34th Annual INCOSE international symposium

hybrid event

Dublin, Ireland
July 2 - 6, 2024

Where are you on your MBSE journey?

SE your MBSE implementation in your organization

Mark Sampson
INCOSE MBSE Initiative Chair

“Fireflies”

Like Christmas lights gently floating in midair, fireflies always add a little bit of magic to the forests they live in.

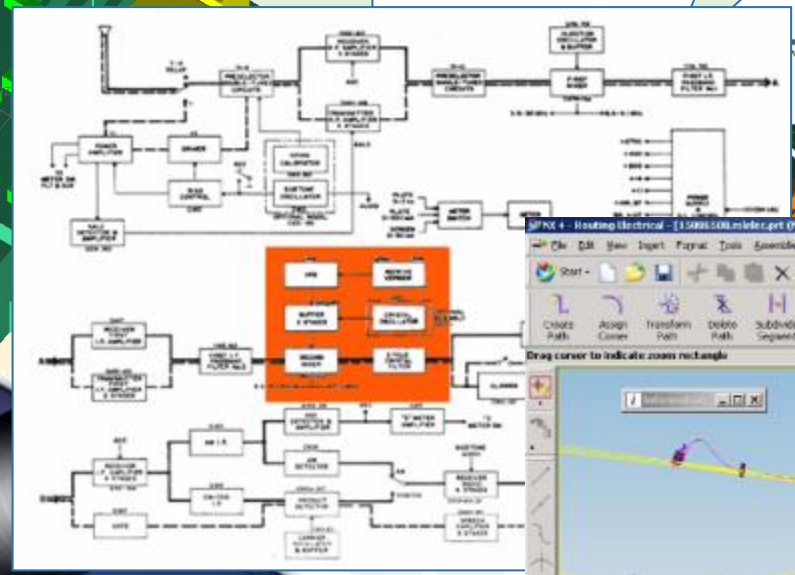
CLICK & DRAG

to create some firefly chaos →

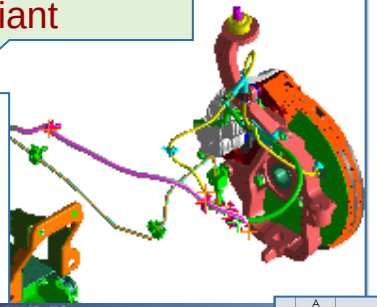
But some firefly species add even *more* magic. In Southeast Asia, if you go out to the riverbank deep in the night, you'll be treated to this stunning lightshow – courtesy of the Thailand firefly:

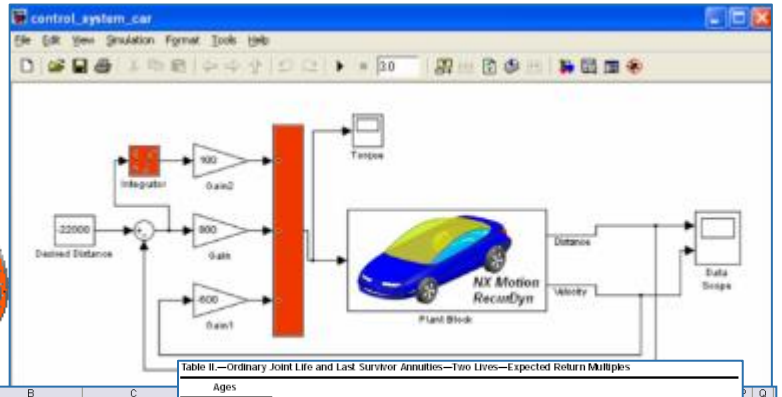
INCOSE Integrated MBSE Vision…
What does MBSE Integration look like

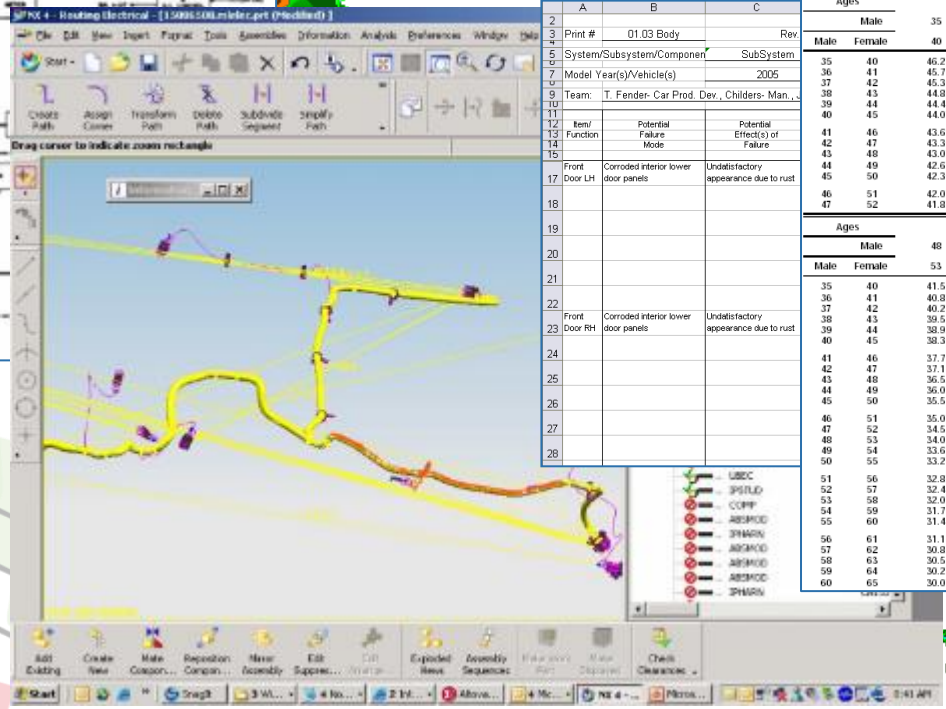
ating:



Hydraulic Fluid:
SAE 1340 not-compliant







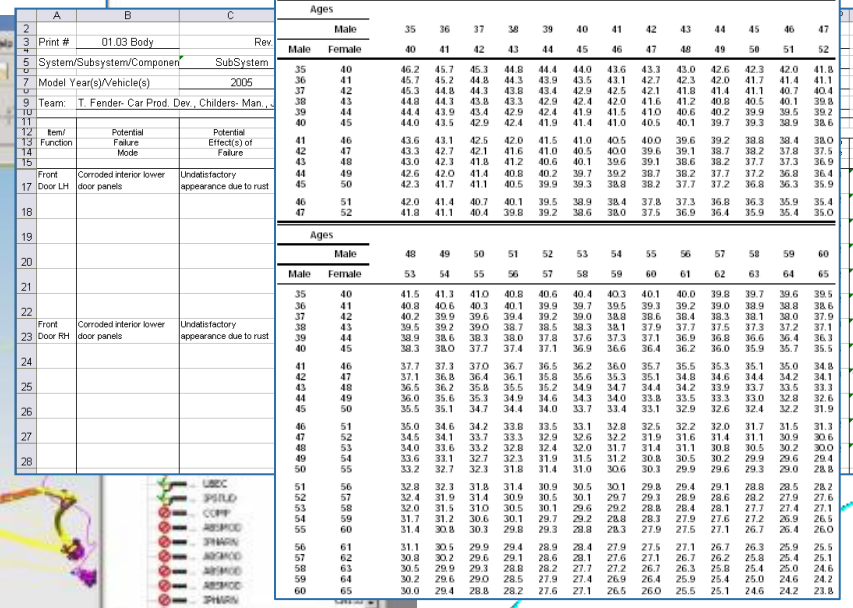
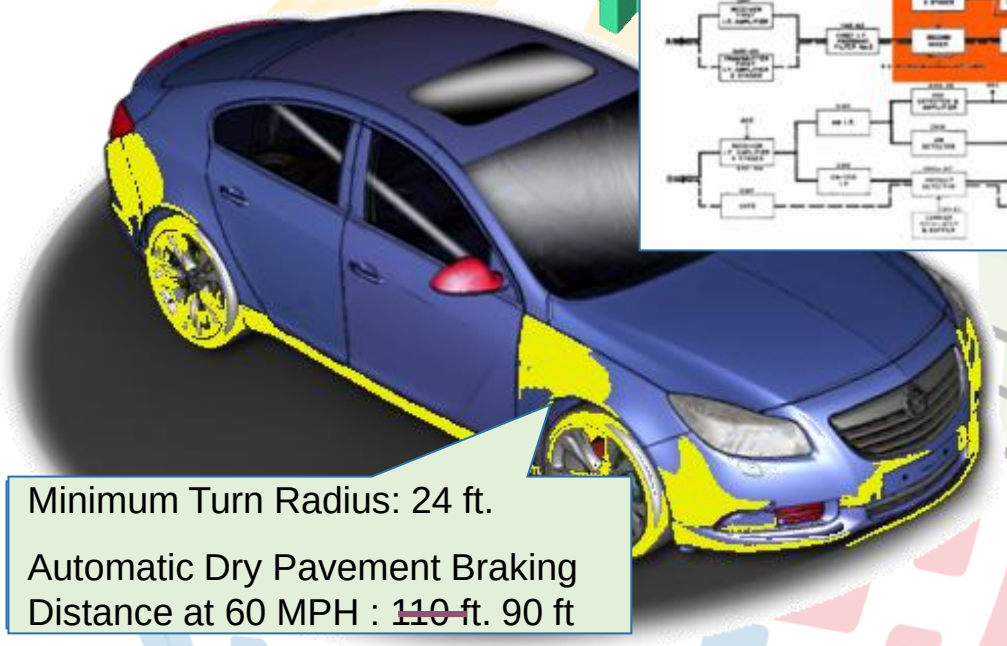


Table II.—Ordinary Joint Life and Last Survivor Annuities—Two Lives—Expected Return Multiples



Minimum Turn Radius: 24 ft.

Automatic Dry Pavement Braking Distance at 60 MPH : ~~110~~ ft. 90 ft

Growing complexity in automotive…

- ~35 million automotive recalls in the US last year
- Per AlixPartners*, each recall costs ~$500/vehicle, that's $13.5 billion in direct costs fixing the problems in 2023
- Auto Manufacturers carrying ~$113B in warranty reserves** (2.5% of revenue) on their books

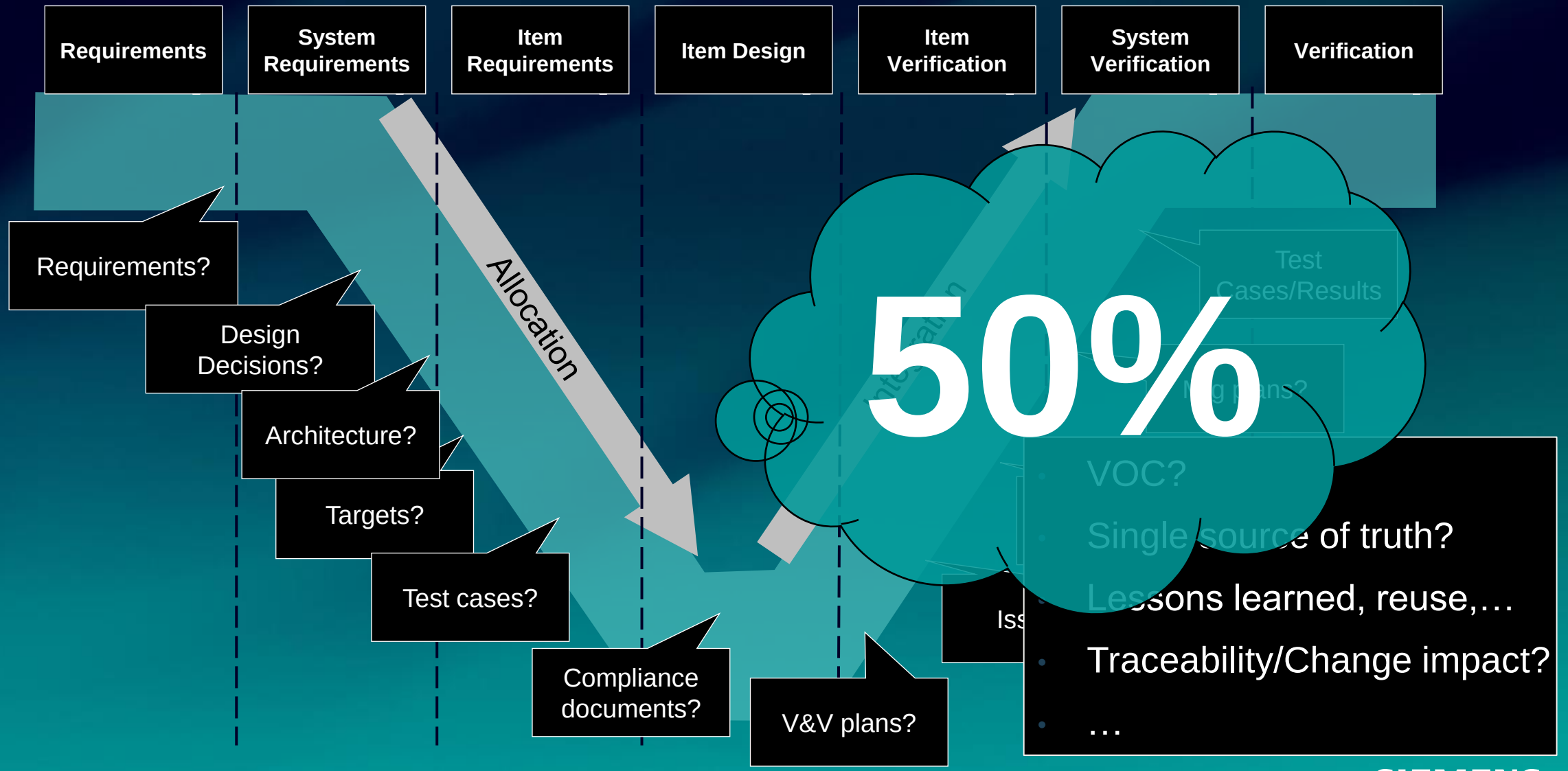
…mostly due to cross organization/interdisciplinary communication issues

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

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

SIEMENS

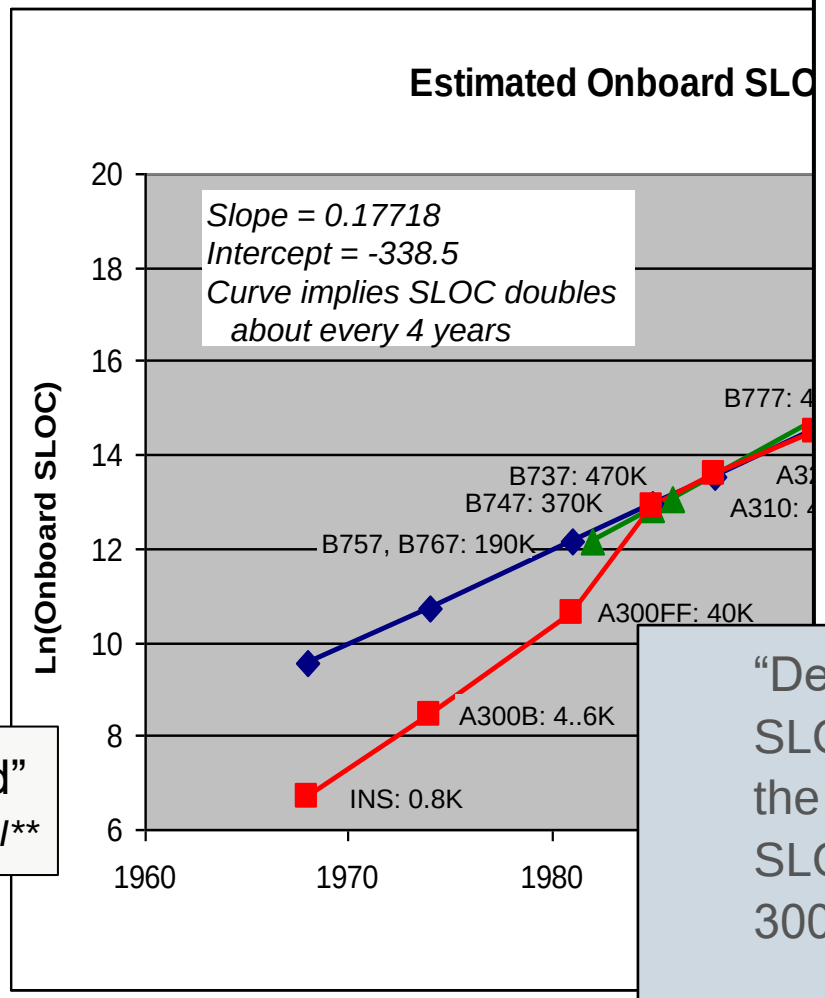
The result of a siloed product development process…
Mel Conway was right *

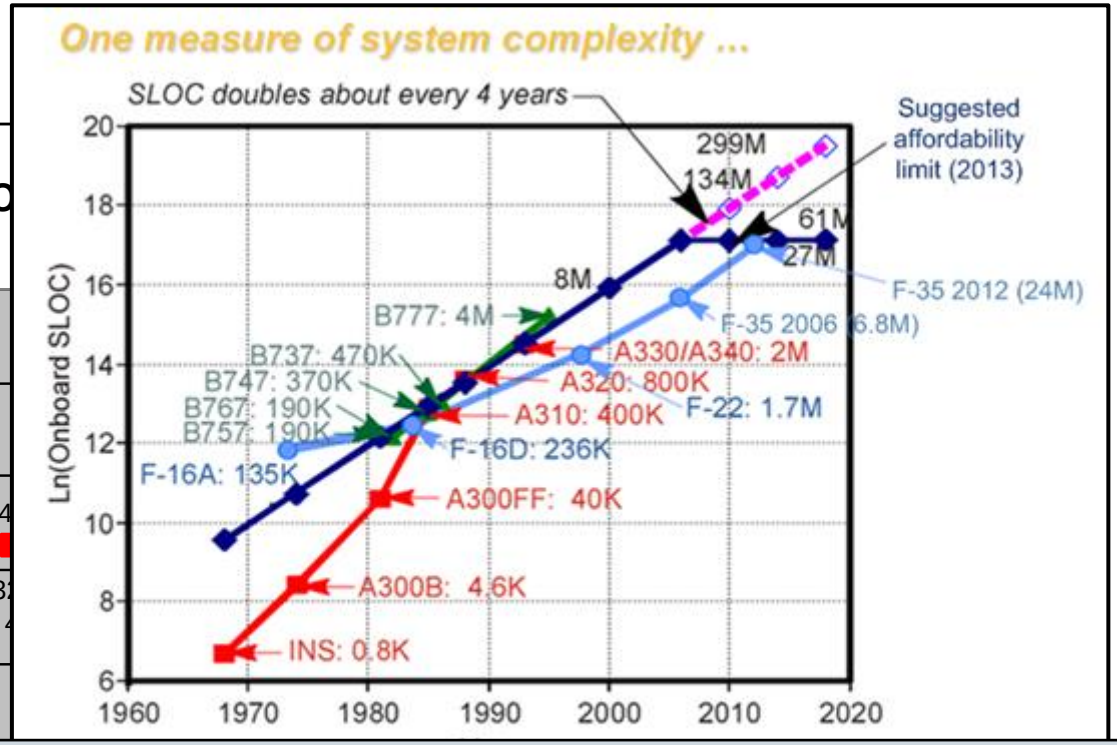


*https://www.melconway.com/

SIEMENS

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

SIEMENS

Result of late cycle integration discoveries…
Mitsubishi SpaceJet Program canceled

- After years of delays, Mitsubishi Heavy Industries admits building Japan's first homegrown passenger jet was too difficult and probably not viable (Feb. 8, 2023)

- $7.6B is written off on failed program

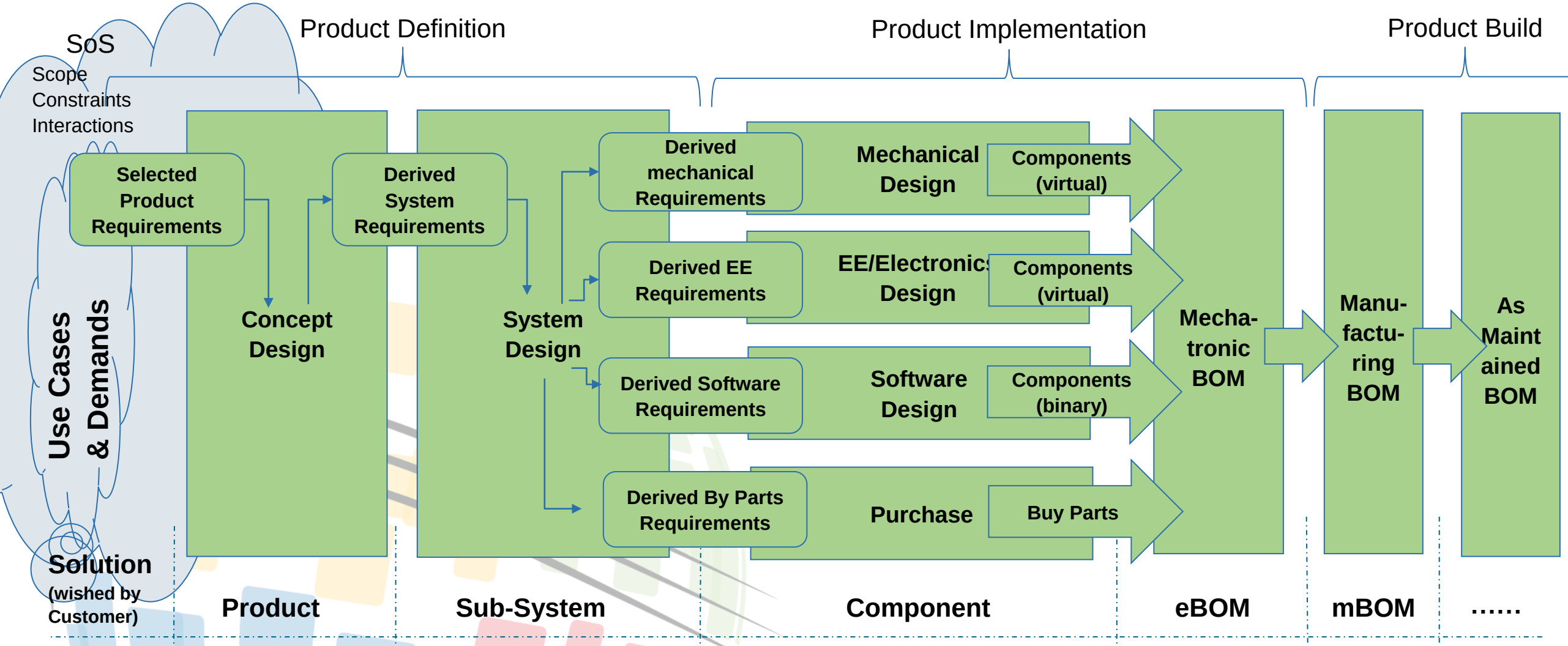
"Some test flights were aborted because of air conditioning defects and other software problems, and the delays meant revisions to the original design were required"

The Guardian

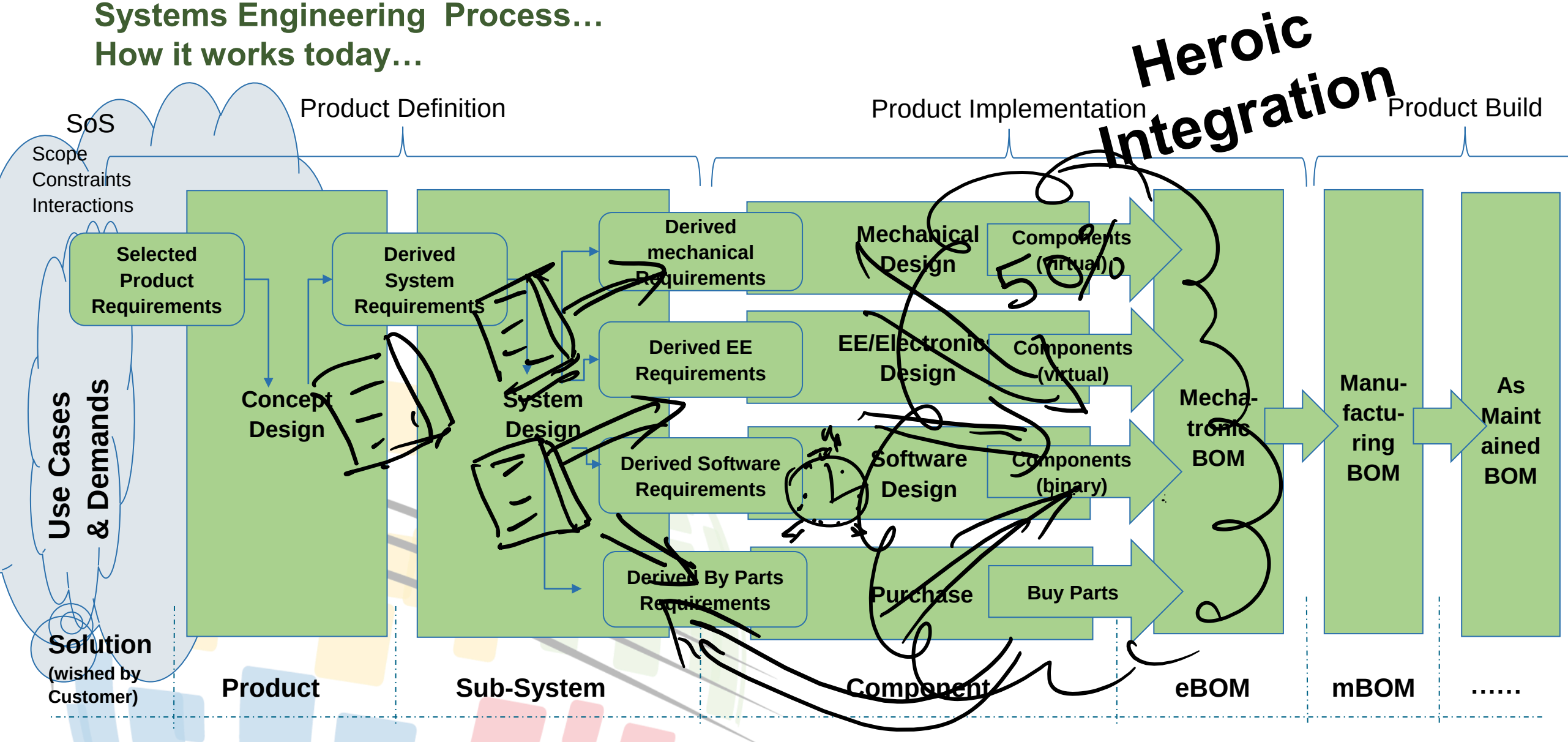
A Mitsubishi SpaceJet takes off during a test flight from Nagoya, central Japan,in March 2020. Photograph: 164811+0900/AP

https://www.theguardian.com/world/2023/feb/08/japan-cancels-mitsubishi-spacejet-grounding-dream-of-homegrown-airliner

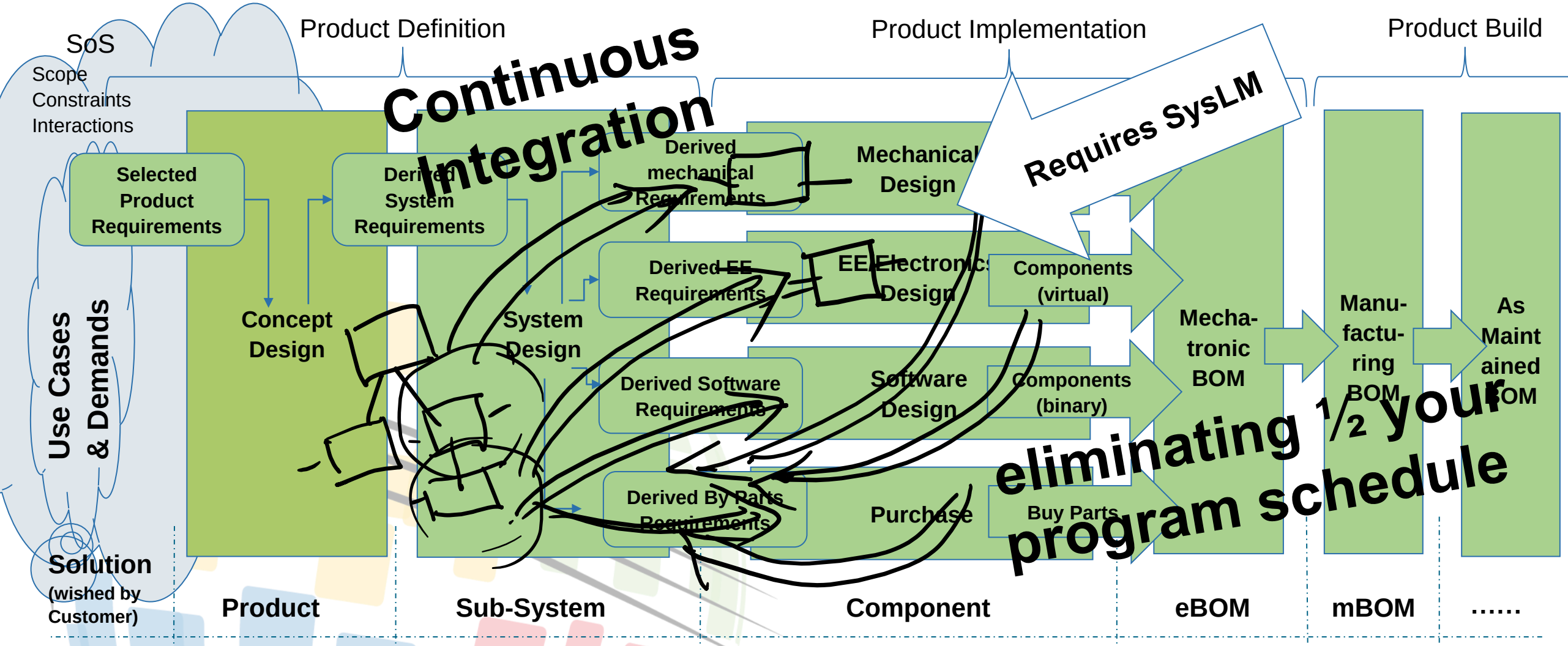
Systems Engineering Process…
Shift left…



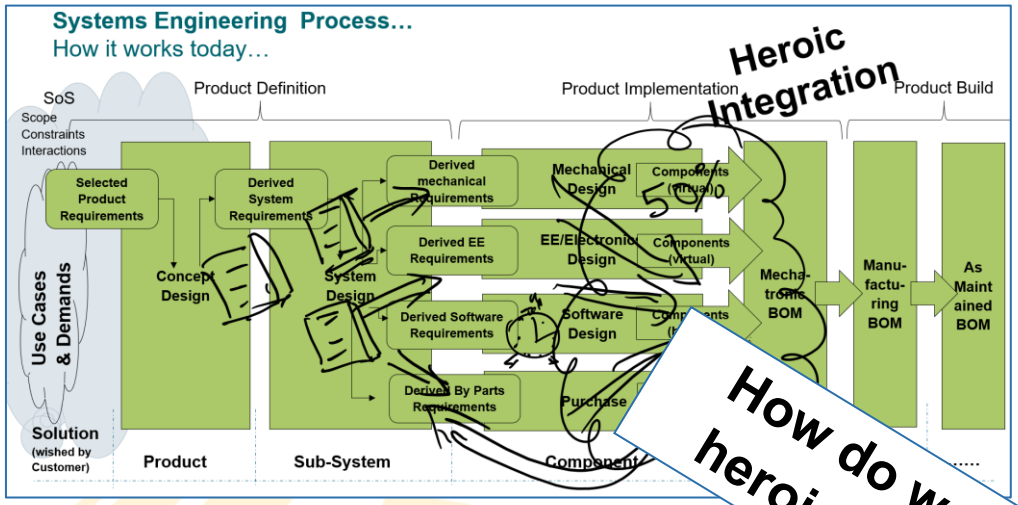
Systems Engineering Process…
How it works today…



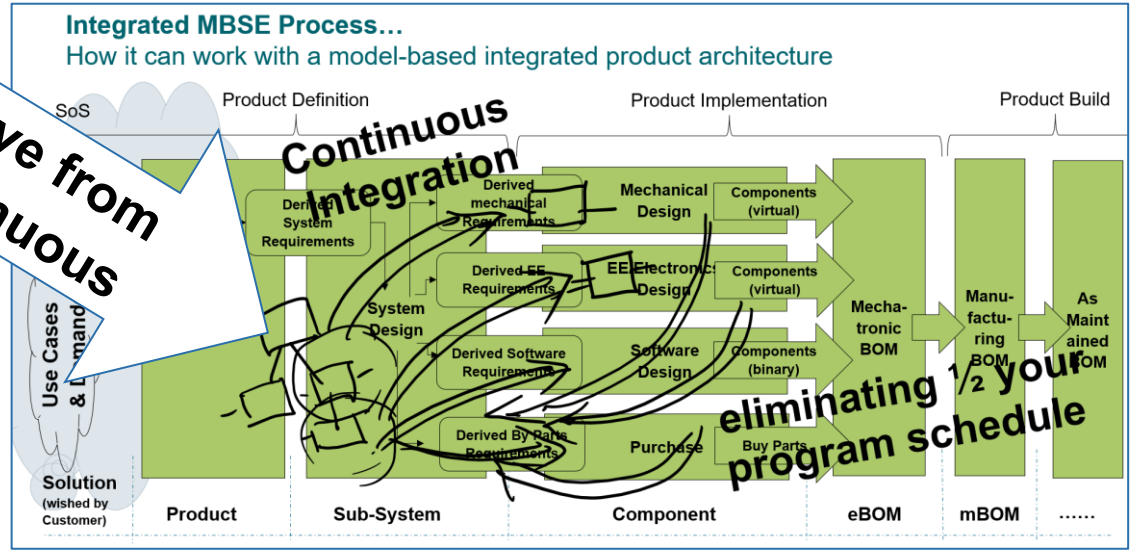
Integrated MBSE Process…
How it can work with a model-based integrated product architecture



MBSE Organization Change…



How do we move from heroics to continuous



eliminating ½ your program schedule

The journey begins with knowing where you are…

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
Parameter Management	Unmanaged spreadsheets	Managed spreadsheets	Parameter library	Integrated with functions	Reusable parameter library with traceability
Feature/Functional Modeling	Functional description docs	Function hierarchy	Isolated functional behavior models	Integrated functional modeling	Functional arch with allocations & Traceability
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

You are here…

Capability Assessment:	Basic	Low	Medium	High	Advanced
	Disintegrated----------Integrated				
System Modeling/Architecture	PPT in docs	Disconnected Visio models	Sys Models with Simulations	Multiple model exchange/optimize	Integrated architecture models for cross-domain sim/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
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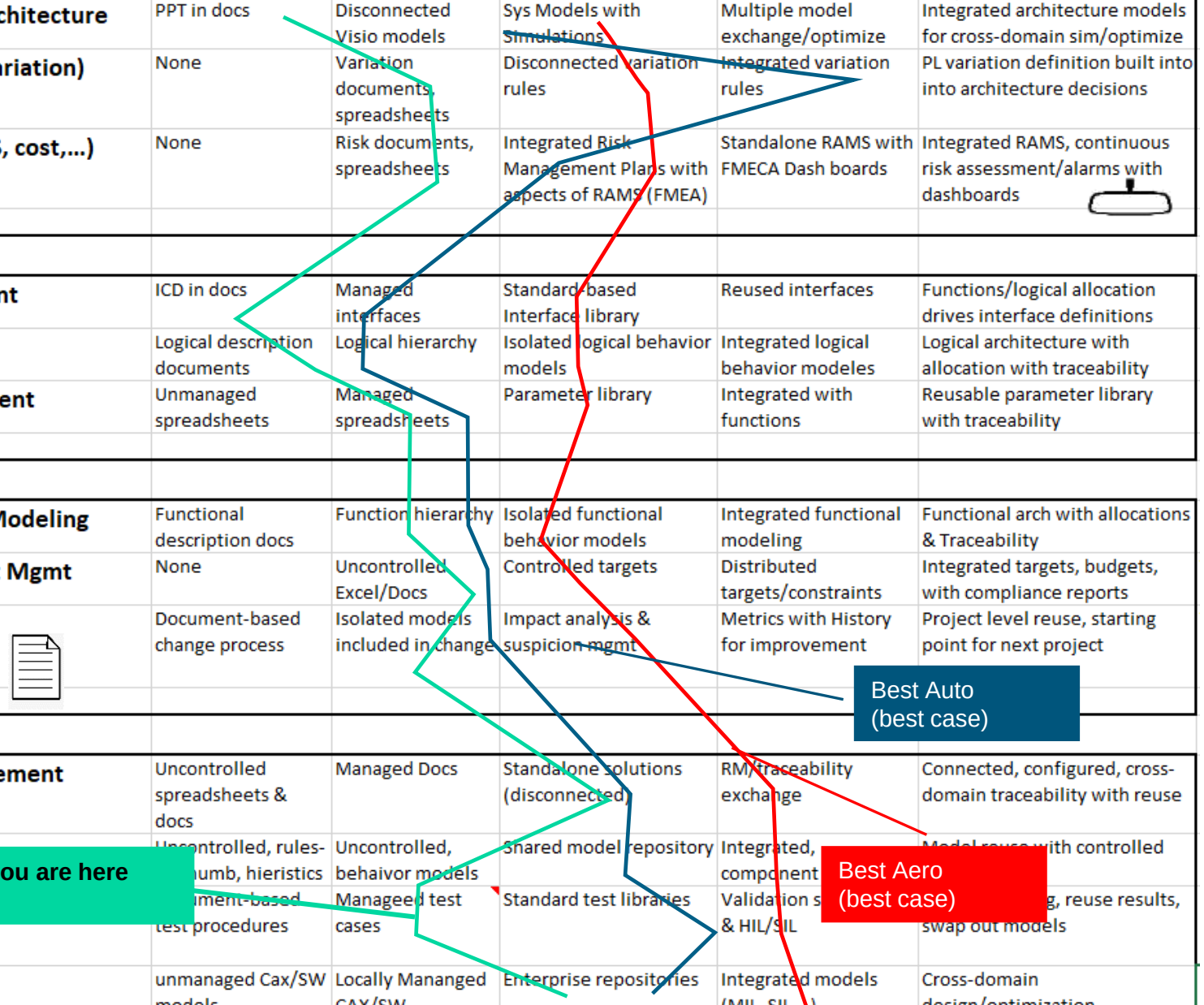

Barriers to implementation…

Silos locked-in by tools creating automated chaos

NxN problem…

Capability Assessment:	Basic	Low	Medium	High	Advanced
System Modeling/Architecture	PPT in docs	Disconnected Visio models	Sys Models with connections	Multiple model exchange/optimize	Integrated architecture models for cross-domain
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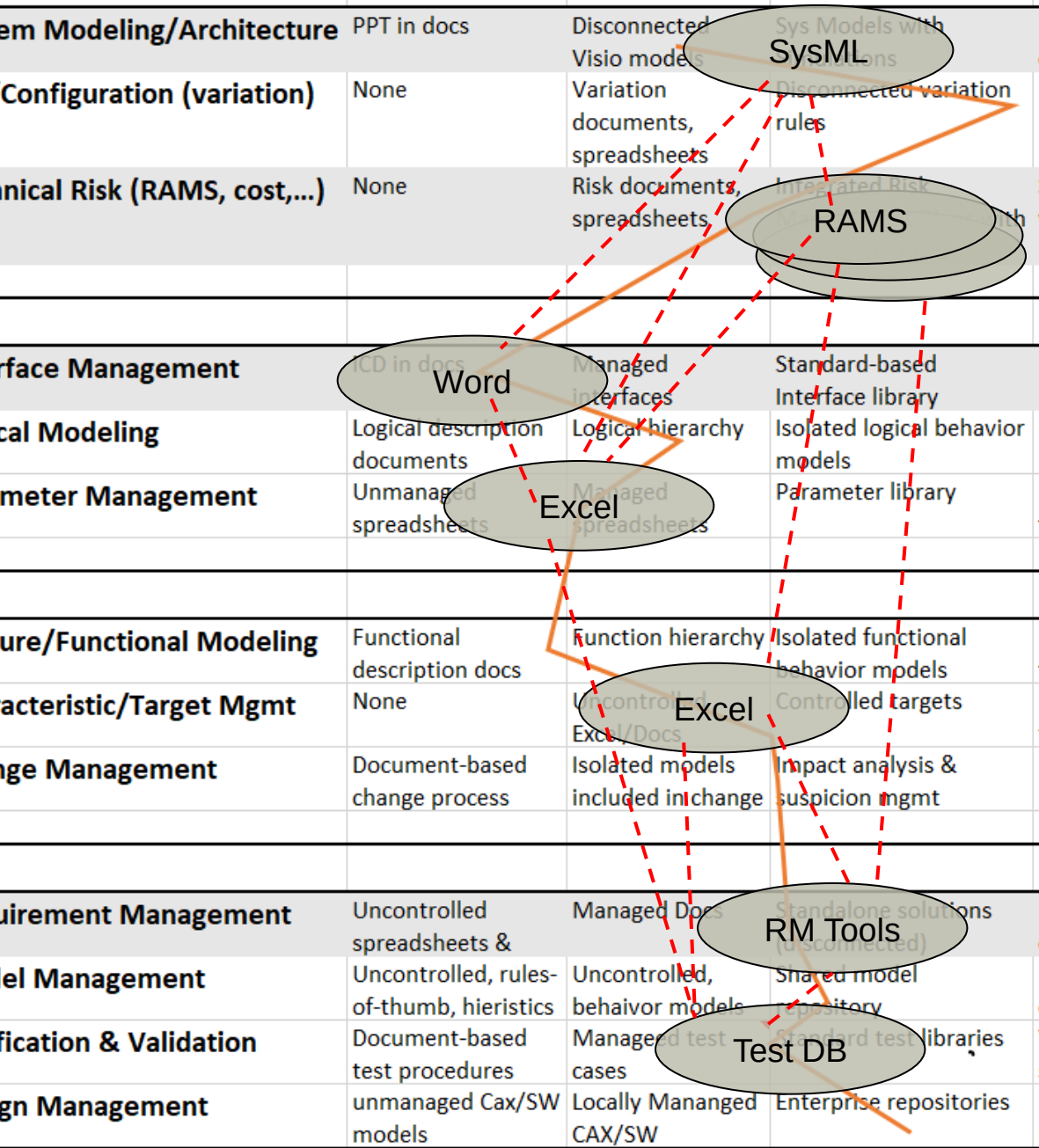

Barriers to implementation

Problem is information exchange not data exchange

PLM is about information; managing the digital thread

Capability Assessment:	Basic	Low	Medium	High	Advanced
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Requirement Management	Uncontrolled spreadsheets &	Ma			
Model Management	Uncontrolled, ru of-thumb, hi				
Verification & Validation	Docume test				
Design Management					
CMMI Staged Levels:					

SysML

RAMS

Word

Excel

Excel

RM Tools

Test DB

PLM→ SysLM

How to implement technology change…
Meta-Dishonesty

“Semmelweis Reflex”

…to dismiss/reject out of hand any information, automatically, without thought, inspection, or experiment

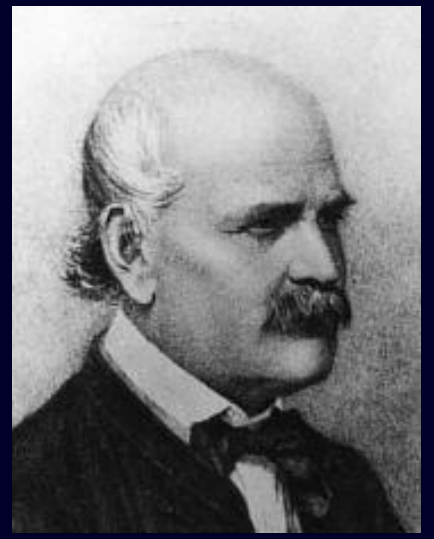
Fore-ordained answers

…will the answer be accepted

Don’t waste your time on the wrong answers, unless…

Dr. Ignaz Semmelweis (1818-1865)

Early Germ Theory



Wash Your Damn Hands

[http://en.wikipedia.org/wiki/Semmelweis]

Organization Pre-prep…

Is your organization prepared to accept the answer?

- Management & customer backing
  - Do you have time to apply the tools
  - Do customers understand what you are doing

  …other wise tools are thrown overboard to get over the next schedule pass
- Properly supported support organizations
  - Who's going to take care of the tools?
  - Who's responsible to maintain, support, answer questions about the tools
- Timely Application of the tools
  - SE tools are time sensitive
  - Money & resources start when…

  …"Catch-22" programs don't get resources until after SE decisions are made

**"We are going on a journey.
We will carry the wounded,
but we will shoot the stragglers."**

--Hallmark Cards

Organization SDB's…

- No time/money to use tools
- No backing for resources
- No training on tools
- Expecting tools to run themselves
- Thinking tools are static
- Not convincing the customer of the tool benefits
- No process for the tools to work within
- No mechanism for using tool results
- Applying the tool to everything
- Funneling everything through a gate keeper
- Expecting "paper" results from tools
- "where's the hardware?"
- Rewarding fire-fighters vs. fire-preventers
- Blockading support organizations (…they cost too much, etc.)

"…next year you will have a 90% probability of this failure…
But you will do nothing about it!"

Dr. Stephen Wheelwright

[Covey 1995, Sampson 2000] [Covey 1970]

Organizational SDB's cont…

How prepared is your organization? →

Culture change vs. getting lucky…

Buckminster Fuller's Magic Log

SE tool management acceptance checklist	Y	N
Did the tool support group help with the proposal?		
Has the manger forecast time & money for tool usage?		
Did the project manager help get the tools for his project?		
Has the manager forecast time & money for tool training?		
Is the manager willing to let the tools be upgraded mid project or are we stuck at this tool version?		
Is the manager willing to let his tool power users share lessons learned, be involved with user groups, etc.?		
Is the manager active in convincing his customer or the benefits of the tools?		
Are the tools used during customer reviews?		
Is there a development process being followed on the project?		
Is there a mechanism for doing something with the results of the tools?		
Is the manager involved with defining requirements?		
Does the manager see "one or two" engineers managing the product requirements?		
Does the manager have a "lets get something built" before requirements are defined mentality?		
Does the manager think the value of the tool is in its paper generation capability?		
Does he want/let the engineering automation support his project?		

Cows drink… [Sampson, 2000, Von Wodtke, 1993]

Cultural Considerations

After choosing a process, picking tools, convincing management/accountants to buy them, how do you get them to “stick”?

- Goal of tools to accelerate SE
- Change is required
- How to get technology/change to stick?

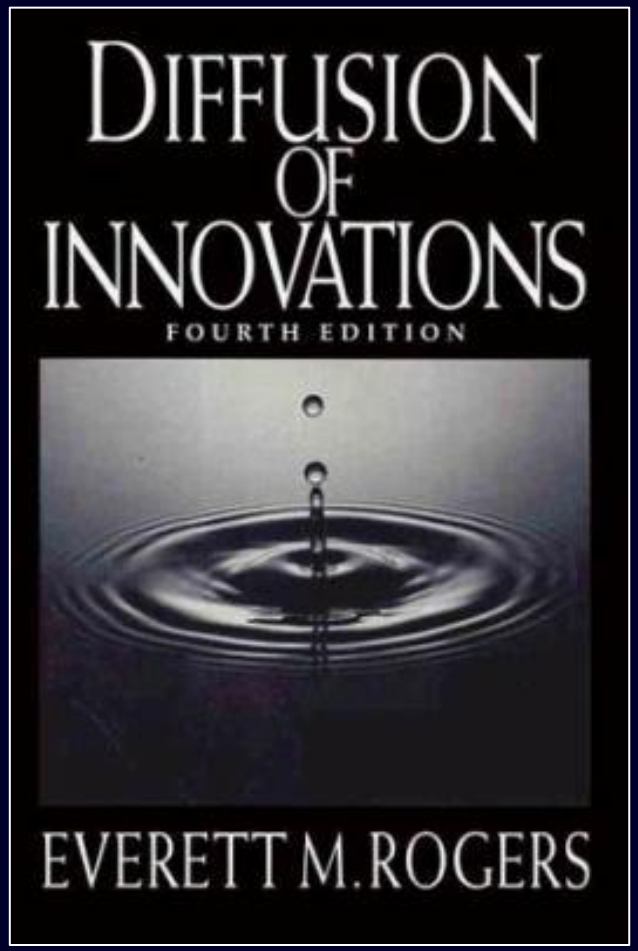
Rogers Technology Diffusion Theory

[Rogers, 1962]

Diffusion of Innovations…

5 characteristics of innovations that affect acceptance:

1. Relative Advantage—perceived as better
2. Compatibility—consistent with values
3. Complexity—how difficult to understand & learn
4. Trialability—experimented with
5. Observability—results visible to others

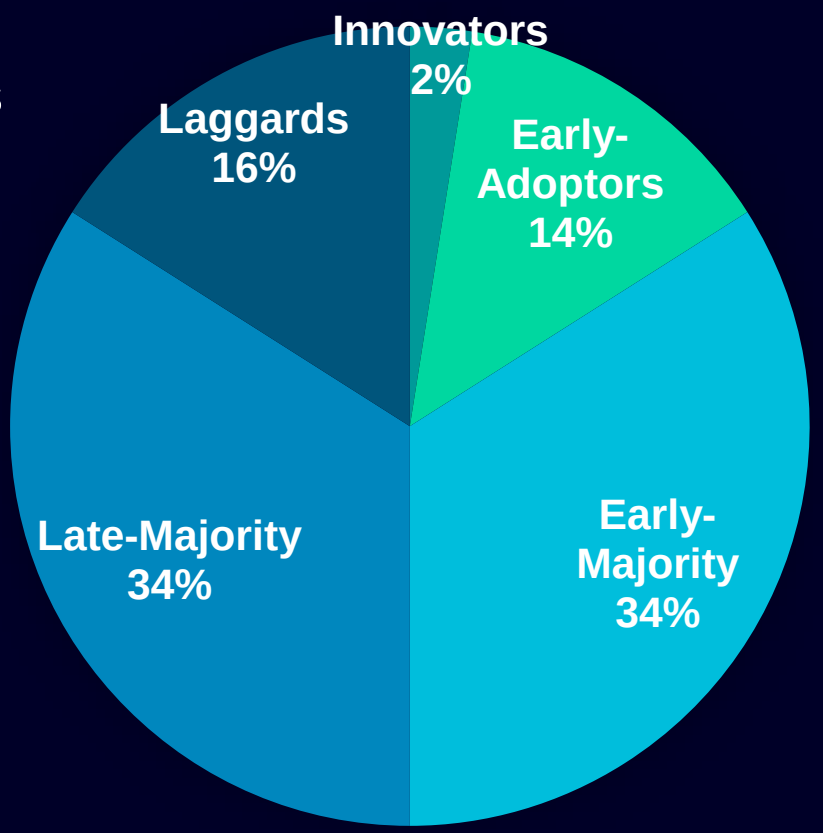


[Rogers, 1962]

Diffusion of Innovations…

5 kinds of people in organizations…

1. Innovators (2.5%)—risk takers, information from many sources, adventure-some
2. Early-adopters (13.5%)—social leaders, popular, fast trackers
3. Early-majority (34%)—deliberate, informal social circles
4. Late-majority (34%)—skeptical, traditional,…
5. Laggards (16%)—fear of change, resistant, militant…

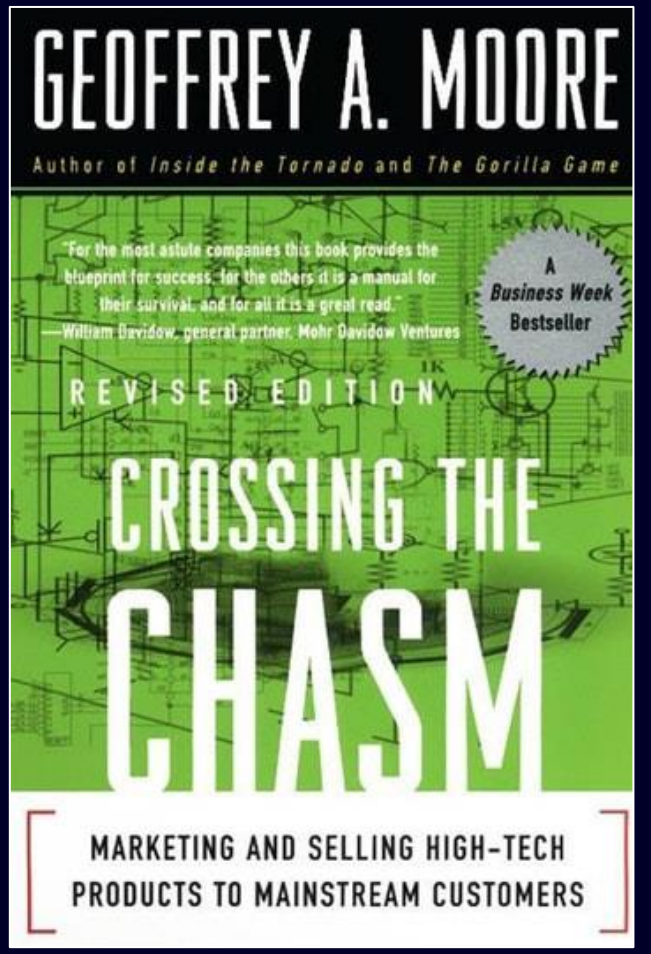


[Rogers, 1962]

Diffusion of Innovations…

…the way people perceive an innovation matters more then the merits of the tool itself. Rogers' Theory Suggests:

1. Start with pioneers on your first project application—innovators, anxious to make it go, & move on the to the next new thing
2. Pass it on to early adopters who find the relative advantages (even if it takes considerable effort)
3. Use these opinion leaders/champions to take it across the "chasm" to the early/late majorities



[Rogers, 1962]

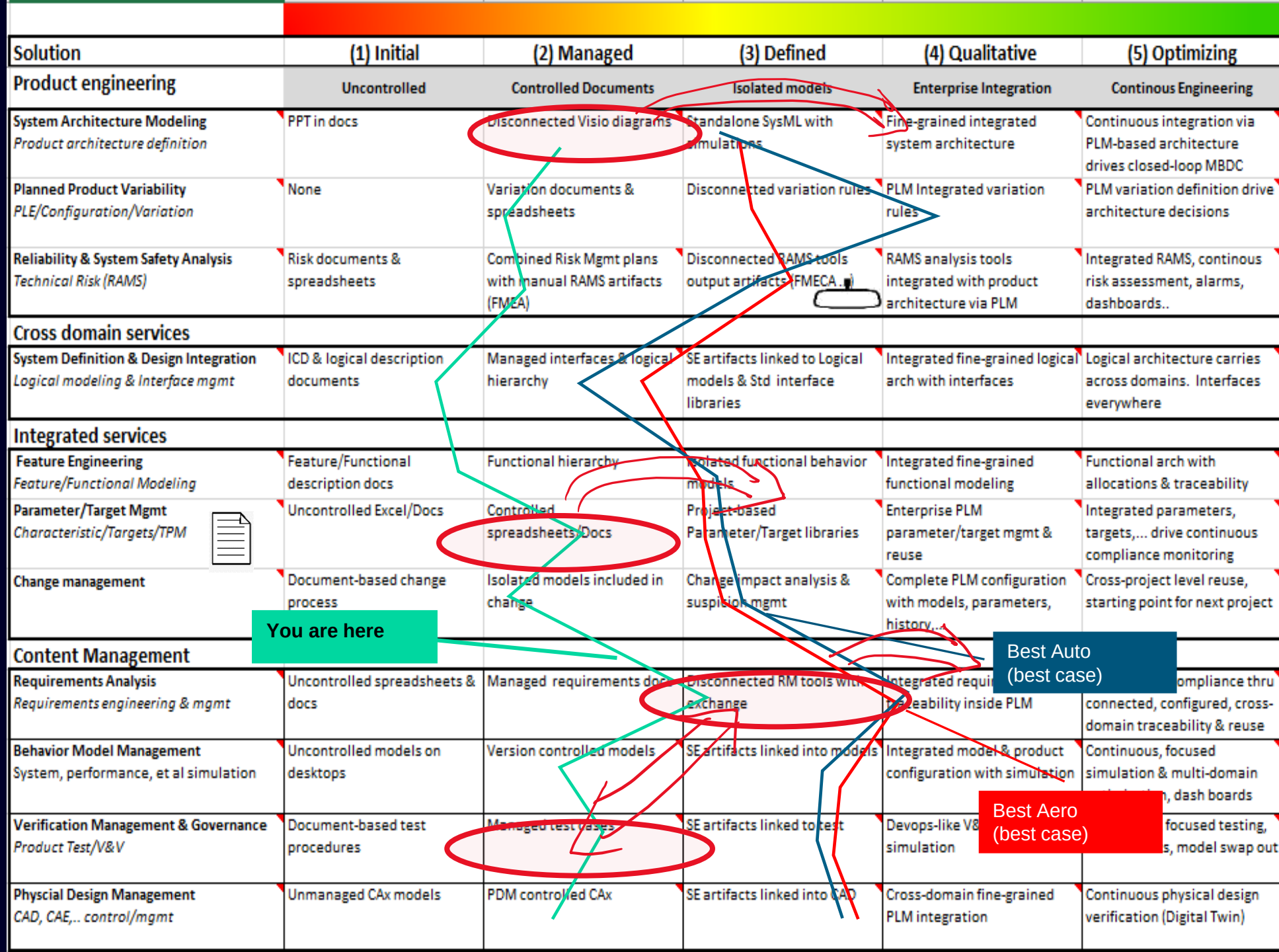
Diffusion of Innovations… Remember the Firefies…

Pioneer Aptitude Test	Y	N
Pioneers keep up with trade journals, computer magazines, etc.		
Pioneers work on computers at home-- i.e., they don't get enough at work		
Pioneers are always looking for new ways and tools to help them do their job (they may even go buy the tool themselves)		
Pioneers are known throughout their project as the first to adopt any new technology that comes along and come up with new and unique ways of applying the tools		
Pioneers are the informal support person in the project (project folks go to them for help on the tools)		
Pioneers are almost always positive on what tools can do for the project		
Pioneers are willing to put in a lot of work to make the tools work		

1. Make your pioneers/champions successful
2. Give them opportunities to communicate successes (opportunity to “nudge” others)
3. Give them a career path to spread the innovation (Design Centers,…)

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)

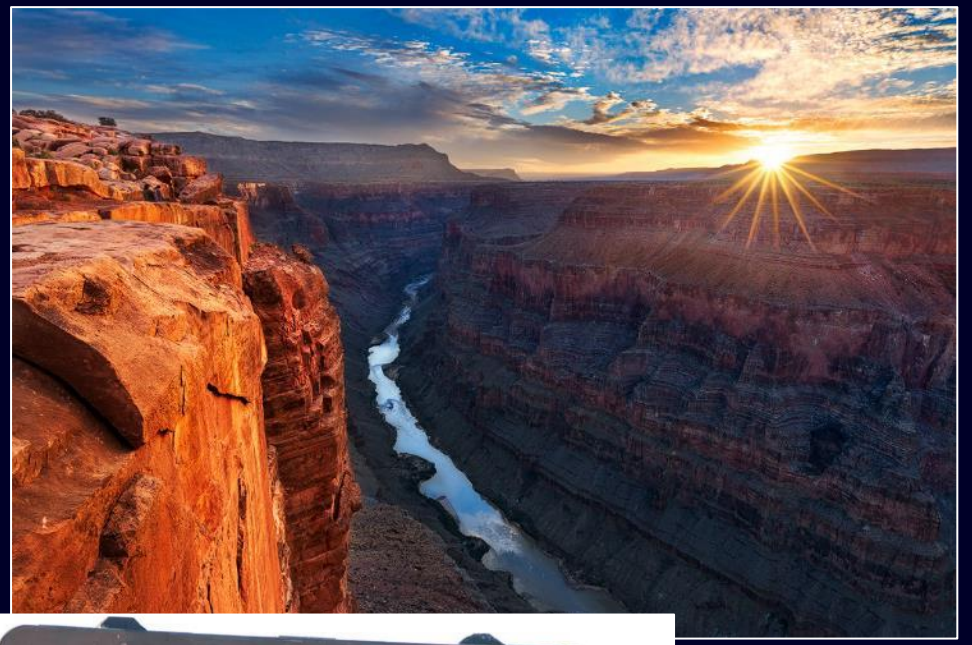
You are here

Best Auto (best case)

Best Aero (best case)

Don’t make us come rescue you…
Ignoring the advice

Toroweep Point
North Rim Grand Canyon



If you lead with tools (ignoring principals, process, & diffusion)…

- Sunk cost
- Cost of rescue
- Wasted engineering time
- Delayed project schedules
- Missing …product architecture
- Late discovery of integration problems
- MBSE black eye…

Choose tools that include/support standard processes (the more OOTB the better)

- Define/Train on processes
- Show how tools support the processes,
- Give users/projects a chance to share their experiences

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 - Record
- e-Enabling (Crew Inform
- Maintenance Systems

Cabin Systems
- Broadband Offboard Sat
- Cabin Services Systems
- Emergency Lighting Sys
- Inflight Entertainment Sy
- Telephone System
- Video Surveillance Syst

Fuels
- Fuel Quantity Indicating
- Nitrogen Generating Sys

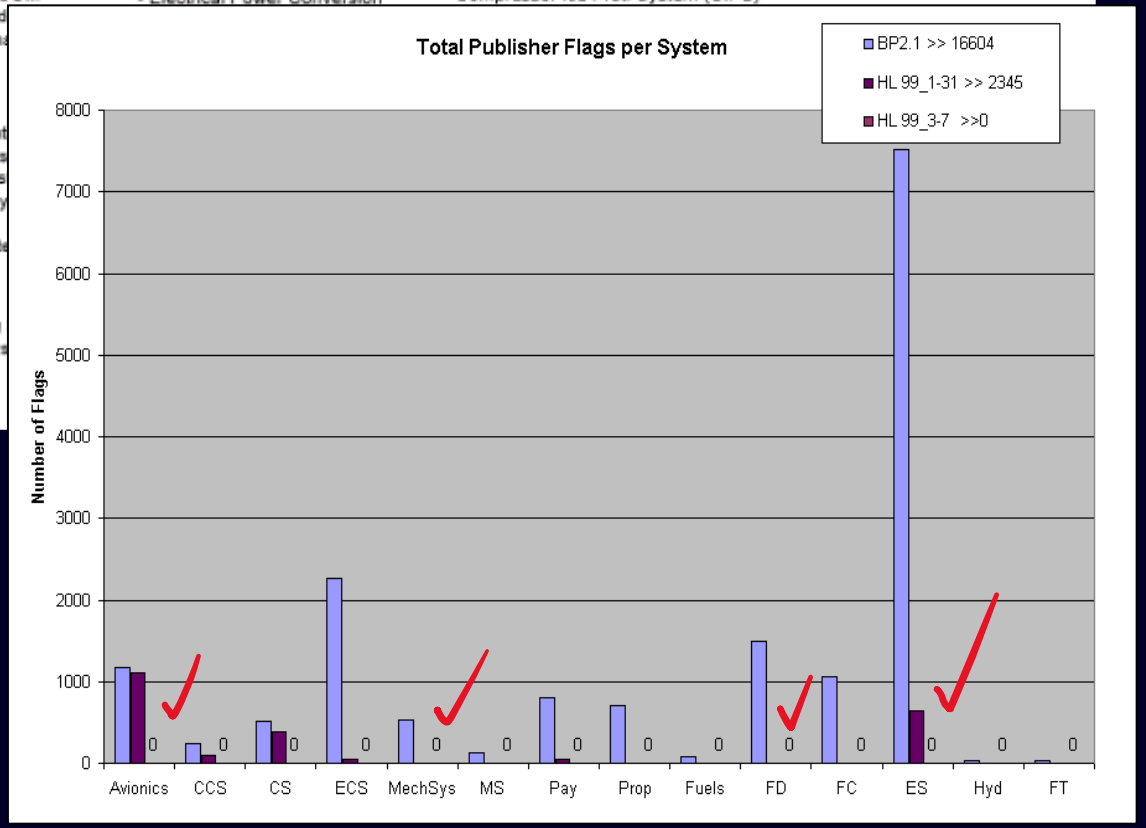
Flight Controls
- Flight Controls Electronics
- High Lift
- Primary Flight Controls
- Autoflight
- Integrated Standby Flight
- Displays

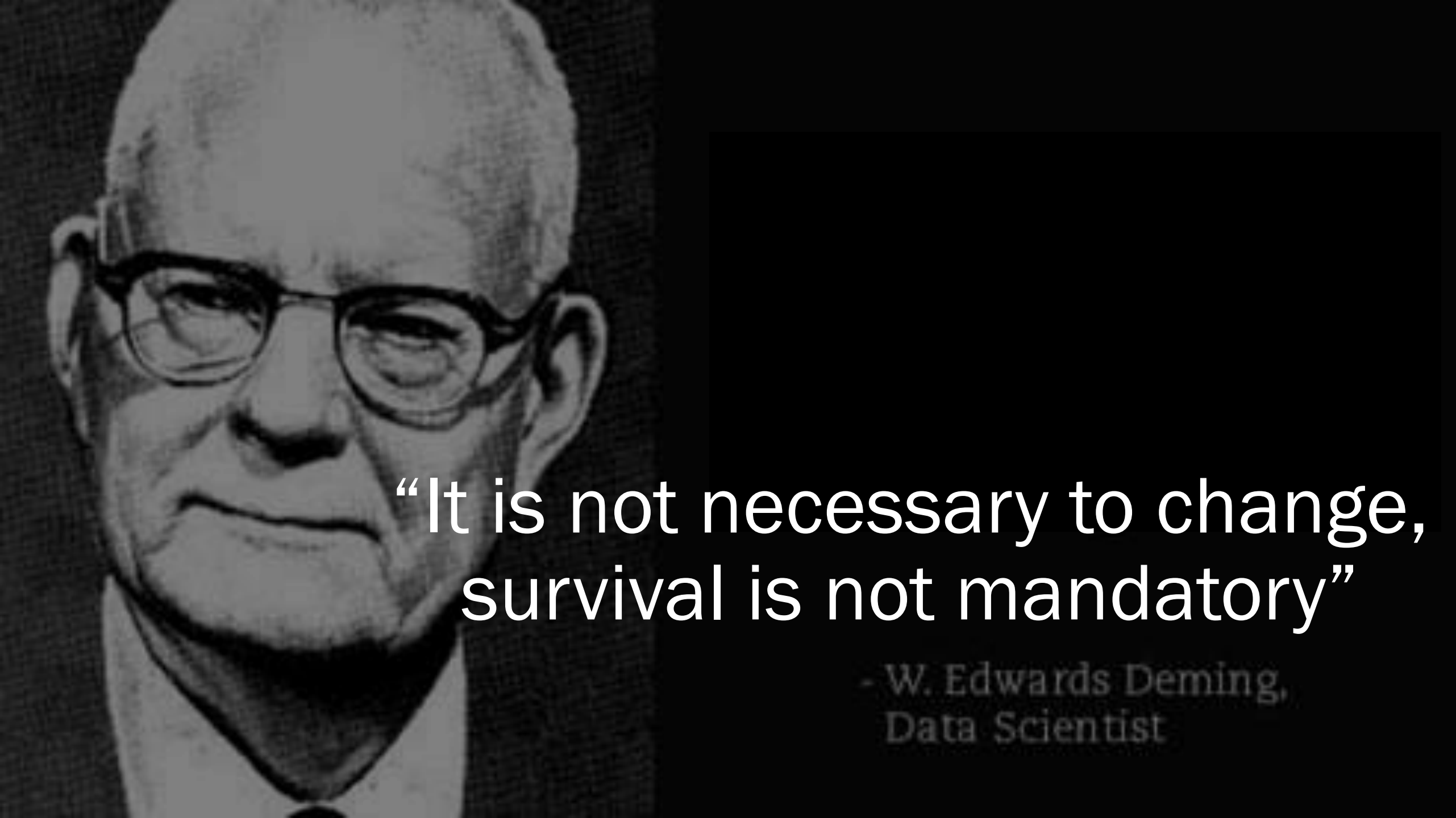
Electrical Sub-systems
- Cargo Compartment Lighting
- Electrical Power Conversion

Environmental Control Systems
- Equipment Cooling
- Moisture Control
- Humidification
- CACTCS
- Cabin Pressure Control System
- Cargo Air Conditioning, Ventilation
- EE Cooling
- Power Elect Cooling
- Integrated Cooling System
- Compressor Ice Prot. System (CIPS)

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

Flight Deck
- Flight Deck Control Panels
- Flight Deck Area Illumination
- Flight Deck Access System




“It is not necessary to change,
survival is not mandatory”
- W. Edwards Deming,
Data Scientist

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