

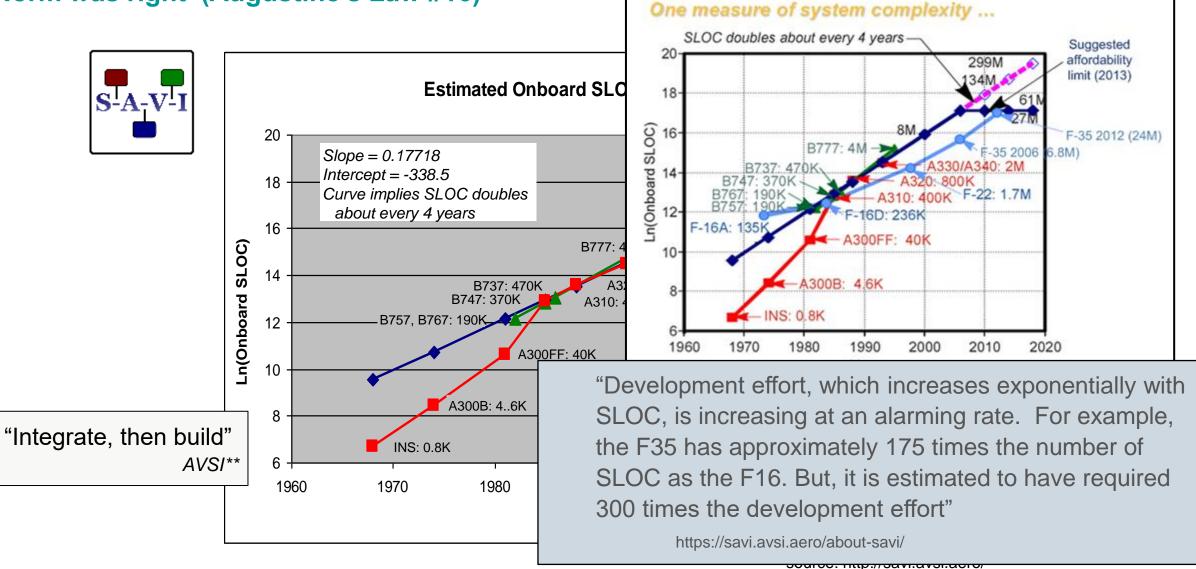
Start Integrated Stay Integrated

Continuous Integration: Moving from Spec→Design→Integrate to Integrate→Build



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Unprecedented Product Complexity: becoming unaffordable... Norm was right (Augustine's Law #16)*



<u>*https://en.wikipedia.org/wiki/Augustine's laws</u> **avsi.aero

SIEMFNS

Requirement disconnects are costly...

- ~21 million automotive recalls in the US last year
- Per AlixPartners*, each recall costs ~\$500/vehicle, that's \$105 billion in direct costs fixing the problems in 2021
- Auto Manufacturers carrying ~\$113B in warranty reserves** (2.5% of revenue) on their books

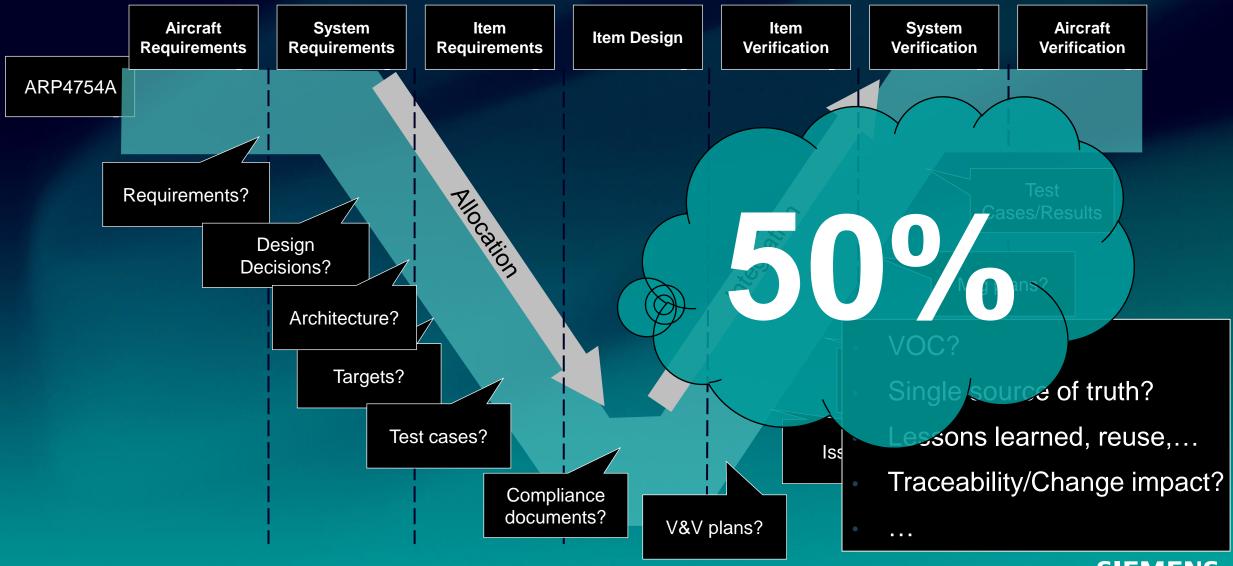
...mostly due to cross organization/interdisciplinary communication issues



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**https://www.warrantyweek.com/archive/ww20200910.html

The result of a siloed product development process... Mel Conway was right *

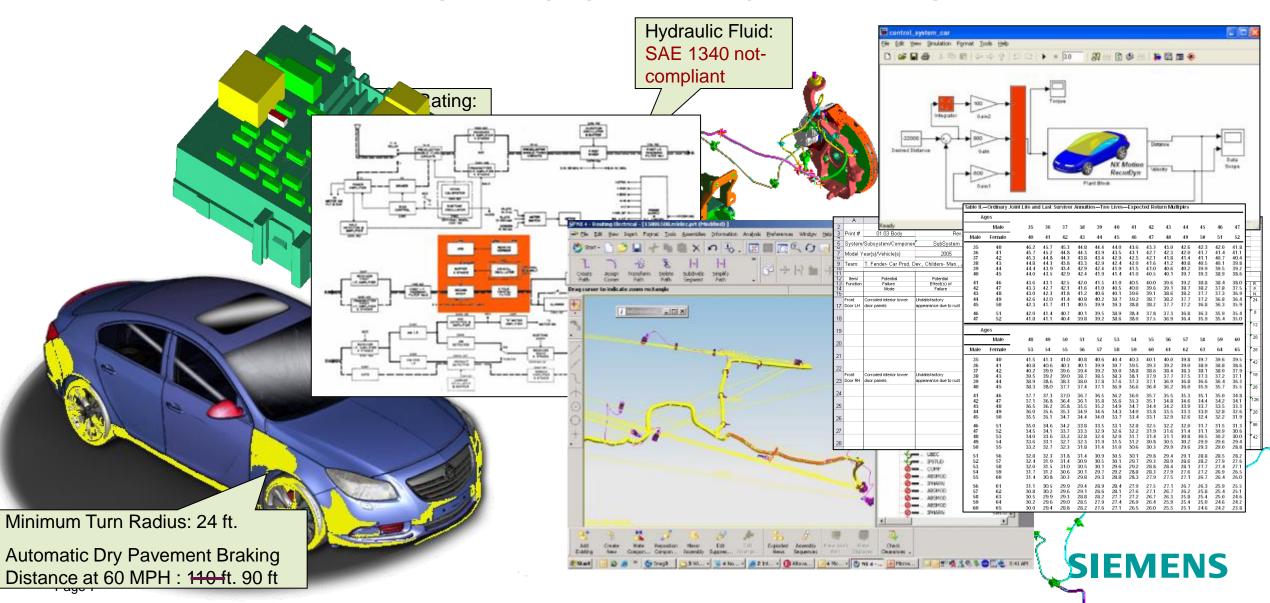


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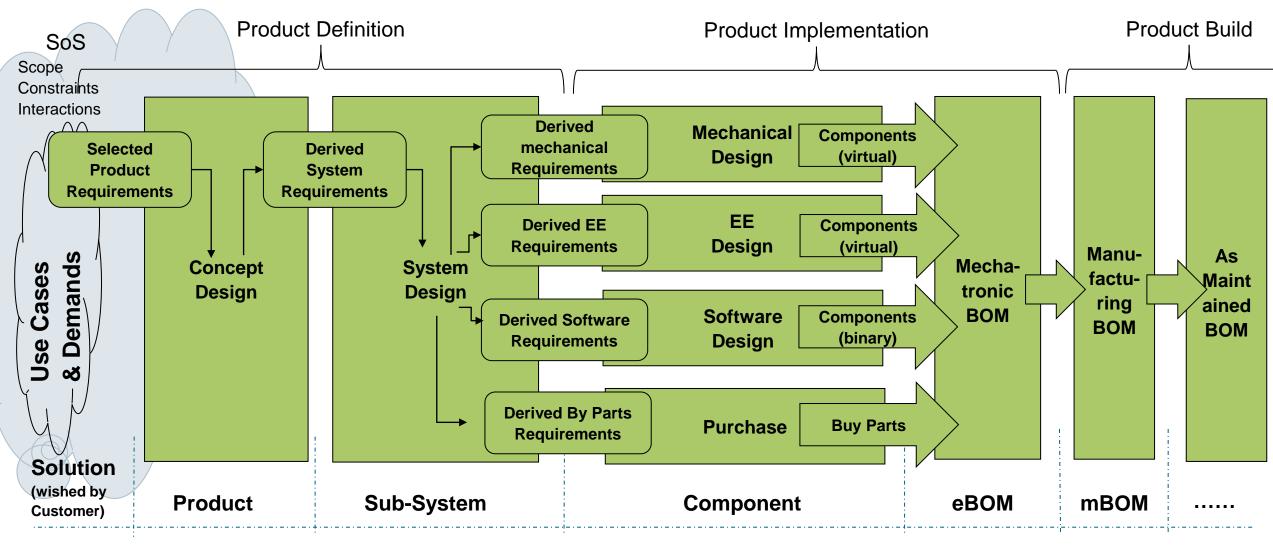
*https://www.melconway.com/

INCOSE Integrated MBSE Vision

What does information integration (Digital Thread) vs data integration look like...



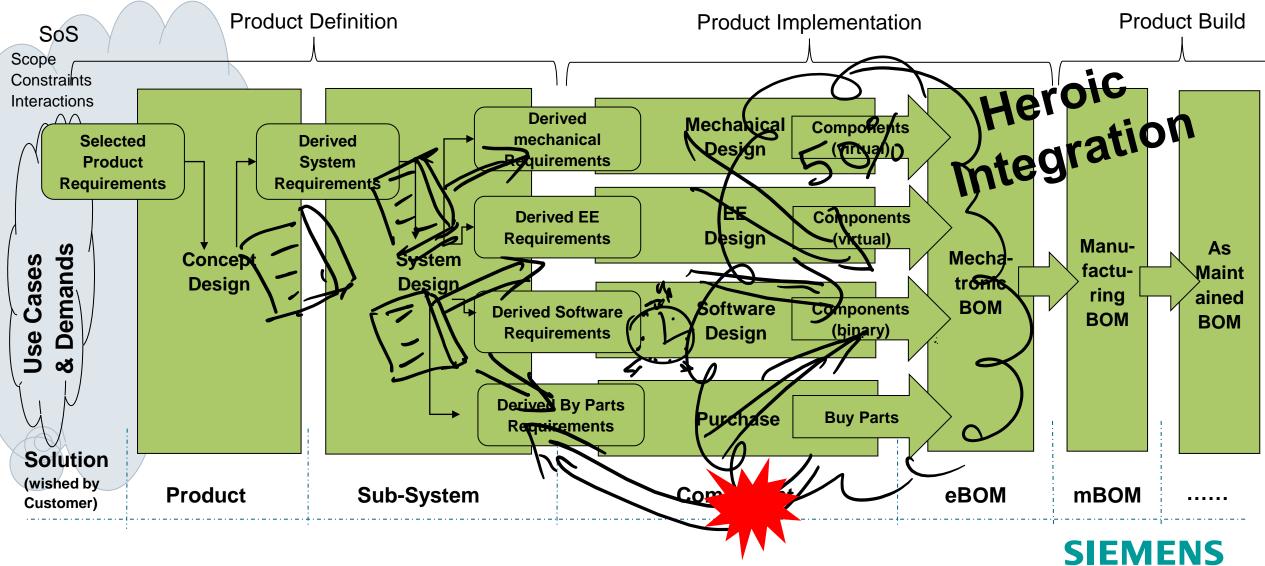
SE Process... Shift left...





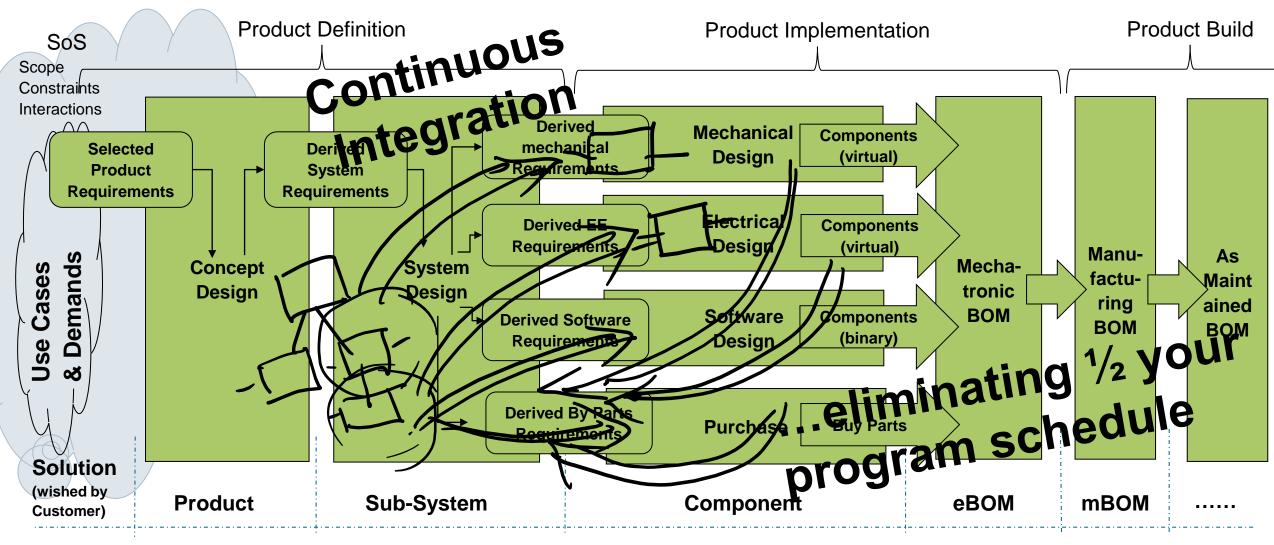
MBSE Process...

How it works today...

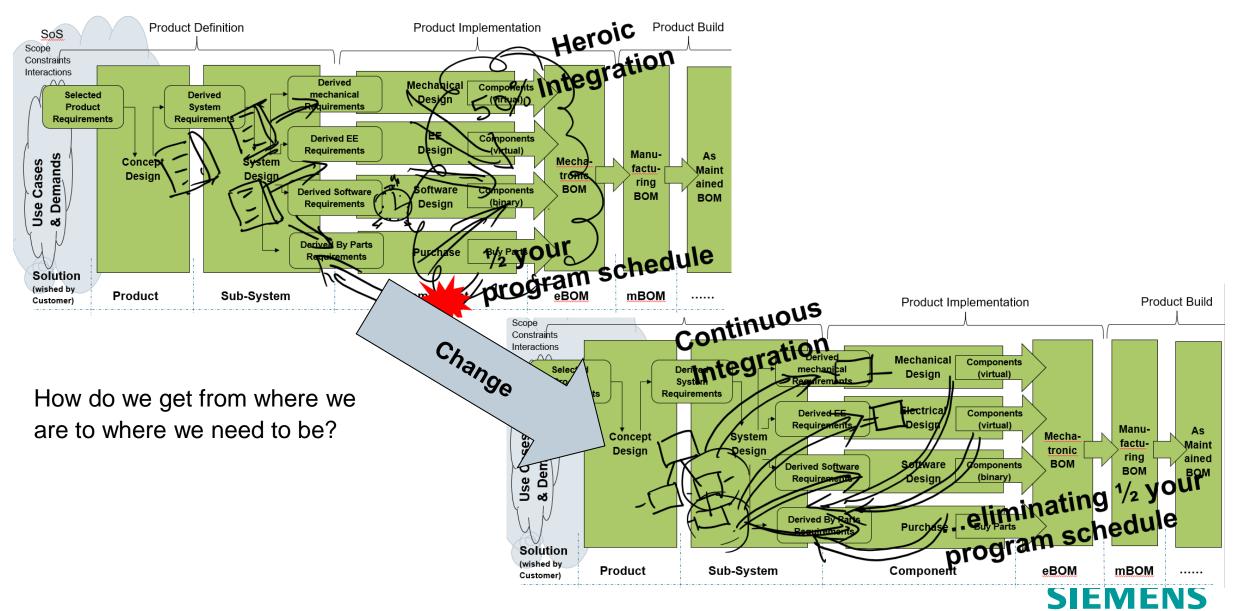


MBSE→MBDC Process...

How it can work with an integrated product architecture



This will require change...



Where are we?

MBSE Maturity

Solution	(1) Initial	(2) Managed	(3) Defined	(4) Qualitative	(5) Optimizing
Product engineering	Uncontrolled	Controlled Documents	Isolated models	Enterprise Integration	Continous Engineering
System Architecture Modeling Product architecture definition	PPT in docs	Disconnected Visio diagrams	Standalone SysML with simulations	Fine-grained integrated system architecture	Continuous integration via PLM-based architecture drives closed-loop MBDC
Planned Product Variability PLE/Configuration/Variation	None	Variation documents & spreadsheets	Disconnected variation rules	PLM Integrated variation rules	PLM variation definition drive architecture decisions
Reliability & System Safety Analysis Technical Risk (RAMS)	Risk documents & spreadsheets	Combined Risk Mgmt plans with manual RAMS artifacts (FMEA)	Disconnected RAMS tools output artifacts (FMECA)	RAMS analysis tools integrated with product architecture via PLM	Integrated RAMS, continous risk assessment, alarms, dashboards
Cross domain services					
System Definition & Design Integration Logical modeling & Interface mgmt	ICD & logical description documents	Managed interfaces & logical hierarchy	SE artifacts linked to Logical models & Std interface libraries	Integrated fine-grained logical arch with interfaces	Logical architecture carries across domains. Interfaces everywhere
Integrated services					
Feature Engineering Feature/Functional Modeling	Feature/Functional description docs	Functional hierarchy	Isolated functional behavior models	Integrated fine-grained functional modeling	Functional arch with allocations & traceability
Parameter/Target Mgmt Characteristic/Targets/TPM	Uncontrolled Excel/Docs	Controlled spreadsheets/Docs	Project-based Parameter/Target libraries	Enterprise PLM parameter/target mgmt & reuse	Integrated parameters, targets, drive continuous compliance monitoring
Change management	Document-based change process	Isolated models included in change	Change impact analysis & suspicion mgmt	Complete PLM configuration with models, parameters, history,	Cross-project level reuse, starting point for next project
Content Management					
Requirements Analysis Requirements engineering & mgmt	Uncontrolled spreadsheets & docs	Managed requirements docs	Disconnected RM tools with exchange	Integrated requirements & traceability inside PLM	Continouous compliance thru connected, configured, cross- domain traceability & reuse
Behavior Model Management System, performance, et al simulation	Uncontrolled models on desktops	Version controlled models	SE artifacts linked into models	Integrated model & product configuration with simulation	Continuous, focused simulation & multi-domain optimization, dash boards
Verification Management & Governance Product Test/V&V	Document-based test procedures	Managed test cases	SE artifacts linked to test	Devops-like V&V HIL/SIL simulation	Continuous, focused testing, reuse results, model swap out
Physcial Design Management CAD, CAE, control/mgmt	Unmanaged CAx models	PDM controlled CAx	SE artifacts linked into CAD	Cross-domain fine-grained PLM integration	Continuous physical design verification (Digital Twin)

Where are we?

Avg MBSE Maturity

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Where are we?

Everyone in the same boat

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Content Management	bu are here			Best Au (best ca	
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Behavior Model Management System, performance, et al simulation	Uncontrolled models on desktops	Version controlled models	SE artifacts linked into moders	configuration with simulation	Continuous, focused simulation & multi-domain
Verification Management & Governance Product Test/V&V	Document-based test procedures	Managed test cases	SE artifacts linked to test	Devops-like V8 simulation	focused testing
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Is SE education helping our design sanity problem?

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Requirements Analysis Requirements engineering (best case)	sity spreadsheets	Managed requirements docs	Disconnected RM tools with exchange	Integrated requirements & traceability inside PLM	Continouous compliance thru connected, configured, cross-domain traceability
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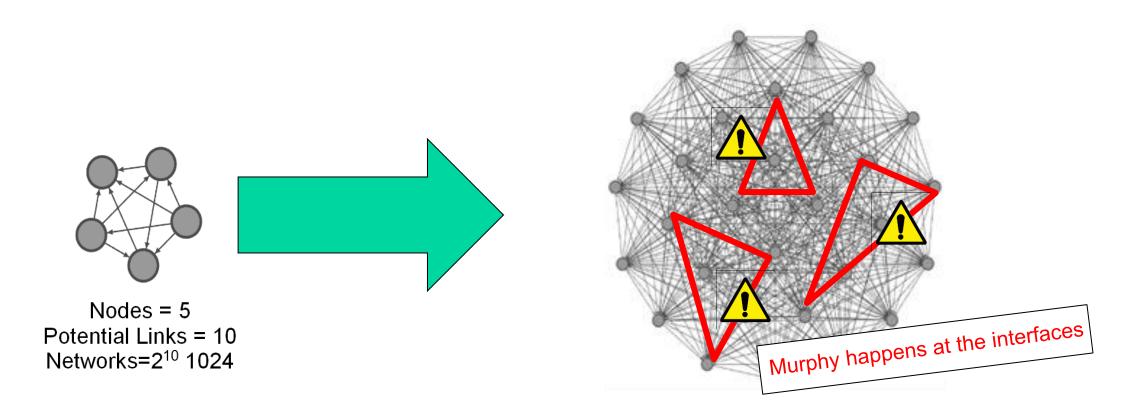
Barriers to implementation...

Silos locked-in by tools creating automated chaos

2ⁿ problem...

Solution	(1) Initial	(2) Managed	(3) Defined	(4) Qualitative	(5) Optimizing
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Cross domain services			<i>i</i> i		
System Definition & Design Integration Logical modeling & Interface mgmt	ICD & log cal descri Word	Managed interfaces & logical merarchy	SE artifacts linked to Logical models & Std interface libyaries	Integrated fine-grained logical arch with interfaces	Logical architecture carries across domains. Interfaces everywhere
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Doing the math...



Nodes = 30, potential links = 435, unique configurations = 2^{435} Number of atoms in the universe est. between 2^{158} and 2^{246}

Barriers to implementation

Problem is information exchange not data exchange

PLM is about information; managing the digital thread

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Product architecture definition			simulations	system architecture	PLM-based architecture
			/ <u>1</u>		drives closed-loop MBDC
Planned Product Variability	None	Variation documents &	Discontrules	PLM Integrated variation	PLM variation definition
PLE/Configuration/Variation		spreadsheets	RAMS	rules	architecture decisi
Reliability & System Safety Analysis	Risk documents &	Combined Risk Mgmt plans		RAMS analysis tools	Integrate
Technical Risk (RAMS)	spreadsheets	with manual RAMS artifacts	output artnocts (InviECA)	integrated with product	risk a
		(PMEA)		architecture via PLM	R
Cross domain services	Word	1			
System Definition & Design Integration	ICD & logical WORK	Interfaces & logical	SE artifacts linked to Logical	Integrated fine-grains	
Logical modeling & Interface mgmt	documents	merarchy	models & Std interface	arch with interfar	
			libraries		
Integrated services		` Excel	1		
Feature Engineering	Feature/Functional	Europtional hierarchy	Isolated functional behavior	lp.	
Feature/Functional Modeling	description docs	N N	models		
Parameter/Target Mgmt	Uncontrolled Excel/Docs	Controlled	Project-based		
Characteristic/Targets/TPM		spreadsheets/Docs	Parameter/Target I'		
Change management	Document-based change	Isolate Excel		Λ	
	process	change EXOCI			
			T I		
Content Management		l i	i i		
Requirements Analysis	Uncontrolled spreadsheets &	Managed requirement			
Requirements engineering & mgmt	docs				
			RM Tools		
Behavior Model Management	Uncontrolled models on	Version			
System, performance, et al simulation	desktops		1		
		ų –	i de la companya de		
Verification Management & Governance	Document-based test	_			
Product Test/V&V	procedures		est DB		
Physcial Design Management	Unmanaged				
CAD, CAE, control/mgmt	Uninanager				
one, one, controlyingint					

Where do we start?

Target rich environment

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Content Management				Best Aut	to
Requirements Analysis Requirements engineering & mgmt	Uncontrolled spreadsheets & docs	Managed requirements docs	Disconnected RM tools with exchange	ntegrated requin (best car ceability inside PLM	SE) ompliance thru connected, configured, cross- domain traceability & reuse
Behavior Model Management System, performance, et al simulation	Uncontrolled models on desktops	Version controlled models	SE artifacts linked into mobils	Integrated model & product configuration with simulation	, dash boards
Verification Management & Governance Product Test/V&V	Document-based test procedures	Managed test dayes	Shartifacts linked to test	Devops-like V8 simulation	focused testing
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Integrated Systems Engineering Stair-steps to the right

Level 1: documents to managed objects

Req. Driven...

- Controlled
 requirements
- Requirement driven
 Agile development

Level 2: requirements & architecture

Arch. Driven...

- Chunk-of-project reuse
- Global change impact understanding now
- Continuous crossdomain communication
- Integrated requirements

Level 3: Teamcenter managed architecture

Global Reuse...

- Arch. & Req. reuse
- Supplier engagement
- Integrated program execution with continuous V&V
- PLM services (config,, change, variation...)

Level 4: Integrated MBSE

Digital Twin...

- Cross-domain digital threads
- Continuous Integration
- Integrated domain tools
- Focused scaled V&V

Moving from disconnected to Integrated product development

Level of collaboration & Integration

"It is not necessary to change, survival is not mandatory"

- W. Edwards Deming, Data Scientist

Thank You

Mark Sampson

Systems Engineering Evangelist INCOSE MBSE Initiative Chair

