



2021
Annual **INCOSE**
international workshop
Virtual Event
January 29 - 31, 2021

Start Integrated, Stay Integrated...

Solving our cross-domain engineering domain communication problem

Mark E Sampson MBSE Initiative Chair

MBSE Workshop Kickoff...



**“There’s a difference between jogging
and being chased by a bear”**

Grandma Sampson



Some sample bears...

- ~47 million automotive recalls in the US last year
- NHTSA est. \$100/recall per vehicle; that's \$4.7 billion in direct costs fixing the problem
- ...many of these are failures to comply with requirements & regulations

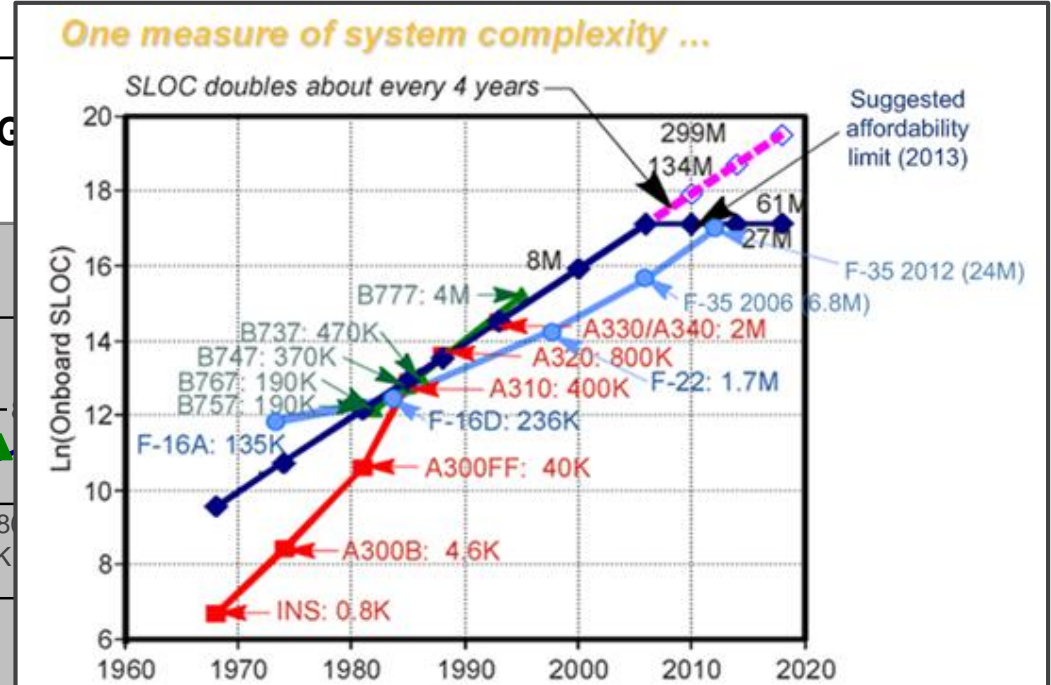
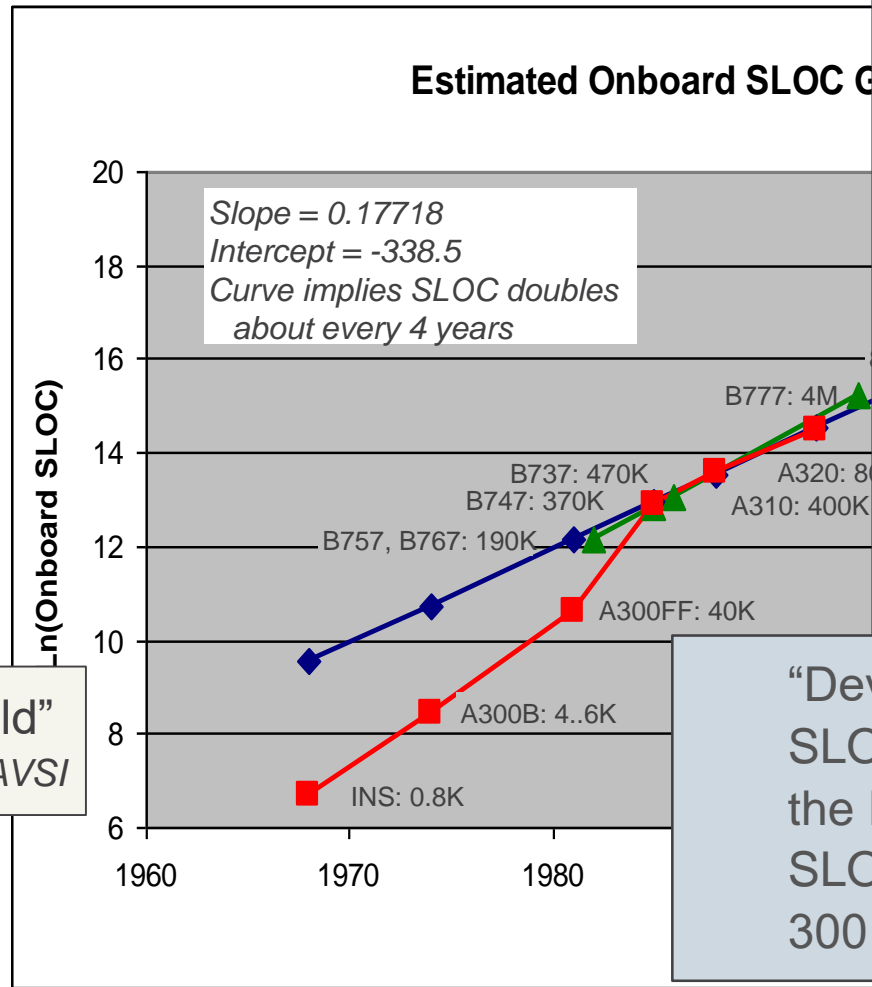
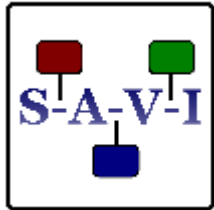


March 2, 2020: Ford & Volvo Door latch [1.4m, \$140m]



Unprecedented Product Complexity: Unaffordable

Norm was right (Augustine's Law #16)

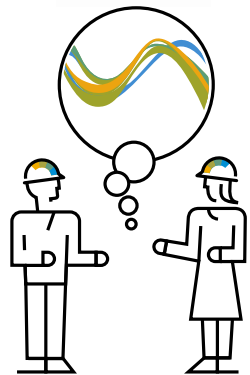
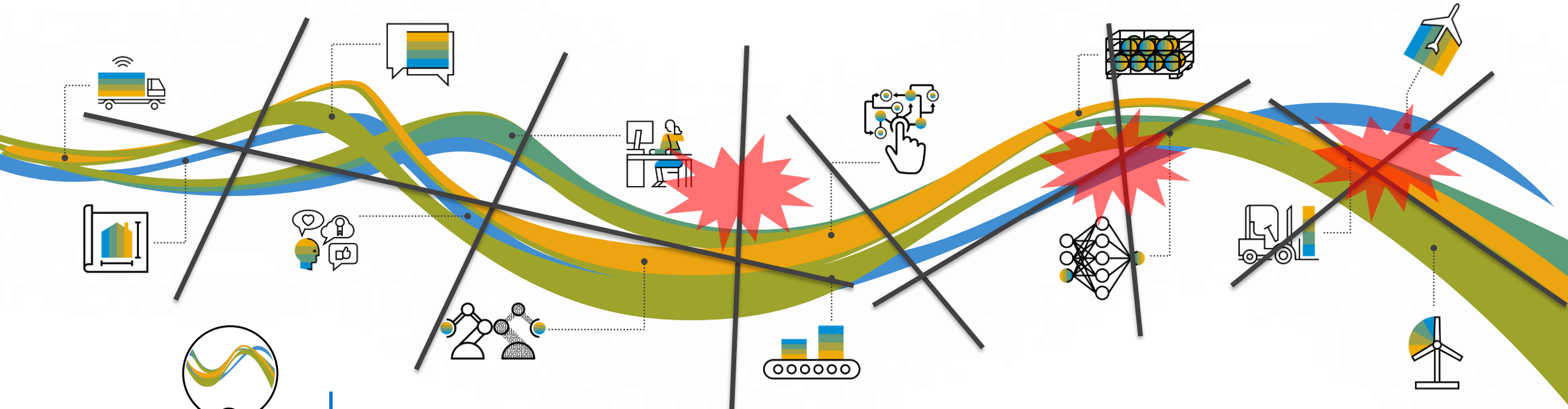


“Integrate, then build”
AVSI

“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”



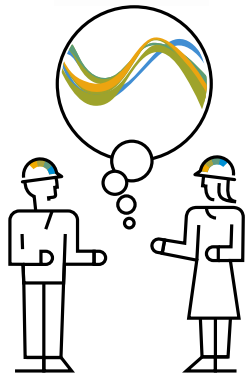
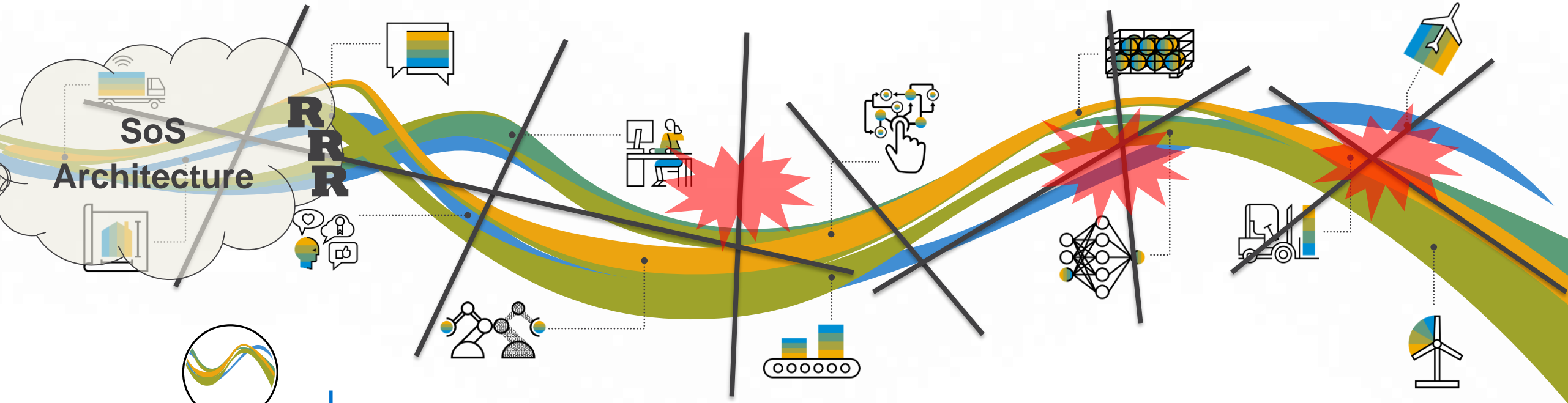
Without the digital thread...



Many different organizations & disciplines interact to create today's complex products
It's at these organization/discipline boundaries where integration problems happen
You already know this and plan to spend half your program schedule/resources for integration problems



The digital thread starts with an integrated product architecture & requirements...



An integrated product architecture with requirement provides the scaffolding for the digital thread & drives the downstream development process for continuous integration

Requirements, Functions, et al. flow through the threads for continuous/closed-loop V&V

Guided by standard integrated process, participating in standard services, delivered thru PLM to everyone (including suppliers) for closed-loop development—continuous integration

This isn't an engineering problem, you have a knowledge communication/management problem



Today's products are built by everyone/everywhere...

- Documents aren't scalable
- Disconnected models provide knotholes
- You can't hire enough brains

Symptoms:

- Half your program schedule spent on system integration (supplier coordination)
- Tedious communication via meetings
- Uncommunicated change
- Innocent impact understanding

An integrated product architecture/blueprint is required

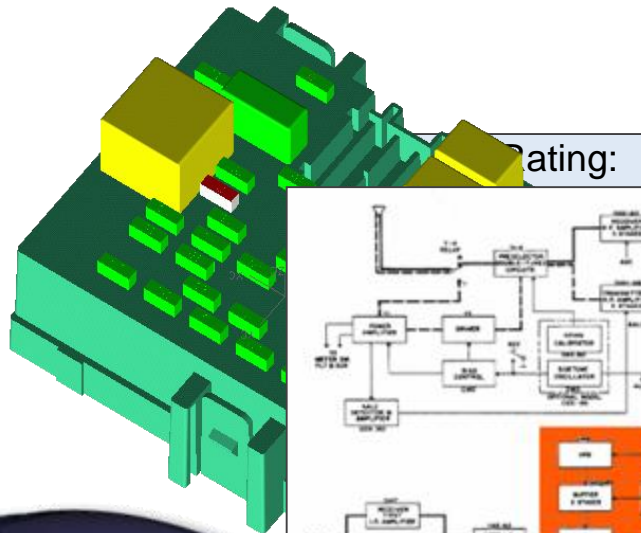
- Delivered thru PLM
- Allocated through suppliers for continuous feedback

...to start integrated, stay integrated



Integrated MBSE Vision

What does the integrated digital thread look like...



Hydraulic Fluid:
SAE 1340 not-compliant

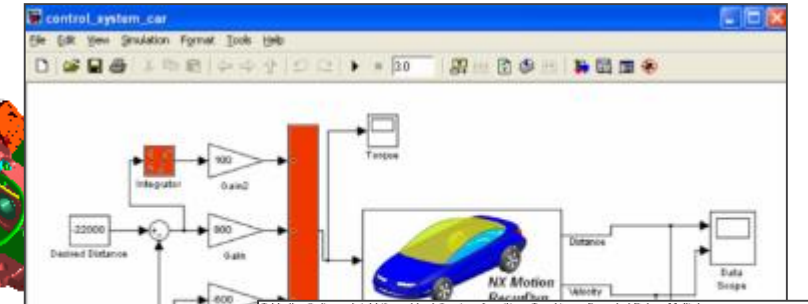
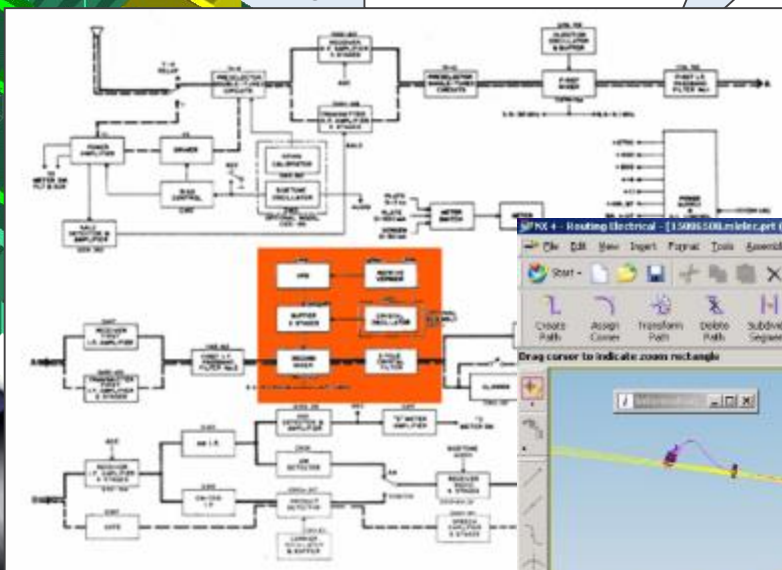
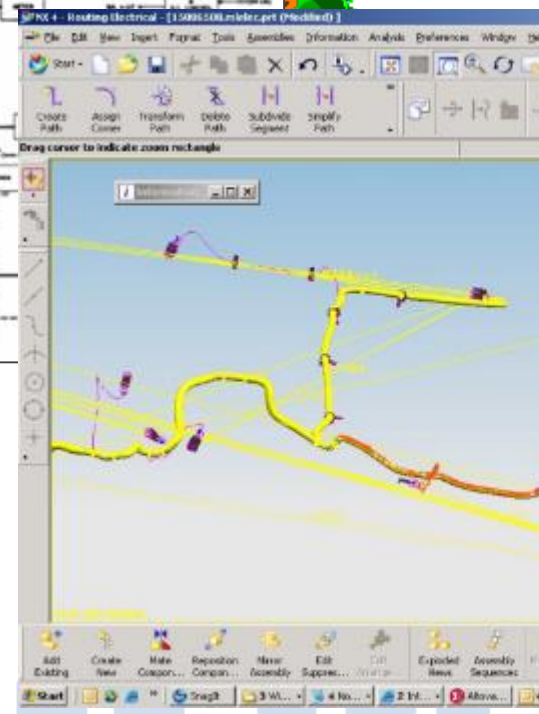


Table II—Ordinary Joint Life and Last Survivor Annuities—Two Lives—Expected Return Multiples

Ages														
Male	Female	35	36	37	38	39	40	41	42	43	44	45	46	47
35	40	46.2	45.7	45.3	44.8	44.4	44.0	43.6	43.3	43.0	42.6	42.3	42.0	41.8
36	41	45.7	45.2	44.8	44.3	43.9	43.5	43.1	42.7	42.3	42.0	41.7	41.4	41.1
37	42	45.3	44.8	44.3	43.8	43.4	42.9	42.5	42.1	41.8	41.4	41.1	40.7	40.4
38	43	44.8	44.3	43.8	43.3	42.9	42.4	42.0	41.6	41.2	40.8	40.5	40.1	39.8
39	44	44.4	43.9	43.4	42.9	42.4	41.9	41.5	41.0	40.6	40.2	39.9	39.5	39.2
40	45	44.0	43.5	42.9	42.4	41.9	41.4	41.0	40.5	40.1	39.7	39.3	38.9	38.6
41	46	43.6	43.1	42.5	42.0	41.5	41.0	40.5	40.0	39.6	39.2	38.8	38.4	38.0
42	47	43.3	42.7	42.1	41.6	41.0	40.5	40.0	39.6	39.1	38.7	38.2	37.8	37.5
43	48	43.0	42.3	41.8	41.2	40.6	40.1	39.6	39.1	38.6	38.2	37.7	37.3	36.9
44	49	42.6	42.0	41.4	40.8	40.2	39.7	39.2	38.7	38.2	37.7	37.2	36.8	36.4
45	50	42.3	41.7	41.1	40.5	39.9	39.3	38.8	38.2	37.7	37.2	36.8	36.3	35.9
46	51	42.0	41.4	40.7	40.1	39.5	38.9	38.4	37.8	37.3	36.8	36.3	35.9	35.4
47	52	41.8	41.1	40.4	39.8	39.2	38.6	38.0	37.5	36.9	36.4	35.9	35.4	35.0

Ages														
Male	Female	48	49	50	51	52	53	54	55	56	57	58	59	60
53	54	55	56	57	58	59	60	61	62	63	64	65		
35	40	41.5	41.3	41.0	40.8	40.6	40.4	40.3	40.1	40.0	39.8	39.7	39.6	39.5
36	41	40.8	40.6	40.3	40.1	39.9	39.7	39.5	39.3	39.2	39.0	38.9	38.8	38.6
37	42	40.2	39.9	39.6	39.4	39.2	39.0	38.8	38.6	38.4	38.3	38.1	38.0	37.9
38	43	39.5	39.2	38.9	38.7	38.5	38.3	38.1	37.9	37.7	37.5	37.3	37.2	37.1
39	44	38.9	38.6	38.3	38.0	37.8	37.6	37.3	37.1	36.9	36.8	36.6	36.4	36.3
40	45	38.3	38.0	37.7	37.4	37.1	36.9	36.6	36.4	36.2	36.0	35.9	35.7	35.5
41	46	37.7	37.3	37.0	36.7	36.5	36.2	36.0	35.7	35.5	35.3	35.1	35.0	34.8
42	47	37.1	36.8	36.4	36.1	35.8	35.6	35.3	35.1	34.8	34.6	34.4	34.2	34.1
43	48	36.5	36.2	35.8	35.5	35.2	34.9	34.7	34.4	34.2	33.9	33.7	33.5	33.3
44	49	36.0	35.6	35.3	34.9	34.6	34.3	34.0	33.8	33.5	33.3	33.0	32.8	32.6
45	50	35.5	35.1	34.7	34.4	34.0	33.7	33.4	33.1	32.9	32.6	32.4	32.2	31.9
46	51	35.0	34.6	34.2	33.8	33.5	33.1	32.8	32.5	32.2	32.0	31.7	31.5	31.3
47	52	34.5	34.1	33.7	33.3	32.9	32.6	32.2	31.9	31.6	31.4	31.1	30.9	30.6
48	53	34.0	33.6	33.2	32.8	32.4	32.0	31.7	31.4	31.1	30.8	30.5	30.2	30.0
49	54	33.6	33.1	32.7	32.3	31.9	31.5	31.2	30.8	30.5	30.2	29.9	29.6	29.4
50	55	33.2	32.7	32.3	31.8	31.4	31.0	30.6	30.3	29.9	29.6	29.3	29.0	28.8
51	56	32.8	32.3	31.8	31.4	30.9	30.5	30.1	29.8	29.4	29.1	28.8	28.5	28.2
52	57	32.4	31.9	31.4	30.9	30.5	30.1	29.7	29.3	28.9	28.6	28.2	27.9	27.6
53	58	32.0	31.5	31.0	30.5	30.1	29.6	29.2	28.8	28.4	28.1	27.7	27.4	27.1
54	59	31.7	31.2	30.6	30.1	29.7	29.2	28.8	28.3	27.9	27.5	27.2	26.9	26.5
55	60	31.4	30.8	30.3	29.8	29.3	28.8	28.3	27.9	27.5	27.1	26.7	26.4	26.0
56	61	31.1	30.5	29.9	29.4	28.9	28.4	27.9	27.5	27.1	26.7	26.3	25.9	25.5
57	62	30.8	30.2	29.6	29.1	28.6	28.1	27.6	27.1	26.7	26.2	25.8	25.4	25.1
58	63	30.5	29.9	29.3	28.8	28.2	27.7	27.2	26.7	26.3	25.8	25.4	25.0	24.6
59	64	30.2	29.6	29.0	28.5	27.9	27.4	26.9	26.4	25.9	25.4	25.0	24.6	24.2
60	65	30.0	29.4	28.8	28.2	27.6	27.1	26.5	26.0	25.5	25.1	24.6	24.2	23.8



Minimum Turn Radius: 24 ft.
Automatic Dry Pavement Braking
Distance at 60 MPH : 110. 90 ft



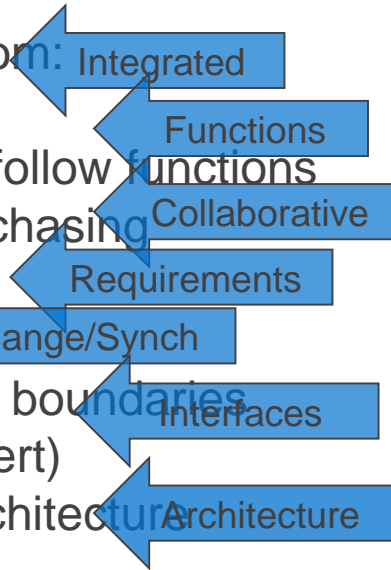
Hidden costs from communication failures... Solving the same problems over & over

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

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



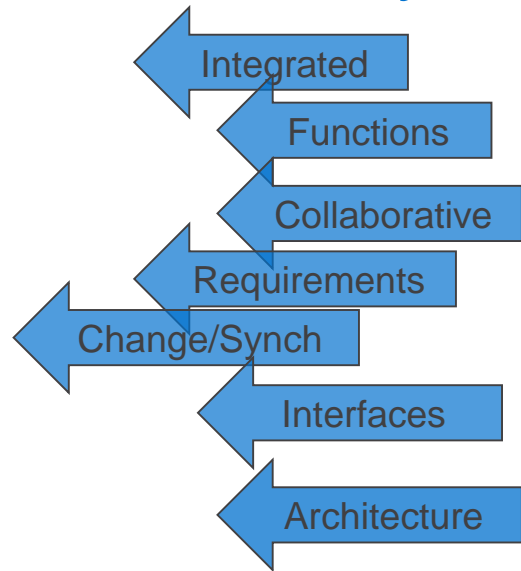
Cross-Domain problems result from:
Siloes/Disconnected Decisions
Form follows function, Problems follow functions
Everyone involved, including purchasing
Disconnected requirements
Uncommunicated change
Happen at domain/organizational boundaries
Migrate with people (overt or covert)
Missing/disconnected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



“Water on the knee”

How bad is our communication problem?

MBSE Maturity



	Disintegrated -----> Integrated				
	Disconnected Communication with documents	Disconnected variation rules	Integrated variation rules	Integrated variation rules	Continuous Communication with models
System Modeling/Architecture					
PLE/Configuration (variation)		variation documents, spreadsheets	Disconnected variation rules	Integrated variation rules	Integrated variation rules built 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 models	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, behavior models	Shared model repository	Integrated, component library	Model reuse with controlled parameters
Verification & Validation	Minimum to no planning	Manually testing everything	Isolated validation simulations	Integrated simulation (HIL, SIL)	Focused testing, reuse results, swap out models
Design Management	unmanaged Cax/SW models	Locally Managed 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 bad is our communication problem?

Avg MBSE Maturity

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

Where are we?

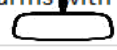
Everyone has a communication problem

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

Avg Organization (best case)

Best Auto (best case)

Best Aero (best case)



Is SE education helping our communication problem?

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

Avg Organization (best case)





Process Dishonesty/Meta-Dishonesty

“Simmelweis Reflex”

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

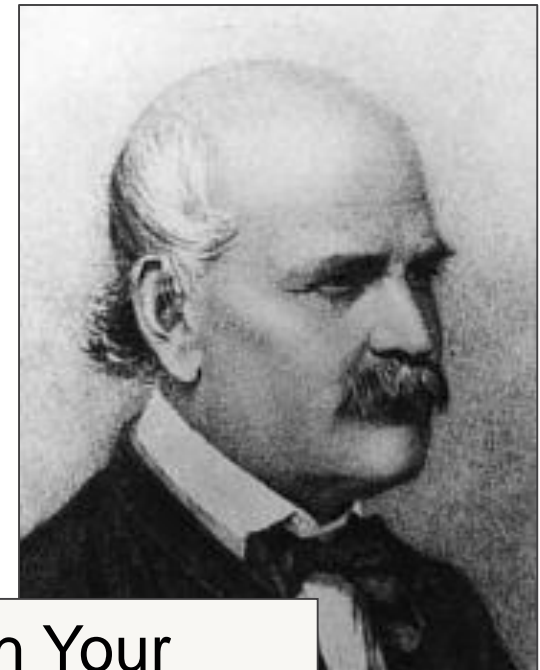
Fore-ordained answers

...will the answer provided by SE tools 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>]

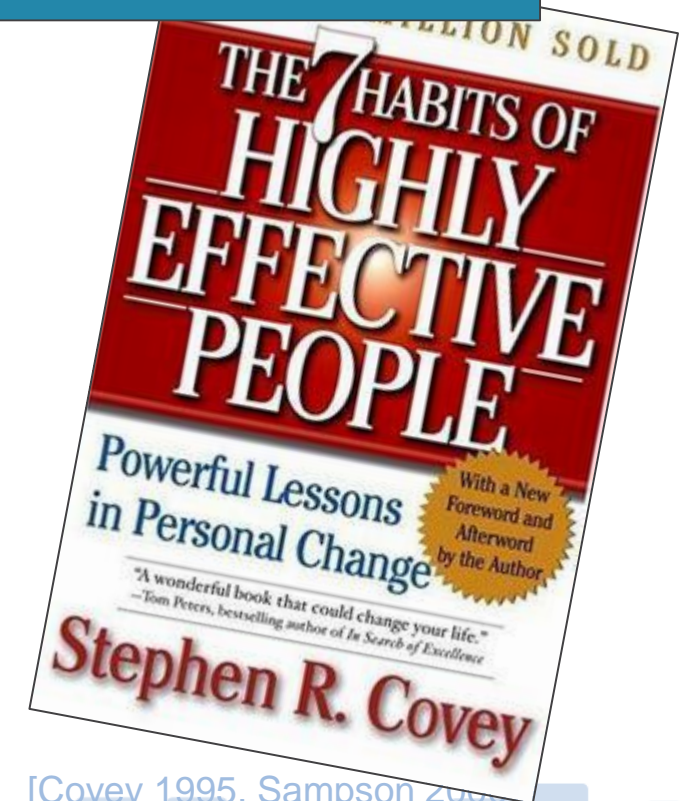


Organization SDB's (Self-Defeating Behaviors)...

- 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]



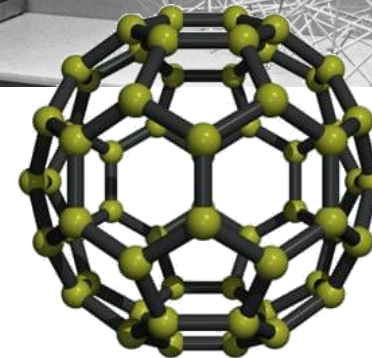
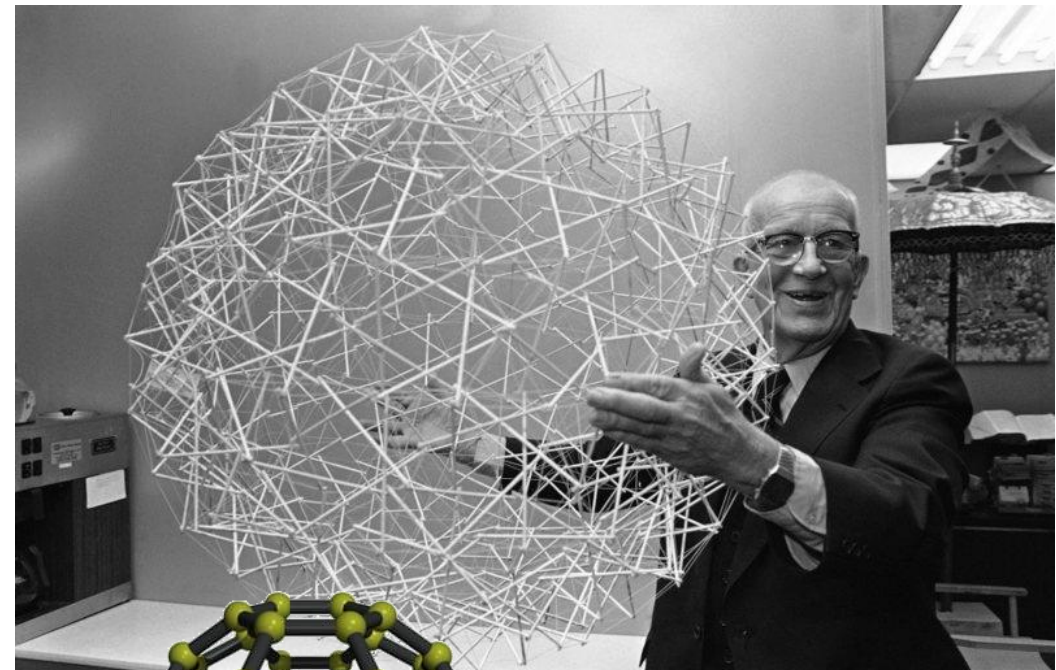
Organizational SDB's cont...

How prepared is your organization?

Culture change vs. getting lucky...



Buckminster Fuller's Magic Log



Buckyballs (Carbo Fullerenum)

[Sampson, 2000, Von Wodtke, 1993]

Cows drink...

You don't have an engineering problem, you have a knowledge communication/management problem



Today's products are built by everyone/everywhere...

- Documents aren't scalable
- Disconnected models provide knotholes
- You can't put enough brains on the job

Symptoms:

- Half your program schedule/resources spent on system integration
- Arm's-length supplier collaboration
- Tedious communication via meetings (inter-team & intra-team)
- Uncommunicated change
- Innocent impact understanding
- ...

Integrated product architecture with requirements is mandatory

- Delivered thru PLM services
- Integrated standards-based process/methodology
- Allocated through to suppliers for continuous feedback

...to start integrated, stay integrated

Where do we start?



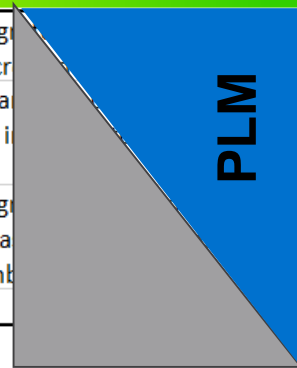
**START WHERE YOU ARE.
USE WHAT YOU HAVE.
DO WHAT YOU CAN.**

- ARTHUR ASHE

How to start solving your communication problem...

Possible starting points to solving your communication problem

	(1) Initial	(2) Managed	(3) Defined	(4) Qualitative	(5) Optimizing
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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 &	Managed Docs	Standalone solutions (disconnected)	RM/traceability exchange	Connected, configured, cross-domain traceability with reuse
Model Management	Uncontrolled, rules-of-thumb, hieristics	Uncontrolled, behavior models	Shared model repository	Integrated, component library	Model reuse with controlled parameters
Verification & Validation	Minimum to no planning	Manually testing everything	Isolated validation simulations	Integrated simulation (HIL, MIL, SIL,...)	Focused testing, reuse results, swap out models
Design Management	unmanaged Cax/SW models	Locally Managed CAX/SW	Enterprise repositories	Integrated models	Cross-domain design/optimization
CMMI Staged Levels:	(1) Initial	(2) Managed	(3) Defined	(4) Qualitative	(5) Optimizing
	Medical/Healthcare	Semiconductor	Aerospace	Automotive	Government





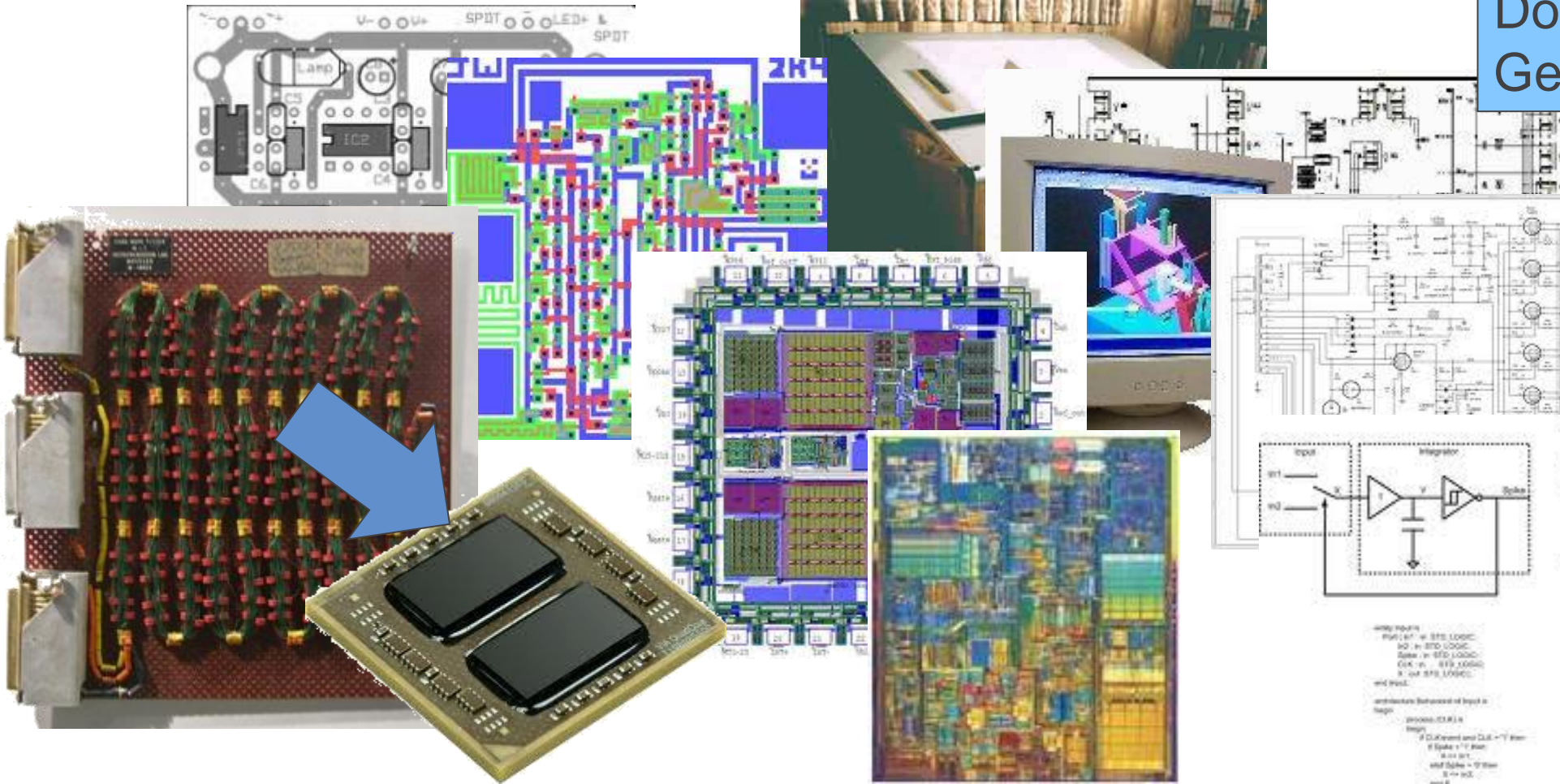
High-tech Experience This requires change...

Documents

Document
Generation

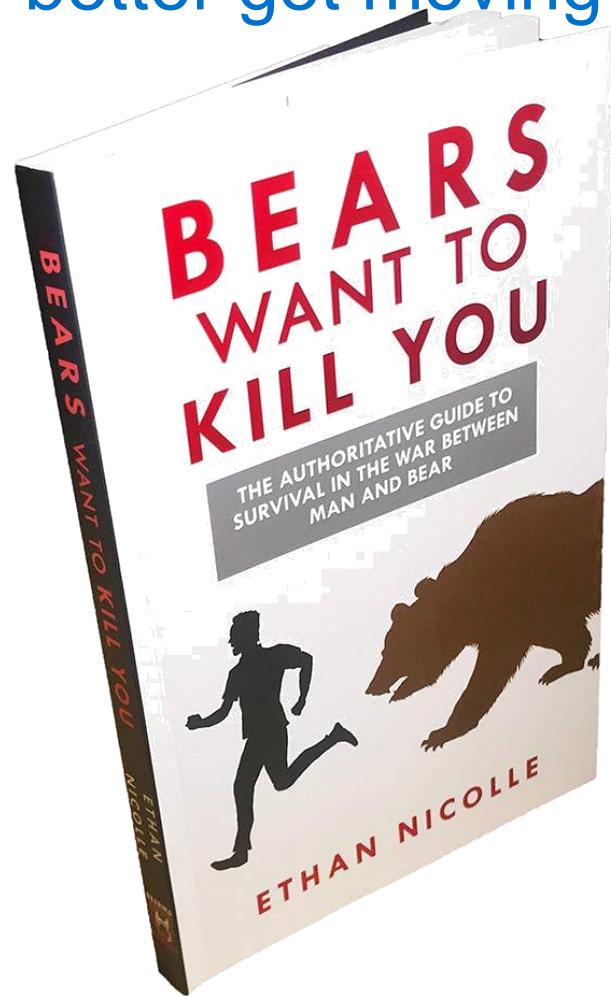
Disconnected
System
Models

iMBSE





Some additional parting motivation...
You better get moving



**WHAT TO DO IF YOU'RE BEING
CHASED BY A BEAR
WHILE ON FIRE**





2021
Annual **INCOSE**
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MBSE Workshop

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