33rd Annual INCOSE international symposium

hybrid event

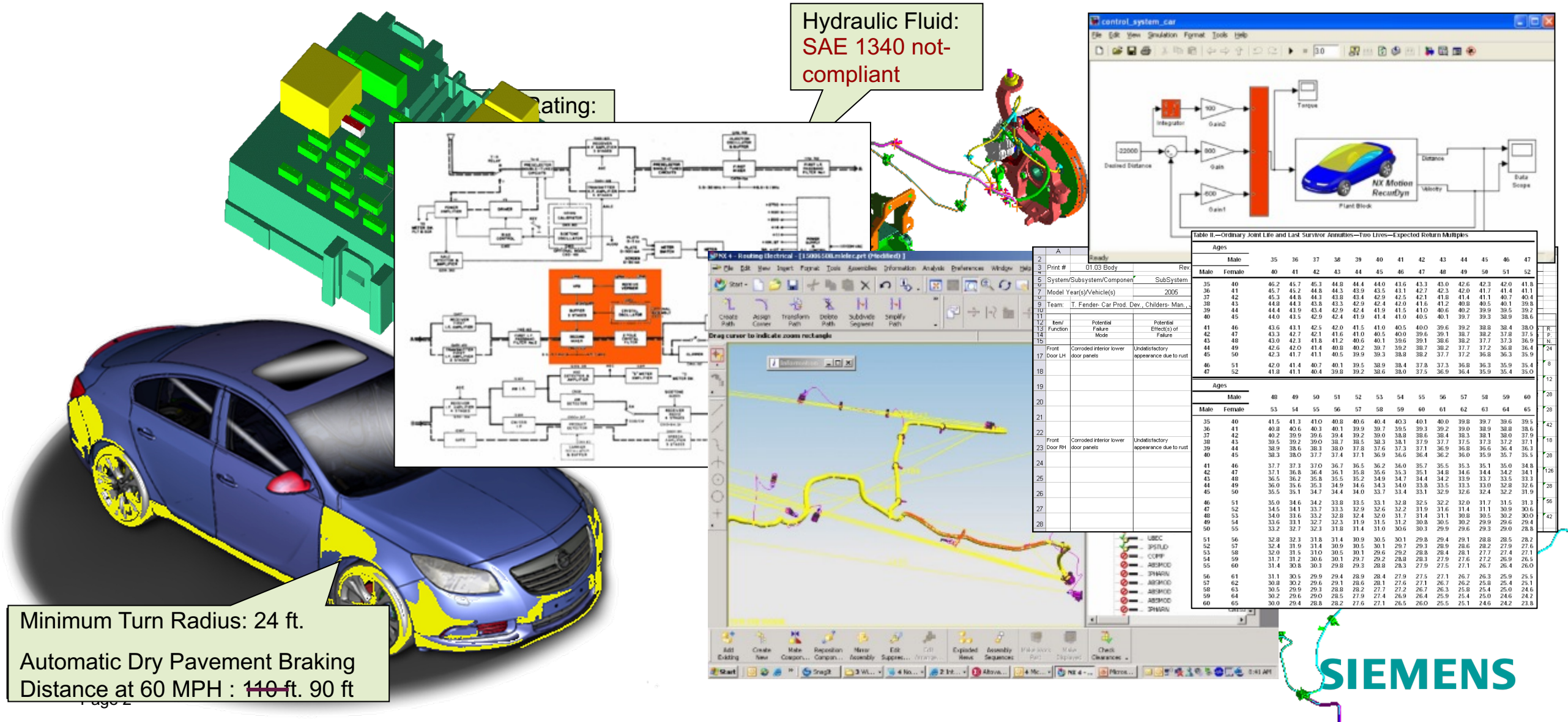
Honolulu, HI, USA
July 15 - 20, 2023

Where are you on your MBSE journey?

SE your MBSE implementation

INCOSE Integrated MBSE Vision

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



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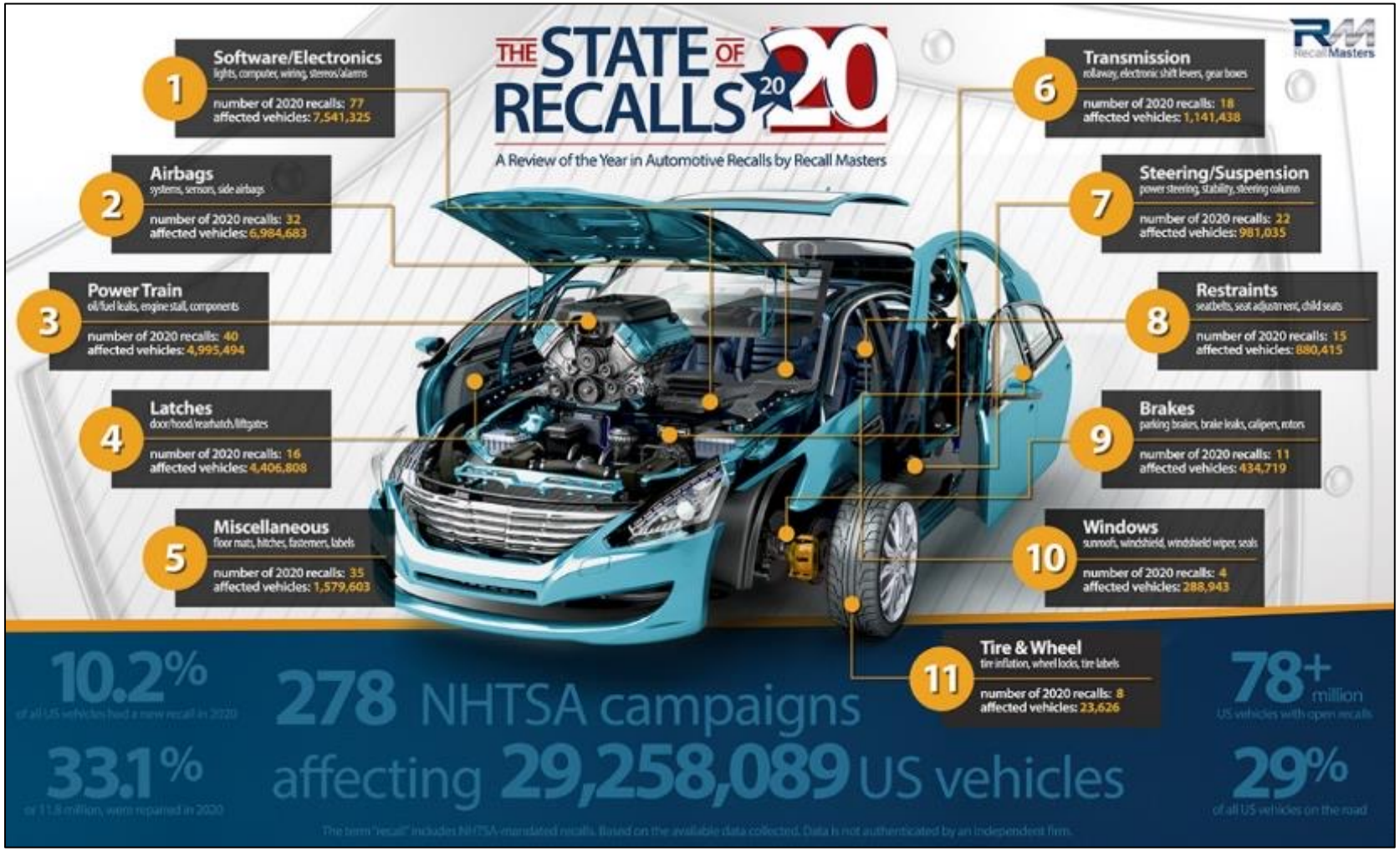
Growing complexity in automotive…

- ~29 million automotive recalls in the US last year
- Per AlixPartners*, each recall costs ~$500/vehicle, that's $145 billion in direct costs fixing the problems in 2020
- Auto Manufacturers carrying ~$113B in warranty reserves** (2.5% of revenue) on their books

…mostly due to cross organization/interdisciplinary communication issues



* http://lite.cnn.com/en/article/h_a9a78e0bc97dc033569b8b2fefe63d47

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

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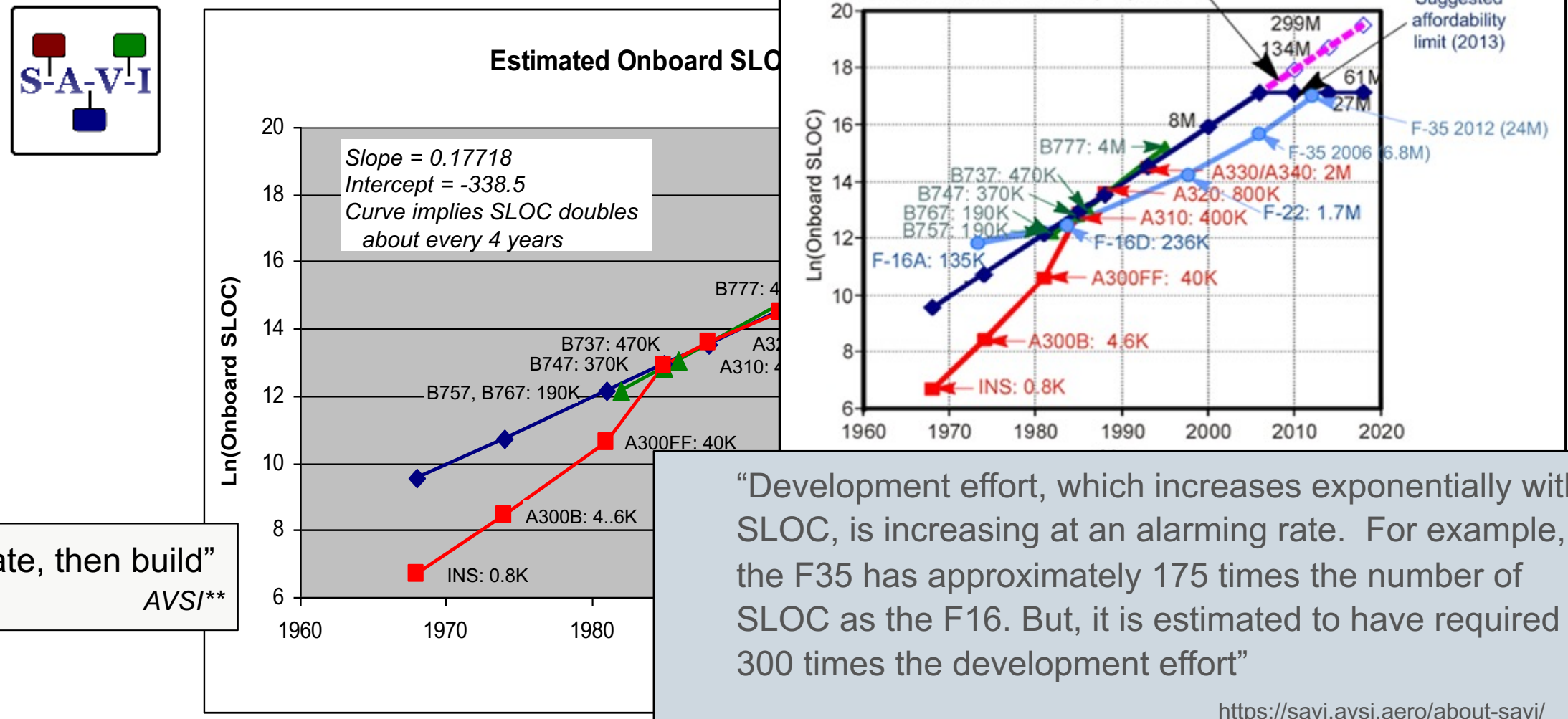
Unprecedented Product Complexity: becoming unaffordable…
Norm was right (Augustine's Law #16)*



"Integrate, then build"
*AVSI***

"Development effort, which increases exponentially with SLOC, is increasing at an alarming rate. For example, the F35 has approximately 175 times the number of SLOC as the F16. But, it is estimated to have required 300 times the development effort"

https://savi.avsi.aero/about-savi/

*https://en.wikipedia.org/wiki/Augustine's_laws
**avsi.aero

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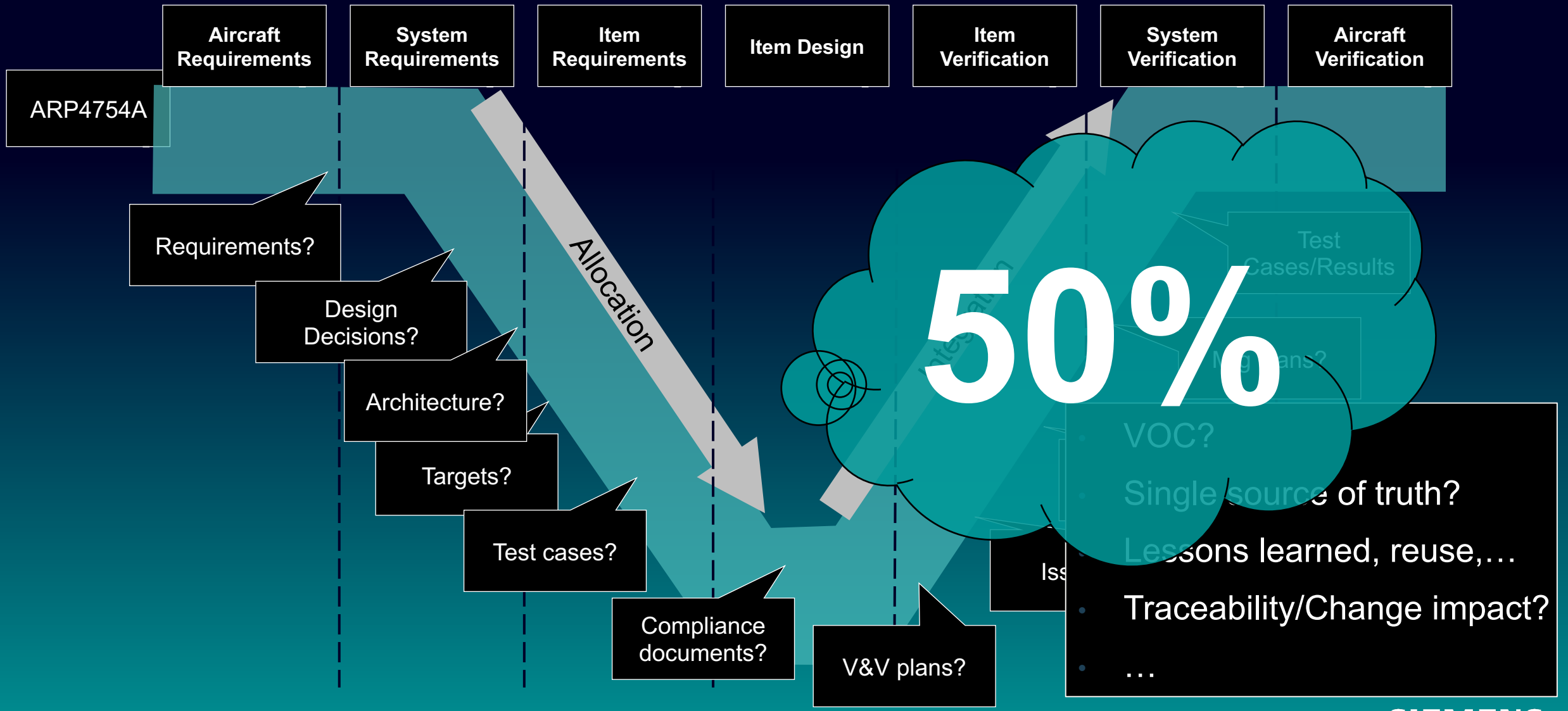
The result of a siloed product development process…
Mel Conway was right *



*https://www.melconway.com/

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Insane Design Behavior
Solving the same problems over & over

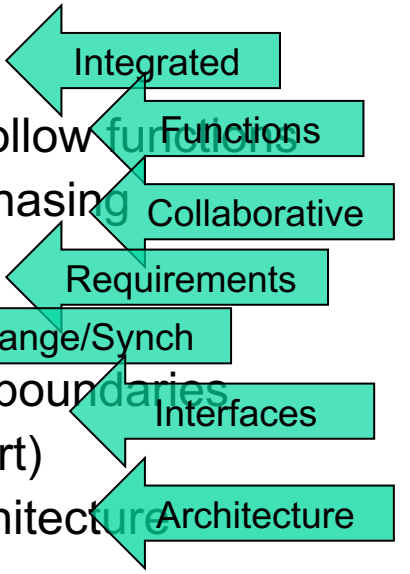
Problem resurface metric: how long does a problem once solved take to come back

- Auto: ~3 years
- High Tech ~6 mo.
- Aero ~15 years

“Water on the knee”

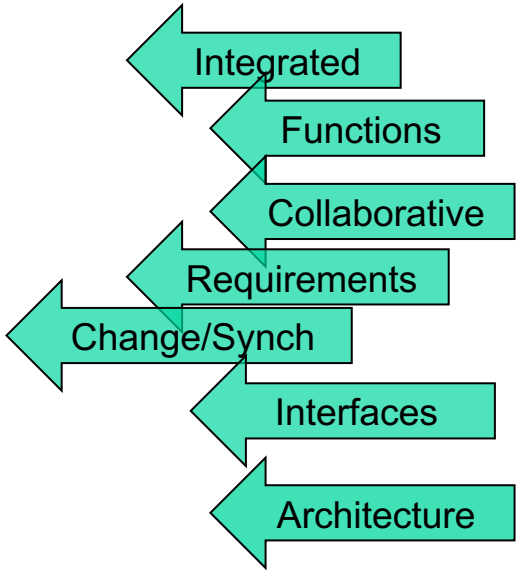
Cross-Domain problems result from:

- Siloed/Disconnected Decisions
- Form follows function, Problems follow functions
- Everyone involved, including purchasing
- Disconnected requirements
- Uncommunicated change
- Happen at domain/organizational boundaries
- Migrate with people (overt or covert)
- Missing/disconnected product architecture



How insane are we?

MBSE Maturity



Capability Assessment:	Basic	Low	Medium	High	Advanced
	Disconnected Communication with documents		Integration Continuum		Continuous Communication with models
System Modeling/Architec		Visi models	Simulations	exchange/optimize	
PLE/Configuration (variation)	None	Variation documents, spreadsheets	Disconnected variation rules	Integrated variation rules	PL variation definition built into into architecture decisions
Technical Risk (RAMS, cost,…)	None	Risk documents, spreadsheets	Integrated Risk Management Plans with aspects of RAMS (FMEA)	Standalone RAMS with FMECA Dash boards	Integrated RAMS, continuous risk assessment/alarms with dashboards
Interface Management	ICD in docs	Managed interfaces	Standard-based Interface library	Reused interfaces	Functions/logical allocation drives interface definitions
Logical Modeling	Logical description documents	Logical hierarchy	Isolated logical behavior models	Integrated logical behavior modeles	Logical architecture with allocation with traceability
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Characteristic/Target Mgmt	None	Uncontrolled Excel/Docs	Controlled targets	Distributed targets/constraints	Integrated targets, budgets, with compliance reports
Change Management	Document-based change process	Isolated models included in change	Impact analysis & suspicion mgmt	Metrics with History for improvement	Project level reuse, starting point for next project
Requirement Management	Uncontrolled spreadsheets & docs	Managed Docs	Standalone solutions (disconnected)	RM/traceability exchange	Connected, configured, cross-domain traceability with reuse
Model Management	Uncontrolled, rules-of-thumb, hieristics	Uncontrolled, behaivor models	Shared model repository	Integrated, component library	Model reuse with controlled parameters
Verification & Validation	Document-based test procedures	Manageed test cases	Standard test libraries	Validation simulation & HIL/SIL	Focused testing, reuse results, swap out models
Design Management	unmanaged Cax/SW models	Locally Mananged CAX/SW	Enterprise repositories	Integrated models (MIL, SIL,…)	Cross-domain design/optimization
CMMI Staged Levels:	(1) Initial	(2) Managed	(3) Defined	(4) Qualitative	(5) Optimizing

How insane are we?

Avg MBSE Maturity

Capability Assessment:	Basic	Low	Medium	High	Advanced
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Avg Organization (best case)

Where are we?

Everyone dealing with design sanity problem

Capability Assessment:	Basic	Low	Medium	High	Advanced
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You are here

Best Auto (best case)

Best Aero (best case)

Is SE education helping our design sanity problem?

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Verification & Validation	Minimum to no planning	Manually testing everything	Isolated validation simulations	Integrated simulation (HIL, SIL)	Focused testing, reuse results, swap out models
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Avg University (best case)

Avg Organization (best case)

The value of continuous integration

The impact of managing system interfaces and interactions across product development

…we have modeled the logical interfaces of virtually the entire airplane and created a database that software design tools can assimilate with minimal human intervention.

Mike Sinnett 787 Chief Systems Engineer

Avionics
- Common Core System (CCS)
- Navigation - FMS
- Navigation – TMS
- Navigation – ADRS
- Navigation – ERS
- Navigation – IRS
- Navigation – CM App
- Displays and Crew Alerting
- Integrated Surveillance
- Communications – SATCOM
- Communication - Recorders
- e-Enabling (Crew Information
- Maintenance Systems

Cabin Systems
- Broadband Offboard Satellite
- Cabin Services Systems
- Emergency Lighting System
- Inflight Entertainment Syster
- Telephone System
- Video Surveillance System

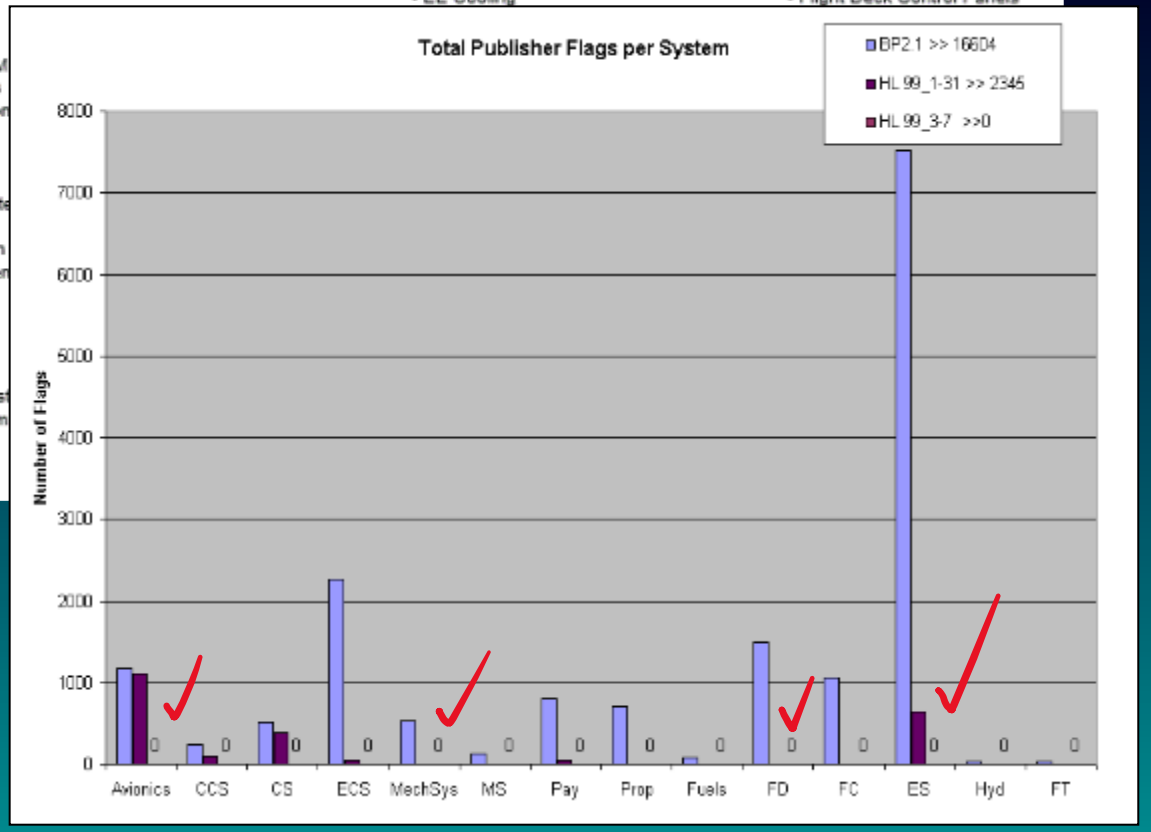
Fuels
- Fuel Quantity Indicating Syst
- Nitrogen Generating System

Flight Controls
- Flight Controls Electronics
- High Lift
- Primary Flight Controls
- Autoflight
- Integrated Standby Flight
- Displays

Environmental Control Systems
- Equipment Cooling
- Moisture Control
- Humidification
- CACTCS
- Cabin Pressure Control System
- Cargo Air Conditioning, Ventilation
- EE Cooling

Mechanical
- Wheels and Brakes
- Brake Control and Monitor
- Landing Gear Actuation
- Nose Wheel Steering

Flight Deck
- Flight Deck Control Panels



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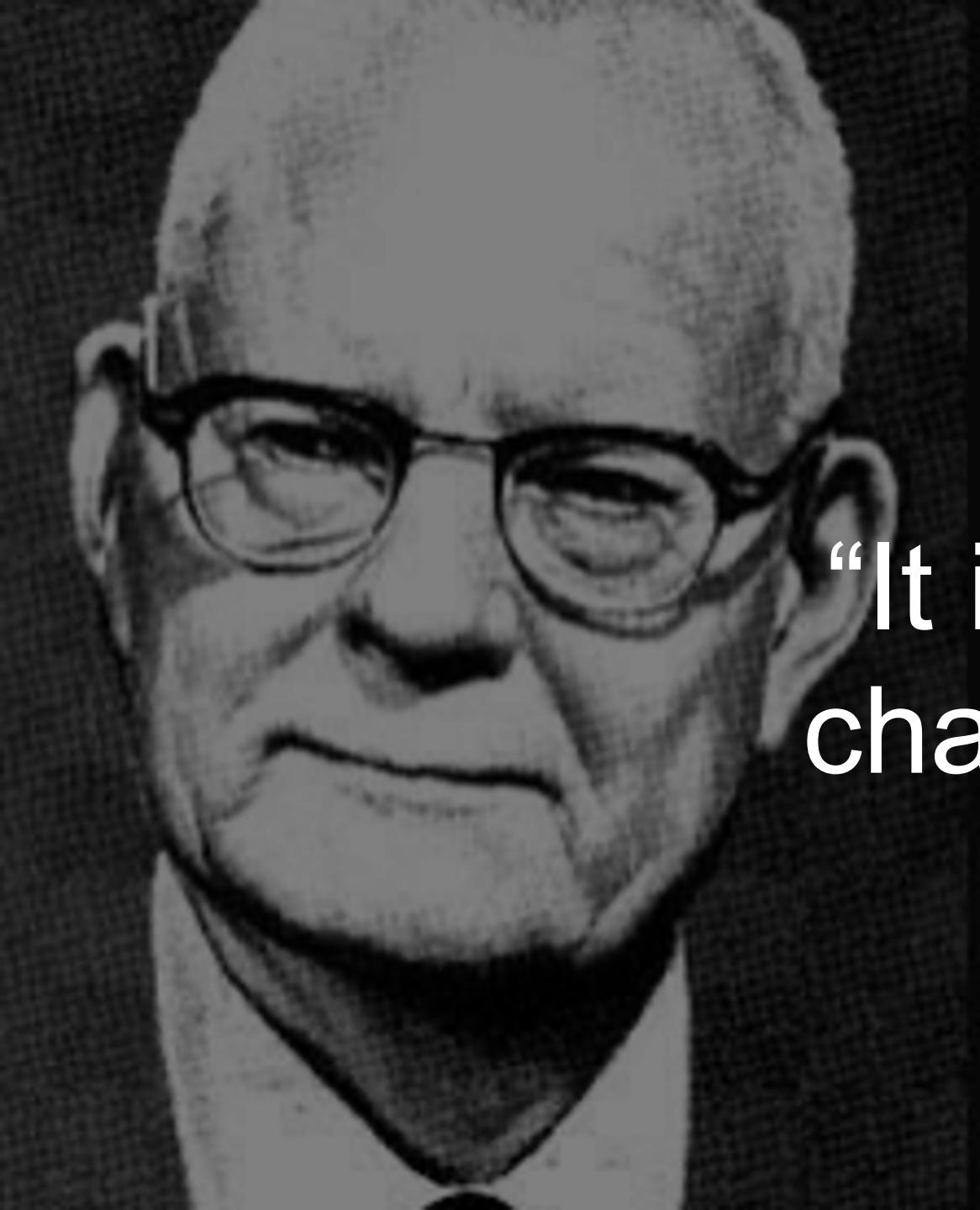

“It is not necessary to change, survival is not mandatory”

- W. Edwards Deming,
Data Scientist

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Legacy systems roadblocks…

Barriers to implementation…

Silos locked-in by tools creating automated chaos

NxN problem…

Capability Assessment:	Basic	Low	Medium	High	Advanced
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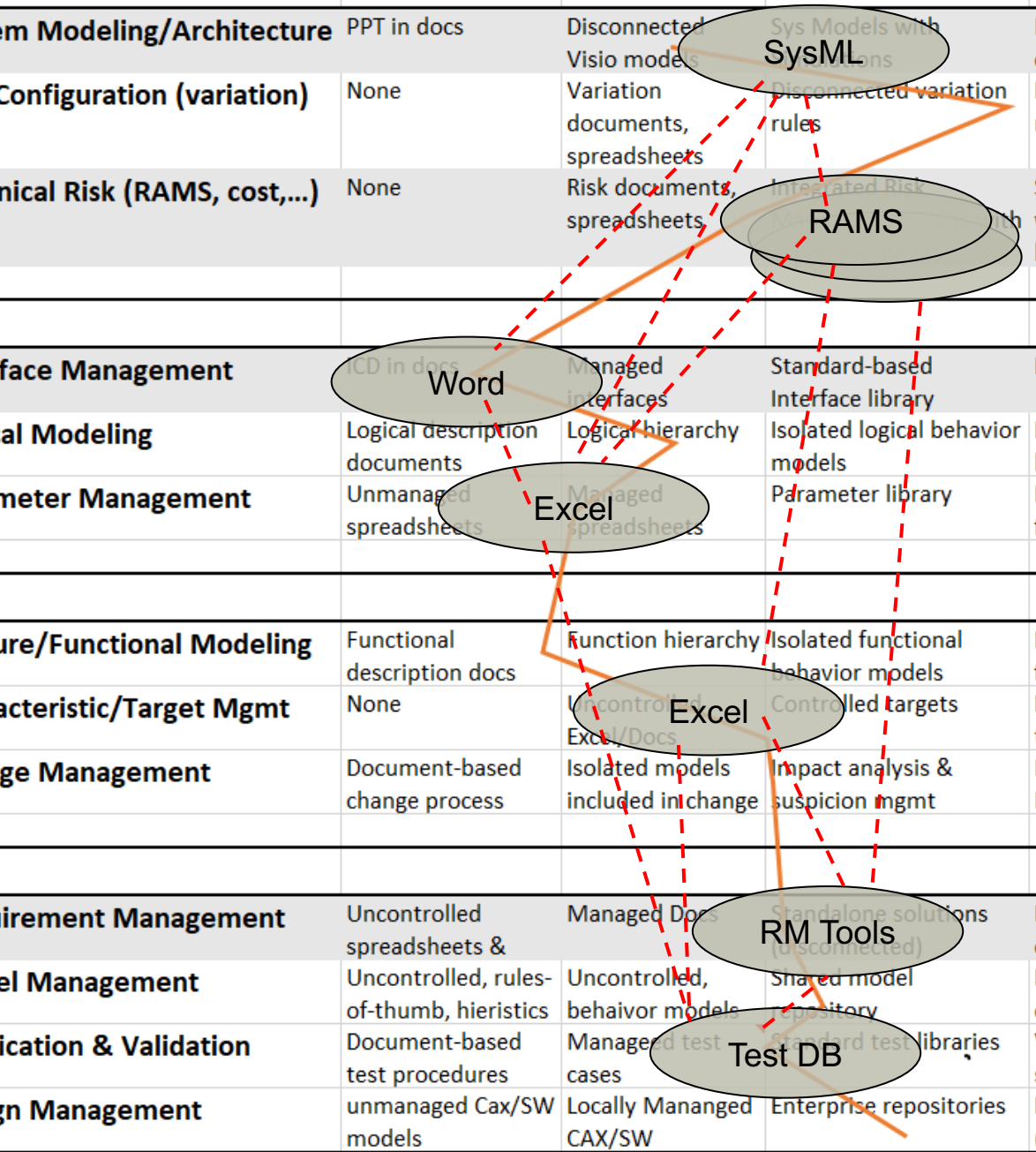
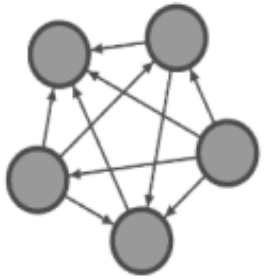
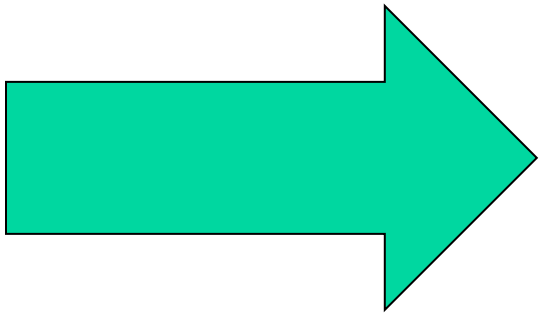
CMMI Staged Levels:	**(1) Initial**	**(2) Managed**	**(3) Defined**	**(4) Qualitative**	**(5) Optimizing**

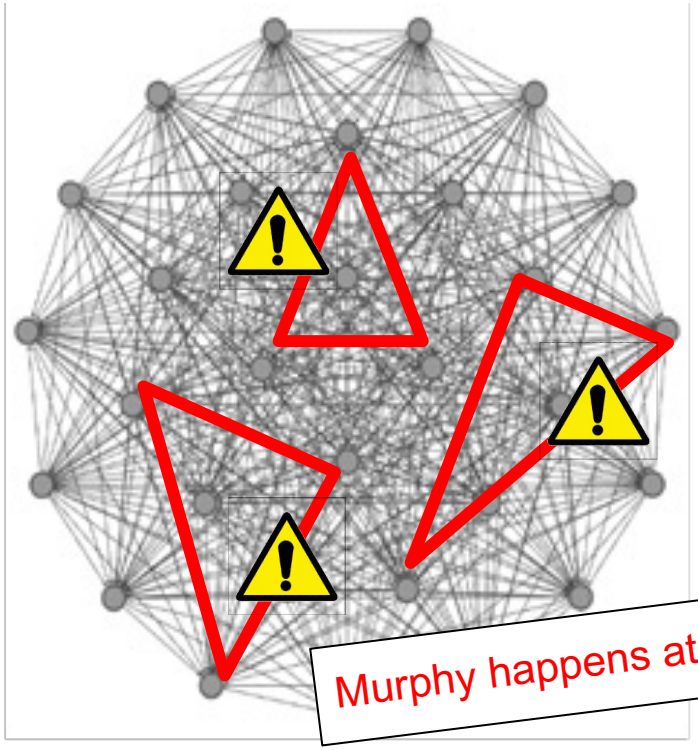


Doing the math…



Nodes = 5
Potential Links = 10
Networks=2^{10} 1024





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 data management; SysLM is about managing the digital thread

Capability Assessment:	Basic	Low	Medium	High	Advanced
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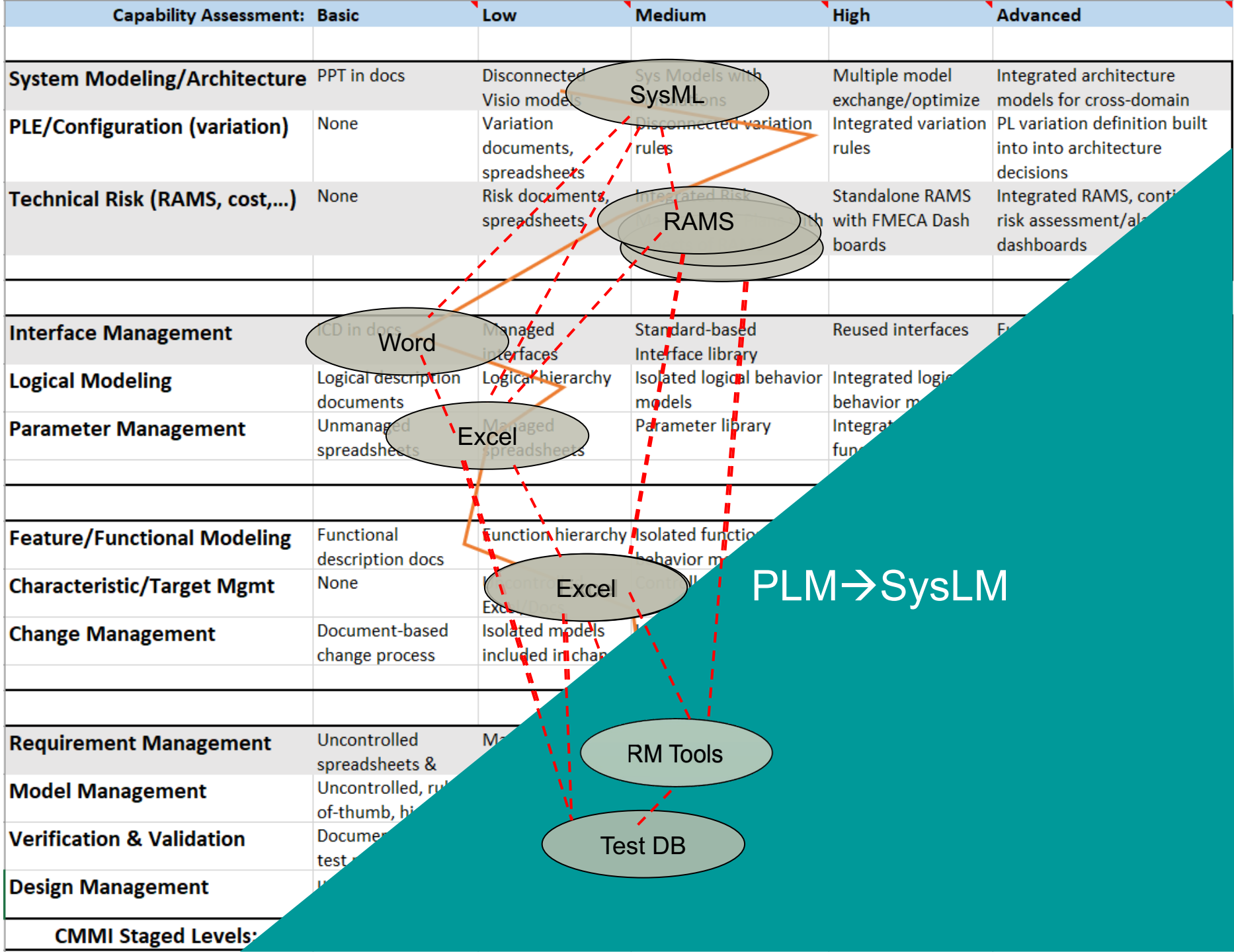
Characteristic/Target Mgmt	None	Excel/Docs			
Change Management	Document-based change process	Isolated models included in chan			
Requirement Management	Uncontrolled spreadsheets &	M			
Model Management	Uncontrolled, ru of-thumb, hi				
Verification & Validation	Docume test				
Design Management					
CMMI Staged Levels:					



"We're pretty good at chip design, 90% of them work as designed, 50% of them fail when we plug them in."

-IEEE

Where do we start?

Some realizations…

- Implementing MBSE on a complex product in a complex organization operating in a complex world = systems engineering problem[3]
- This is not an individual tool problem (MCAD works, ECAD works, Mfg works,…systems fail when you bring them together) that consumes half of program schedules today
- It's not at a tool problem, it's an integrated MBSE journey—Start Integrated, Stay Integrated

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Where do we start our MBSE Journey?

Target rich environment

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 & suspision 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 requi... traceability inside PLM	...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 models	Integrated model & product configuration with simulation	Continuous, focused simulation & multi-domain ..., dash boards
Verification Management & Governance *Product Test/V&V*	Document-based test procedures	Managed test cases	SE artifacts linked to test	Devops-like V&... simulation	...focused testing, ...s, 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)

You are here

Best Auto (best case)

Best Aero (best case)

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www.incose.org/symp2023