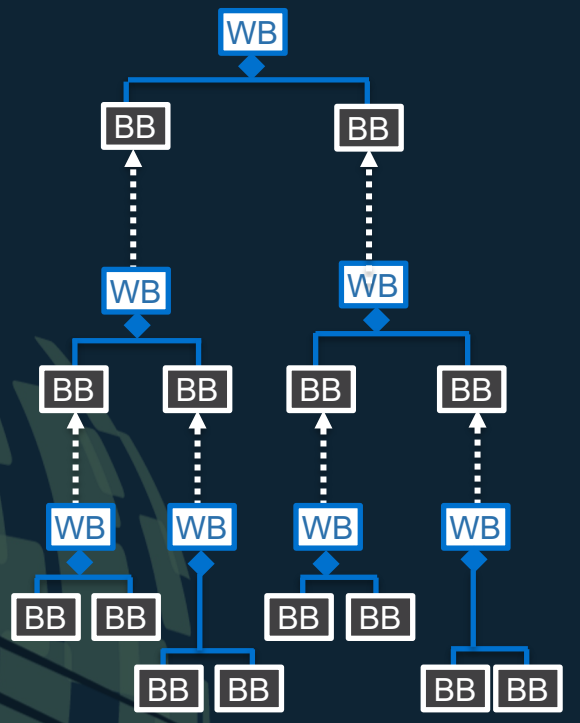
A modularized model is the key benefit

Pros

Easier configuration management

Permits integration of different modeling fidelity and styles without reworking truth

Efficient distributed modeling for very large teams



Cons

Reduced vertical simulation ability across decomposition layers

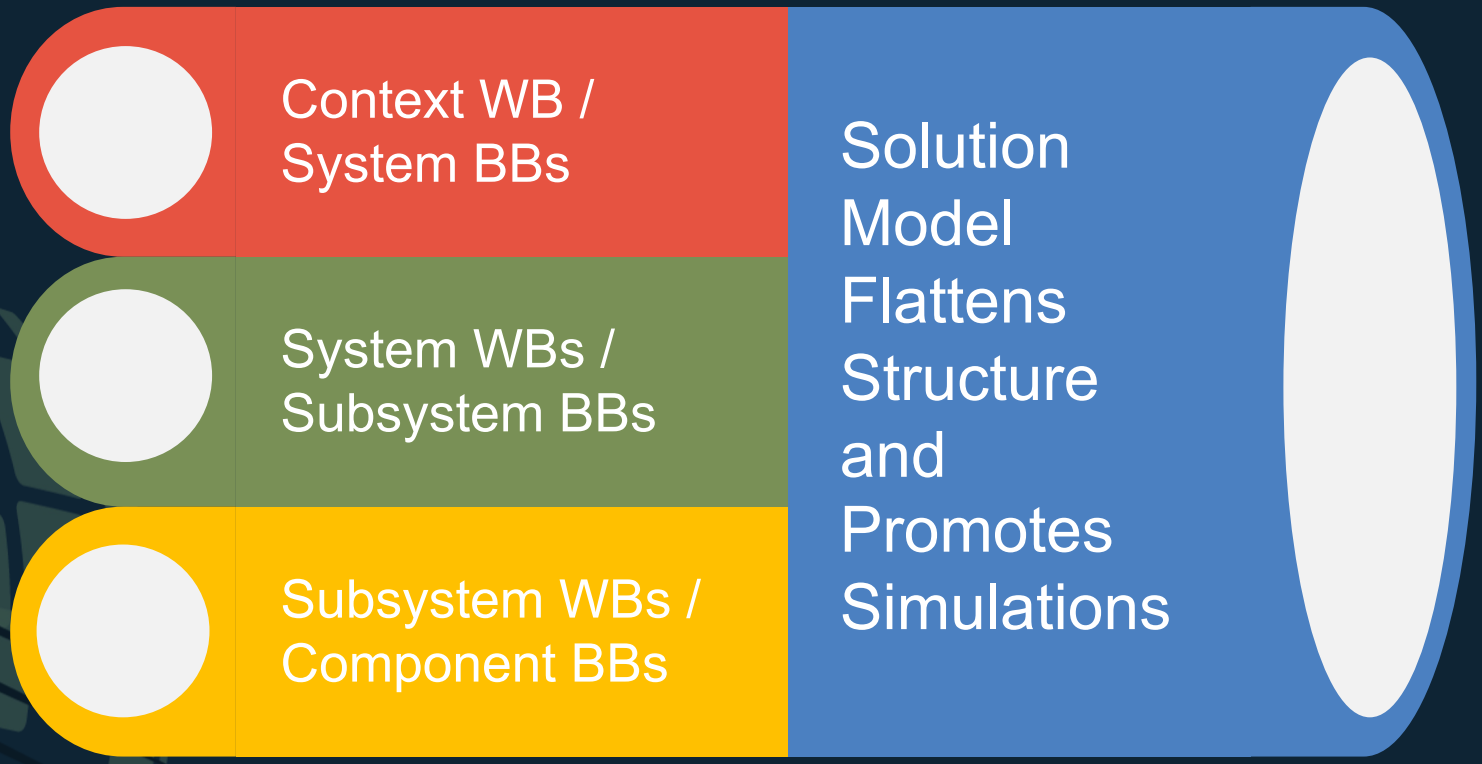
Higher up-front modeling investment

Model customizations require additional data architecting

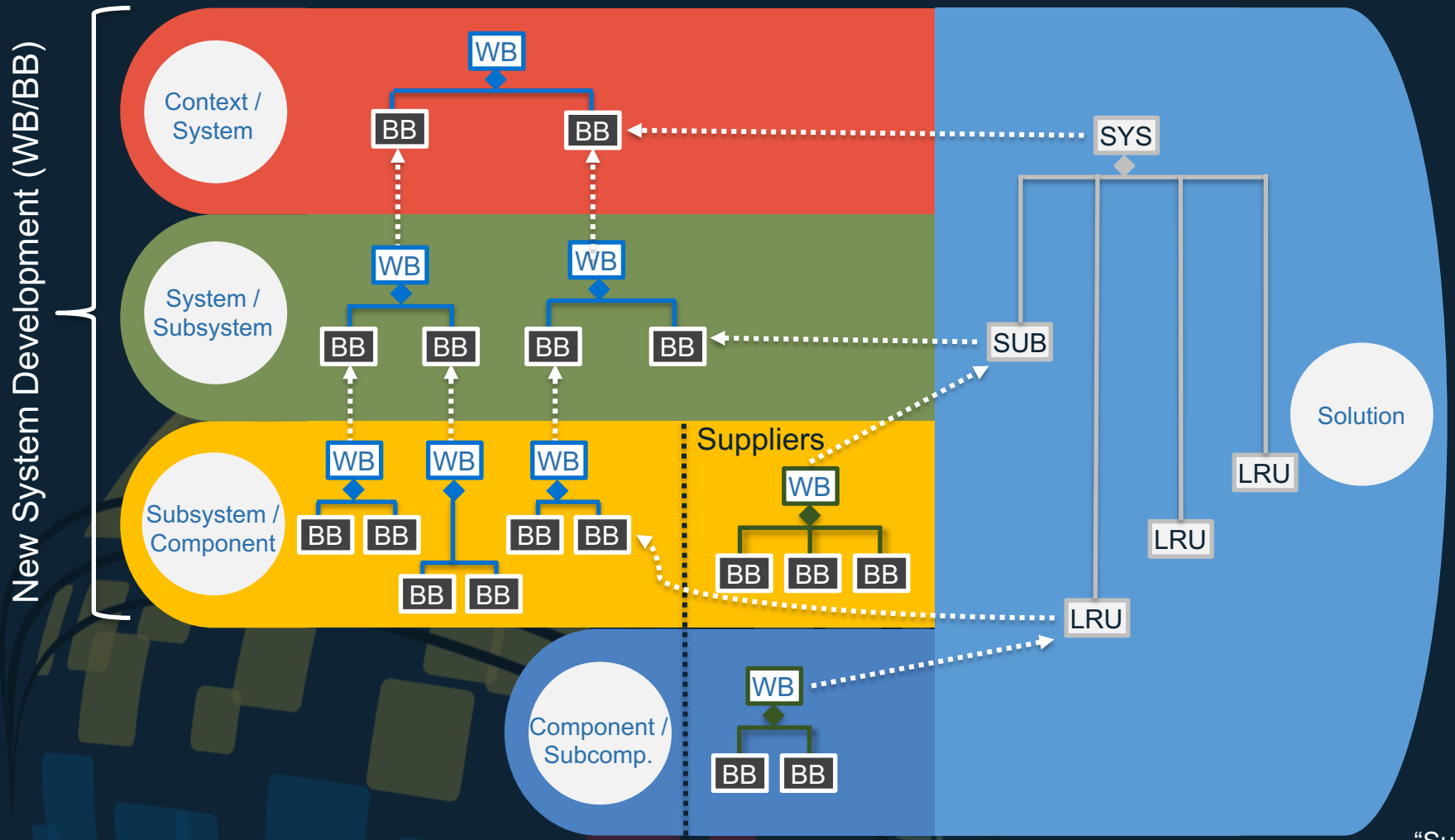
Solution Modeling to Address Vertical Gap

A Solution model helps fill in the vertical simulation gap caused by loose coupling of the logical model

1. Solution represents real product, e.g. things with part numbers
2. Behaviors model signals on physical connections
3. Loosely coupled to logical elements



Model Integration Approach



Solution represents real product, e.g. things with part numbers

Suppliers Integration Approach

- ❑ System Integrator Delivers Models As Specification
- ❑ Supplier Delivers WB/BB Models As Response to Specification

"Supplier" can represent any organizational boundary, such as internal groups

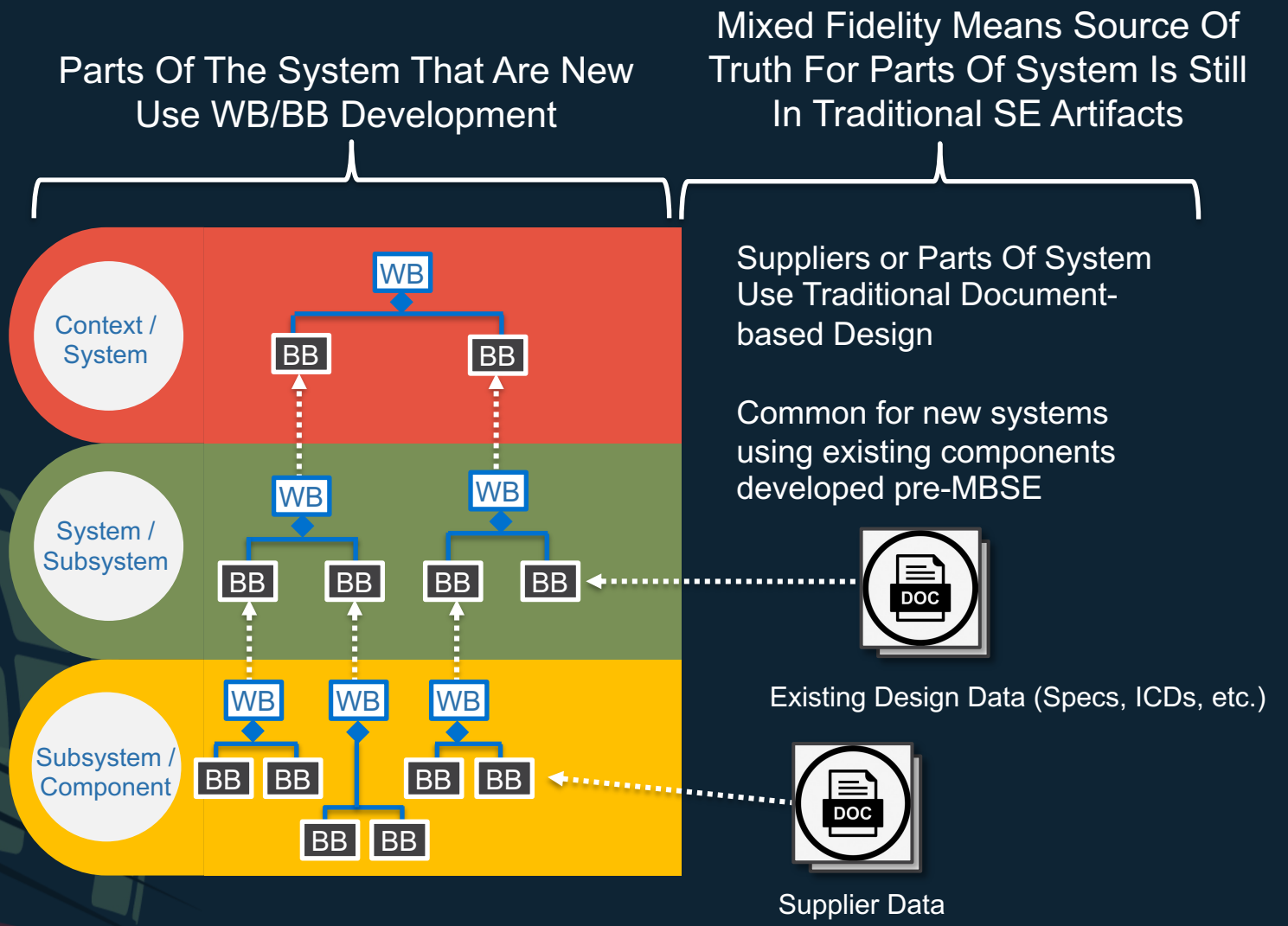
Boeing Examples

Real World Examples

Program 1

This program is an example of a brand-new development with heavy build-to-print reuse of legacy components

Full MBSE definition is used at the context and system levels, but as decomposition crosses the boundary to document-based sources-of-truth, a minimum set of BB data is copied into MBSE tool based on pre-defined MBSE analysis needs

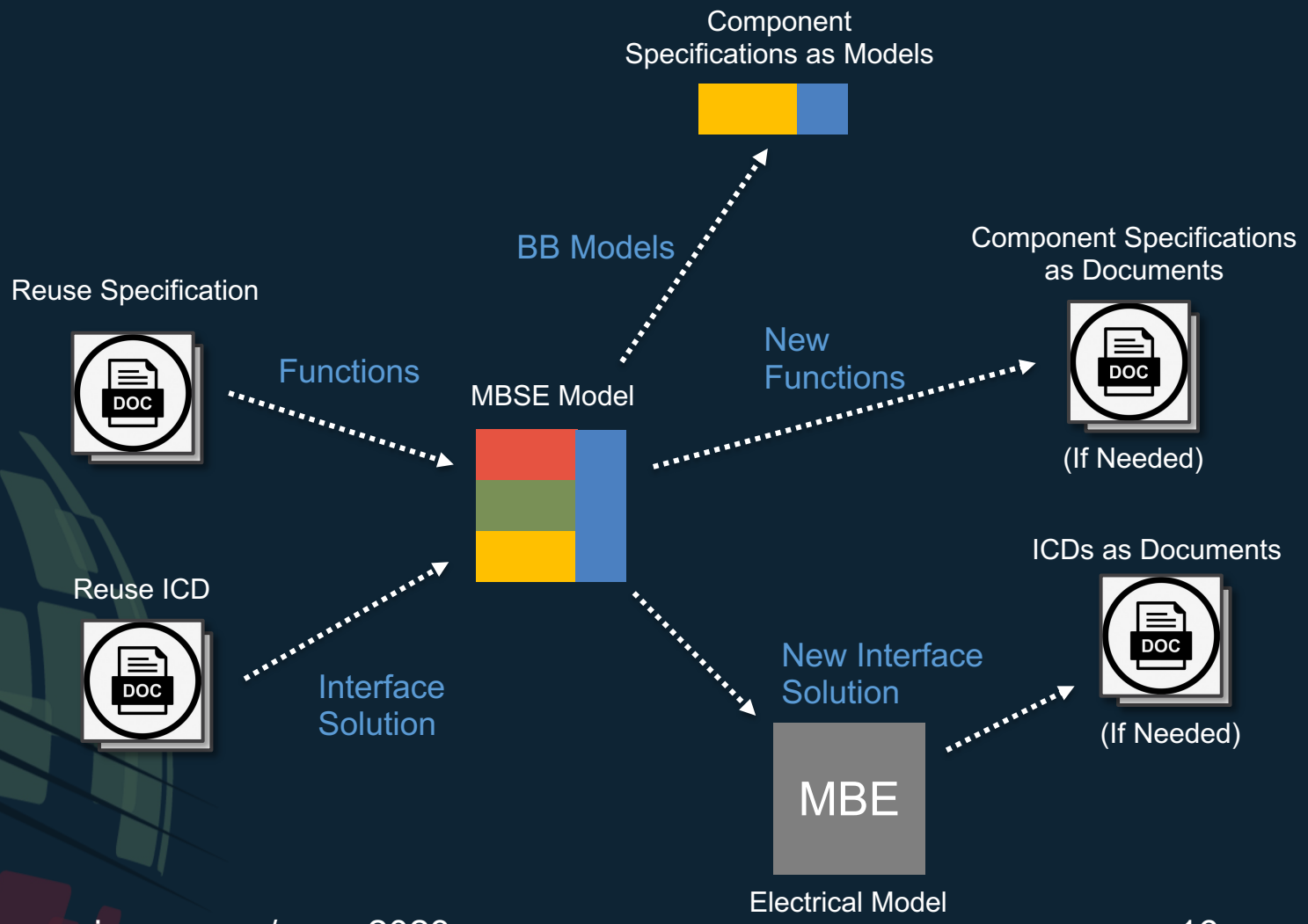


Up-Front Definition of Modeling Goals

Key requirement for MBSE success is to define the modeling inputs and outputs

Program 1 Example

- Inputs
  - Reuse / to be modified specifications
  - Reuse / to be modified Interface Control Documents (ICDs)
- Outputs
  - Program ICDs
  - Program Specifications

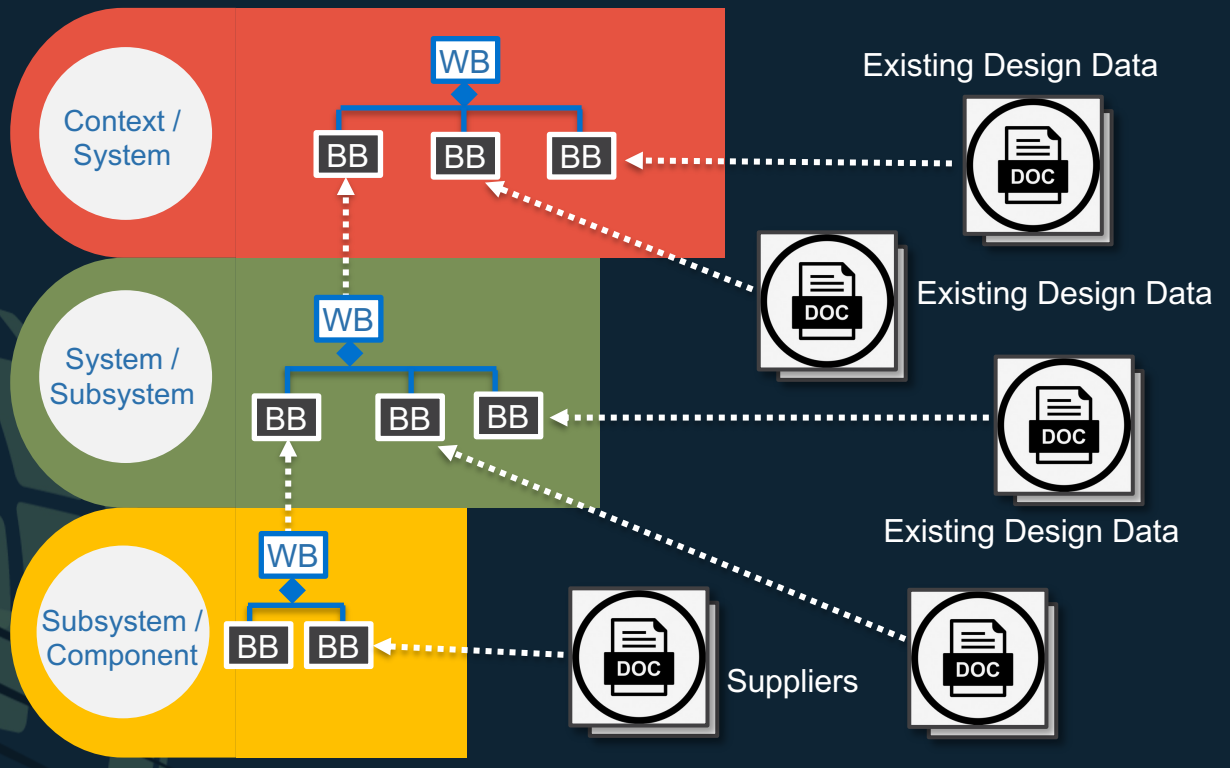


Program 2 Upgrades

Program 2 features new development on a legacy platform

Program 2 leans heavily into need-based modeling approach, modeling only what is necessary to produce pre-defined outputs

Full MBSE definition is used on the new systems being integrated, suppliers required to use MBSE and integrate models with Boeing

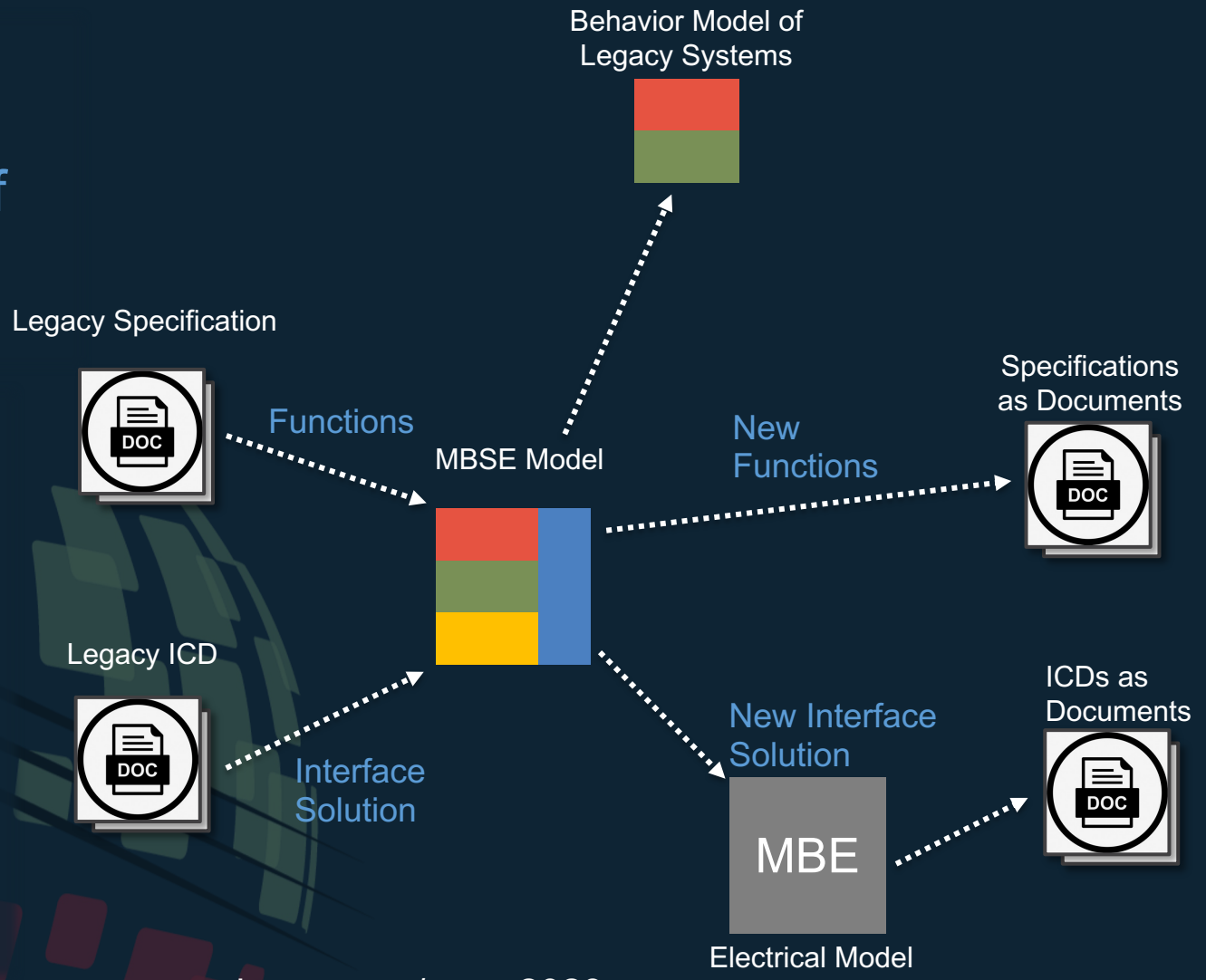


Program 2 MBSE Inputs vs Outputs

Unique for Program 2, helping engineers understand functionality of legacy systems was an output

Program 2 Example

- Inputs
  - Legacy specs
  - Legacy ICDs
- Outputs
  - Interface Design Docs
  - Guidance on system functions
  - Behavior validation
  - Upgrade specs



Multiple New Programs

Several new programs at Boeing follow loose coupling to take maximum benefit from mixed fidelity modeling

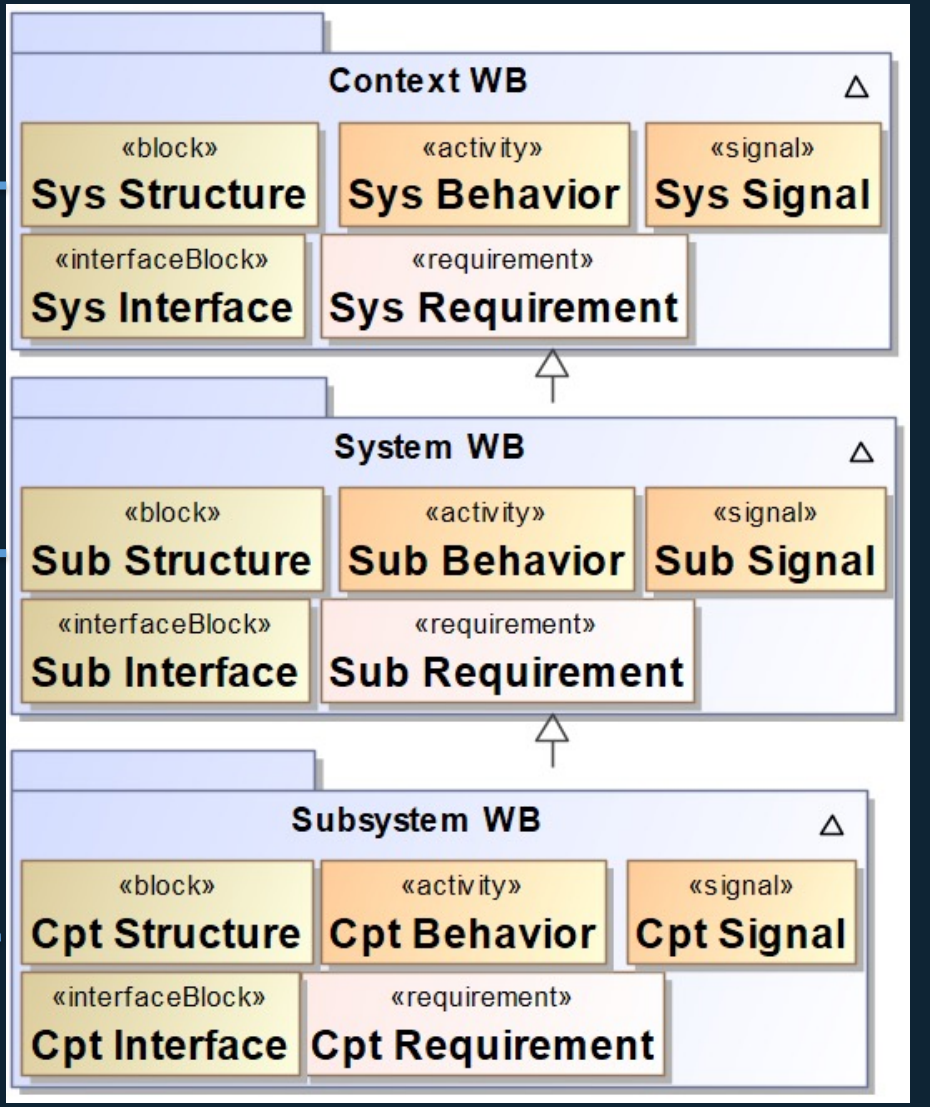
Modeling decomposition stops once a “procurable” black box is defined, and becomes the specification for a supplier either through export to documentation or directly as a model

New product models are validated/verified independently so source of truth is not modified during reuse

The System Black Box is Boeing’s customer’s procurable unit

Subsystem Black Boxes can be procured as-is without more decomposition (e.g. an engine)

Component Black Boxes can be defined and procured at lower levels (e.g. avionics)



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