29th Annual INCOSE international symposium

Orlando, FL, USA

July 20 - 25, 2019

Systems Engineering

Transforming Digital Transformation

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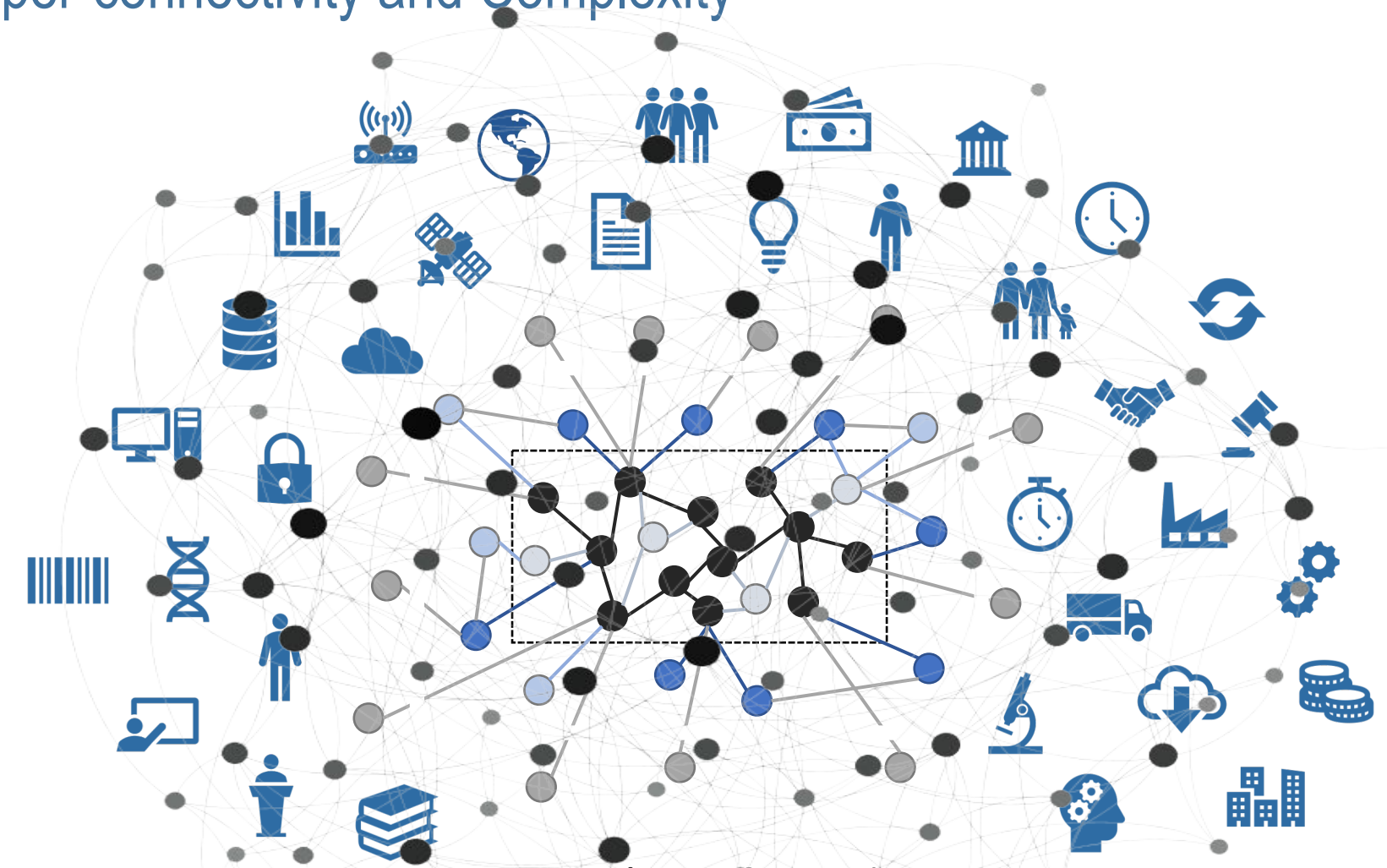
System Strategy, Inc. (SSI)

www.incose.org/symp2019

Systems Complexity

Hyper-connectivity and Complexity



System Elements & Interactions

External Elements & Interactions

Increased Density of System Elements & Interactions

Increased Density of System External Elements & Interactions

Increased Interactions Between External Elements

Expanding System Domain Boundary Increasing Interactions

$PL = N(N-1)/2$

N=Nodes

PL=Potential Links

Potential System Configurations = 2^{PL}

N=20, PL =190, PSC = 2^{190*}

**Number of known atoms in the universe ~ 2^{158} and 2^{246}*

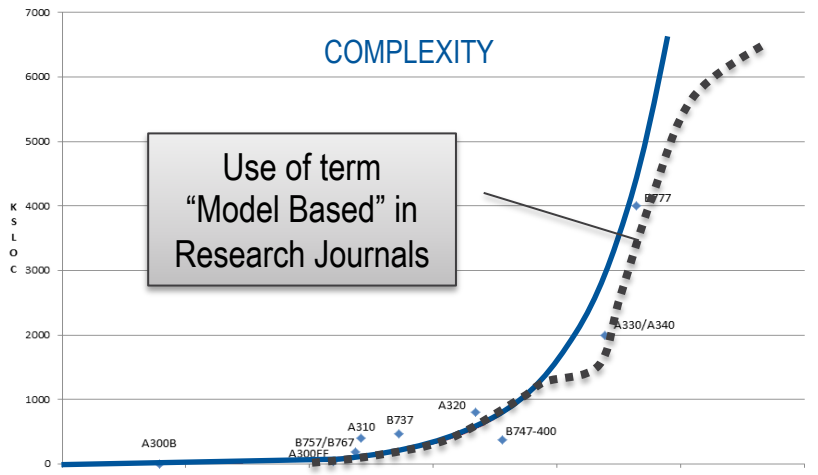
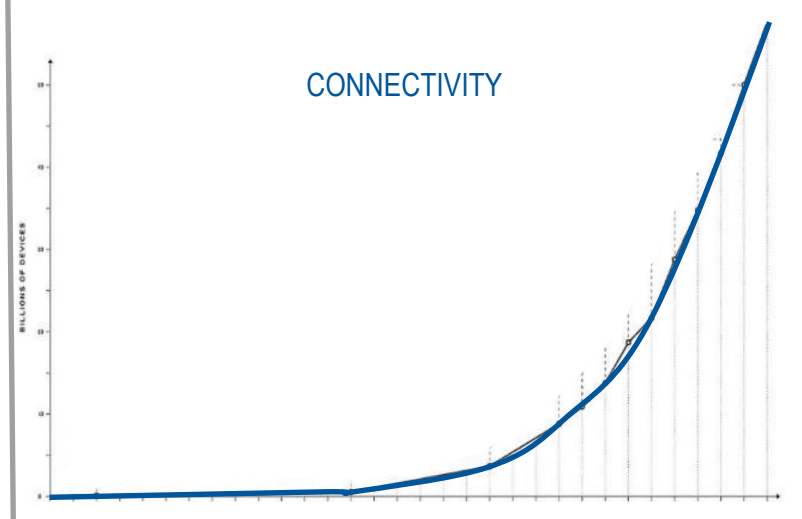
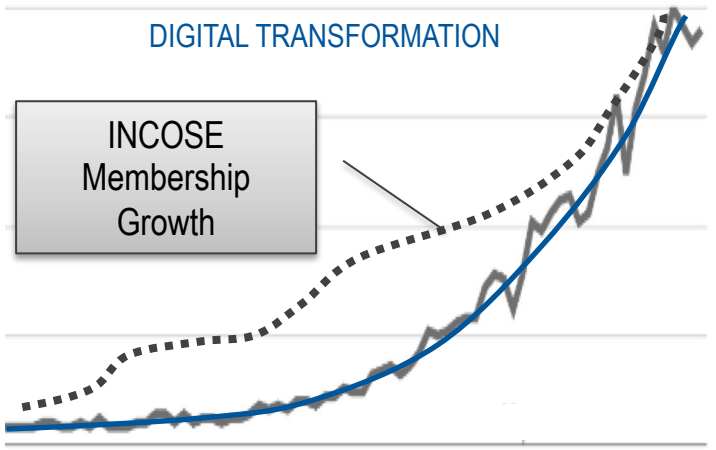
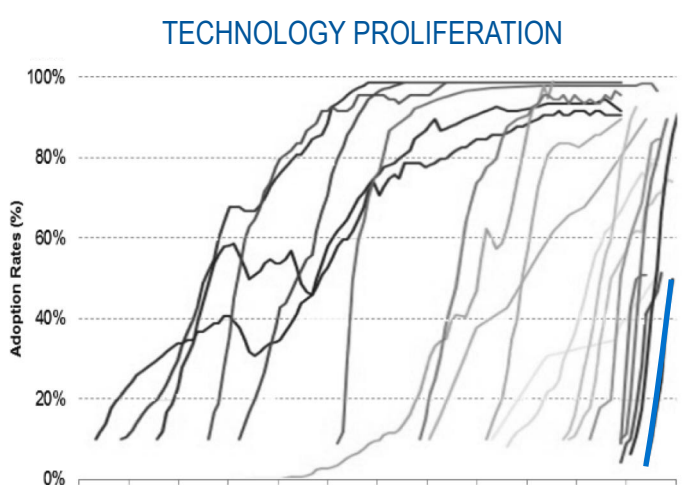
The Context for Digital Transformation and MBSE

"Today more and more design problems are reaching insoluble levels of complexity."[1]

"At the same time that problems increase in quantity, complexity and difficulty, they also change faster than before."[1]

"Trial-and-error design is an admirable method. But it is just real world trial and error which we are trying to replace by a symbolic method. Because trial and error is too expensive and too slow."[1]

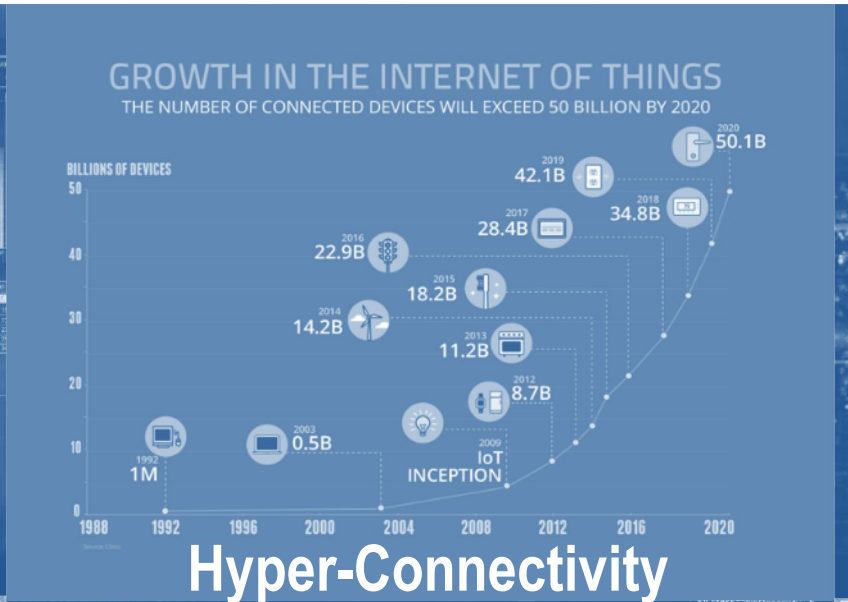
NSF is calling for methods to conceptualize and design for the deep interdependencies inherent in Cyber-Physical Systems.

	INTERNAL	EXTERNAL
SYSTEM		
CONTEXT		

1. Christopher Alexander, "Notes on the Synthesis of Form" Harvard University Press, Cambridge Massachusetts, 1964

Trends and Technologies Driving Digital Transformatoin

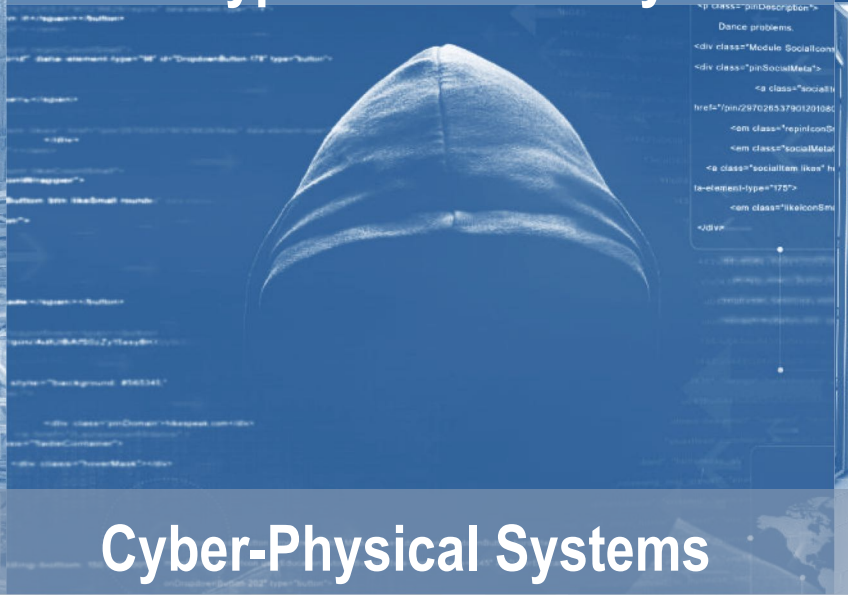
Data Rich Environments



Hyper-Connectivity

Artificial Intelligence

Industry 4.0



Cyber-Physical Systems

High Performance Computing

"When the rate of external change exceeds the rate of internal change, the end of your business is in sight."

Jack Welch

model based

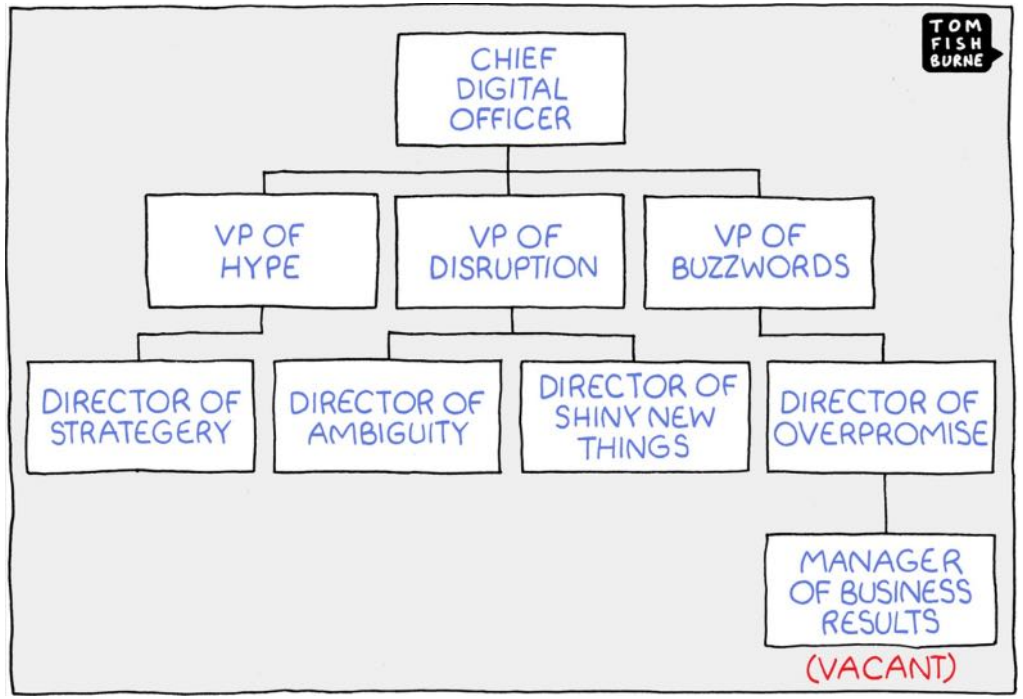
Systems Engineering

is the essential discipline for

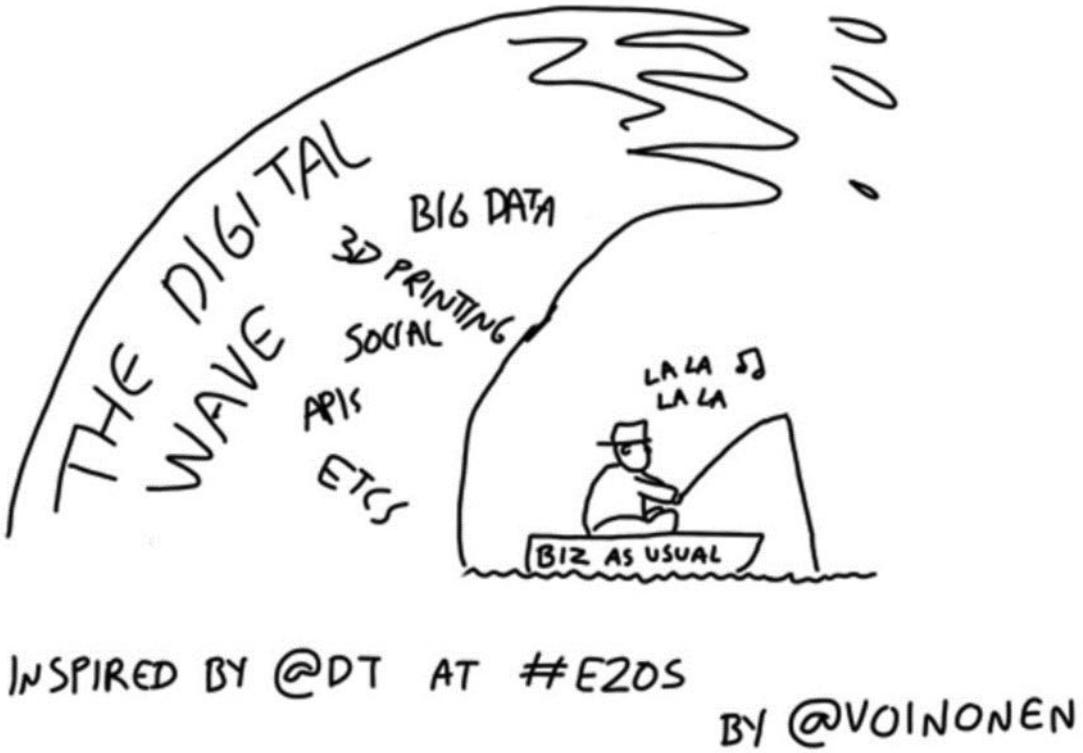
Digital Transformation

Systems Engineering Transformation

The Digital Transformation Spectrum



Digitally Zealous



Digital Denial

- The previous state is unrecognizable
- The world view from later phases is completely new
- It doesn’t happen overnight, it takes time, and effort

INCOSE Vision 2025

Transforming Systems Engineering

Systems engineering will lead the effort to **drive out unnecessary complexity** through well-founded architecting and deeper system understanding

A **virtual engineering environment** will incorporate modeling, simulation, and visualization to support all aspects of systems engineering by enabling improved prediction and analysis of complex emergent behaviors.

Composable design methods in a virtual environment **support rapid, agile and evolvable designs of families of products**. By combining formal models from a library of component, reference architecture, and other context models, different system alternatives can be quickly compared and probabilistically evaluated.

From: Model-based systems engineering has grown in popularity as a way to deal with the limitations of document-based approaches, but is still in an early stage of maturity similar to the early days of CAD/CAE.

To: Formal systems modeling is standard practice for specifying, analyzing, designing, and verifying systems, and is fully integrated with other engineering models. System models are adapted to the application domain, and include a broad spectrum of models for representing all aspects of systems. The use of **internet-driven knowledge representation** and immersive technologies enable highly efficient and **shared human understanding** of systems in a virtual environment that span the full life cycle from concept through development, manufacturing, operations, and support.

https://www.incose.org/docs/default-source/aboutse/se-vision-2025.pdf?sfvrsn=b69eb4c6_4

MBSE Top Enablers, Needs and Obstacles

Documents to Models

Enablers
- Translate models into decision maker language
- Ability to analyze quickly, proper level of fidelity
- Change management best practices

Needs
- Models need to answer stakeholder questions
- Connect modeling to programmatic success
- Demonstration how modeling speeds innovation

Obstacles
- Why change, what is the ROI
- Inability to know if model used is reliable; VVUQ
- Up front costs in resources, time to learn etc.

Process / Methods

Enablers
- Clearly demonstrate the value of system model(s)
- Models uncover errors in existing artifacts
- Aid an early adopter with a pain point

Needs
- Systems engineering and domain ontologies
- Common MBSE methods and practices
- Better ability to review model quality/accuracy

Obstacles
- Contracting, Intellectual Property and Policy
- Use of requirements documents versus models
- Benefits are not obvious but they should be

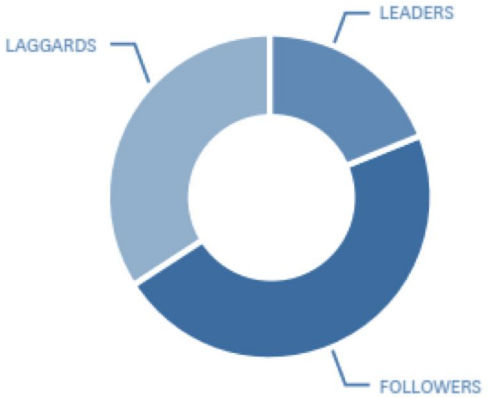
Model Based ROI

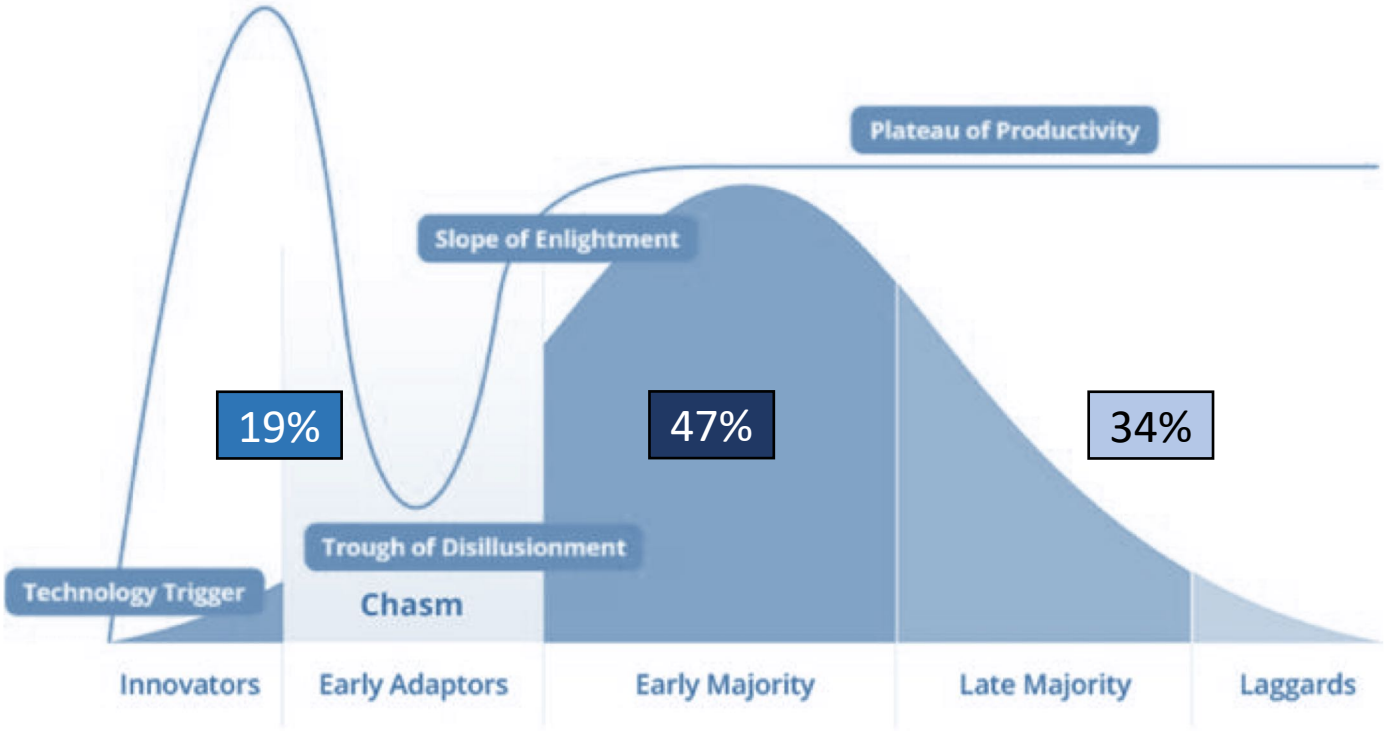
Enablers
- Seeing through the “Mystique” of MBSE
- Framework to view ROI by process area
- Capitalizing models as intellectual property

Needs
- Baseline to compare MBSE application Viewpoint of ROI from multiple stakeholders
- Covering all of ISO 15288 process areas

Obstacles
- Weak Systems Eng. foundation for MBSE
- Lack of understanding; one size does not fit all
- Expressing “Soft” versus “Hard” ROI for MBSE

Accelerating: Technology Adoption – Hype and Chasm





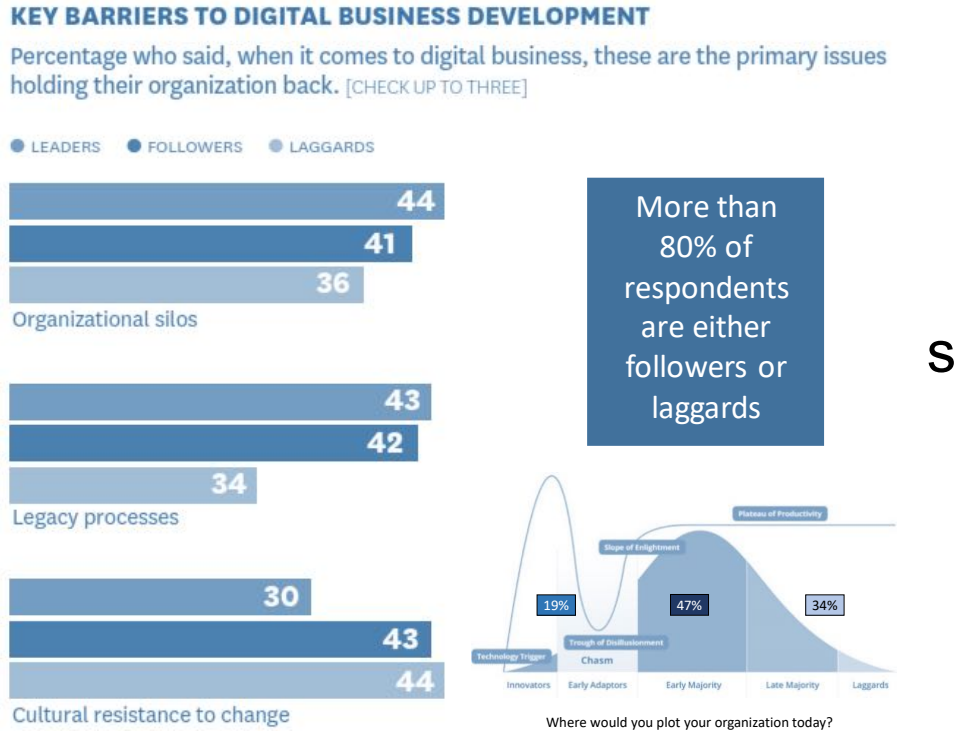
Rating of company's digital maturity in leadership and management[5]

More than 80% of respondents are either followers or laggards

Where would you plot your organization today?

1. Hype Cycle is a branded graphical presentation developed and used by IT research and advisory firm Gartner
2. Hype Cycle Graphic: https://en.wikipedia.org/wiki/Hype_cycle
3. Moore, Geoffrey A. "Crossing the Chasm – and Beyond" Strategic Management of Technology and Innovation Third Edition 1996
4. Hype Cycle, Chasm Combined Graphic: http://www.datameer.com/blog/big-data-analytics-perspectives/big-data-crossing-the-chasm-in-2013.html
5. Driving Digital Transformation: New Skills for Leaders, New Role for the CIO, Harvard Business Review

Transformation: Change Management



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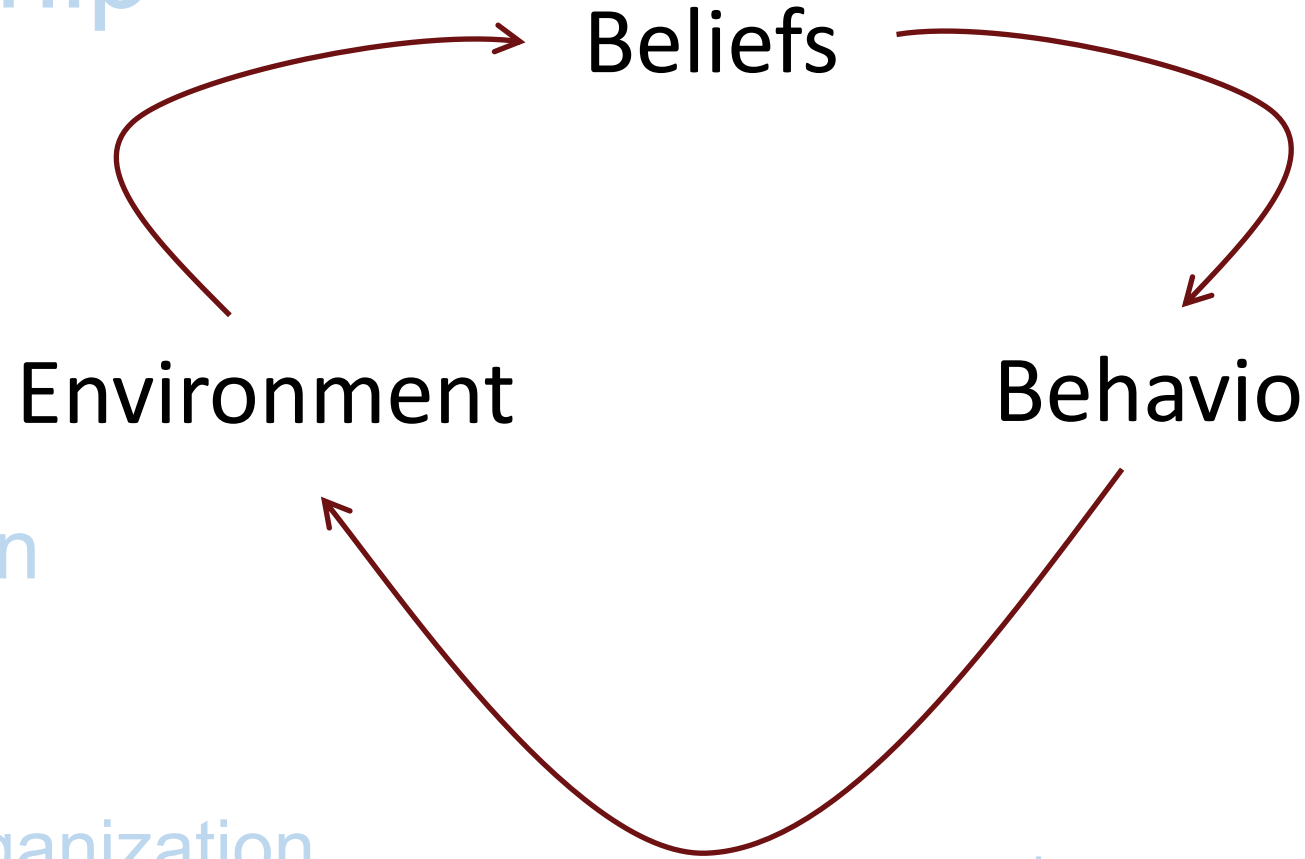
Consider:

ABP = CM(OE + PR + IT)

- ABP = Achieving Breakthrough Performance
- OE = Organizational Environment
- BPR = Business Process Reengineering
- IT = Information Technology
- CM = Change Management

Transformation is very much a people focused endeavor.

Transformation: Change Beliefs to affect Outcomes



Leadership

Method

Funding

Experience

Collaboration

Culture

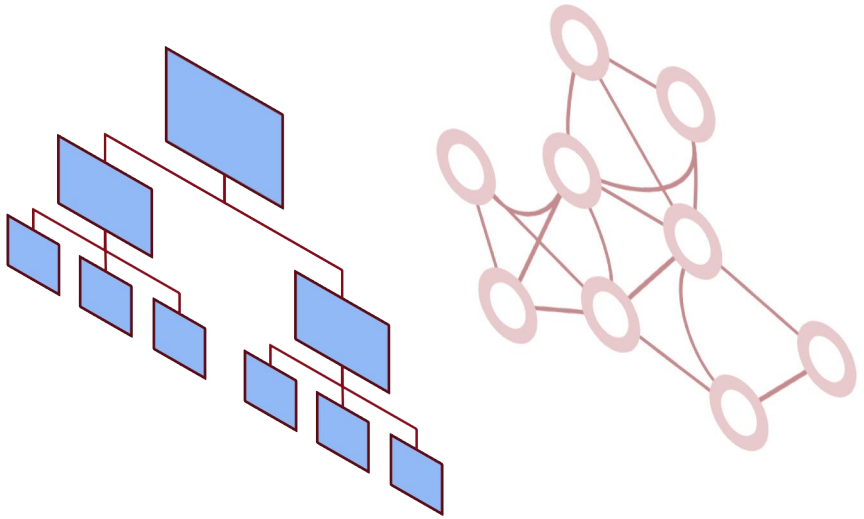
Organization

Language

Organizational Transformation - Creating a Sense of Urgency

Leading Change: John P. Kotter
Eight-Step Process for undertaking major change.

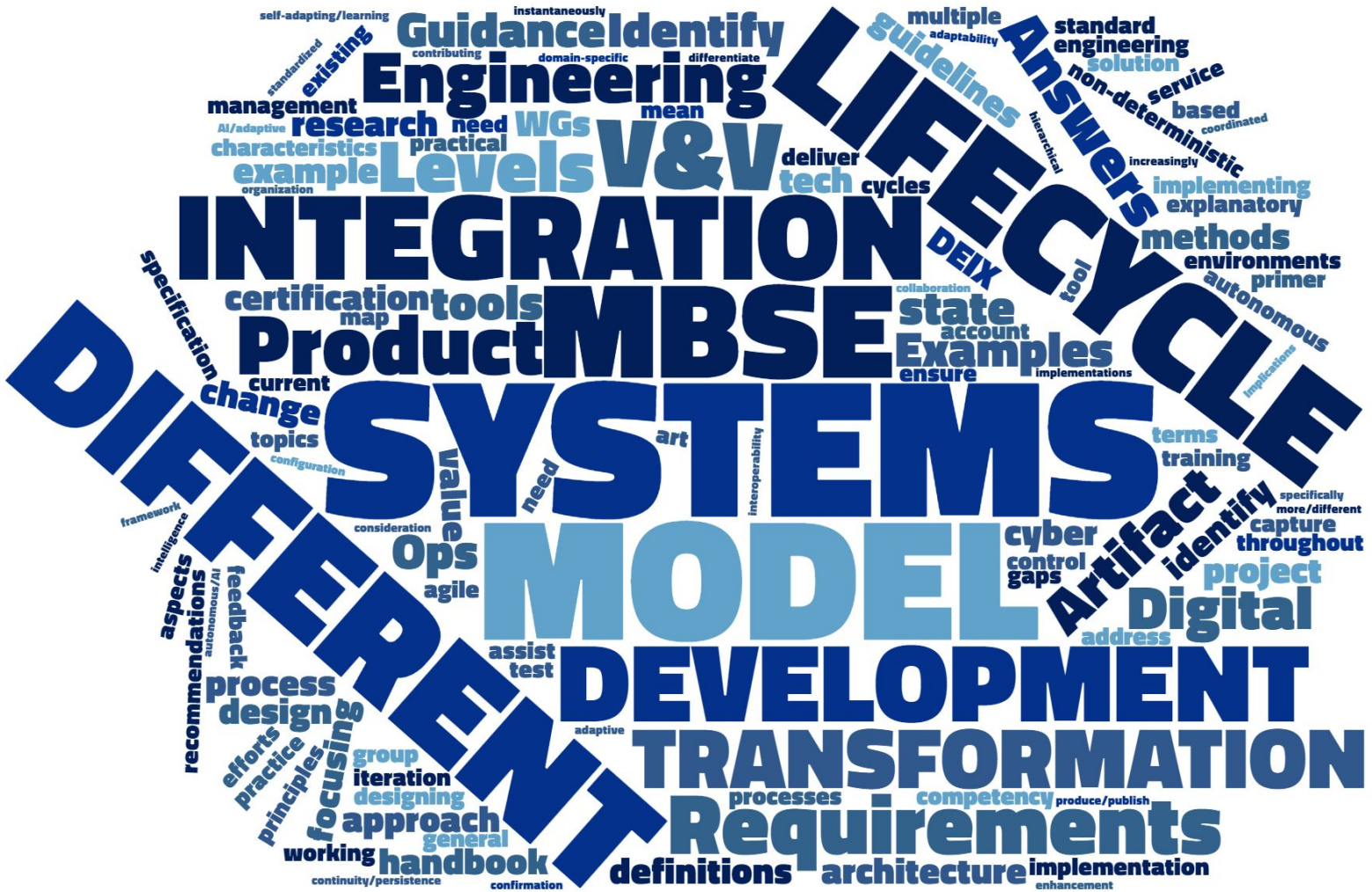
1. ***Creating a Sense of Urgency***
2. Building a Guiding Coalition
3. Developing a Strategic Vision and Initiatives
4. Expanding the Network of Change Agents
5. Empowering Broad-Based Action
6. Generating Short-Term Wins
7. Consolidating Gains and Producing More Change
8. Instituting Change in the Culture



Accelerate: John P. Kotter
Kotter's new book *Accelerate* refines principals and adds the concept of a "dual operating system".

- One operating system is characterized by management, hierarchy and driven toward efficiency
- The other is characterized by leadership, networks, strategic acceleration and driven to innovate.
- Operating systems align nicely with the System of Innovation framework used in INCOSE's Agile and Patterns Working Groups where we see the distinct roles of executing and managing systems development and managing knowledge and what is learned in execution.

Systems Modeling Transformation



Will Models Run the World?

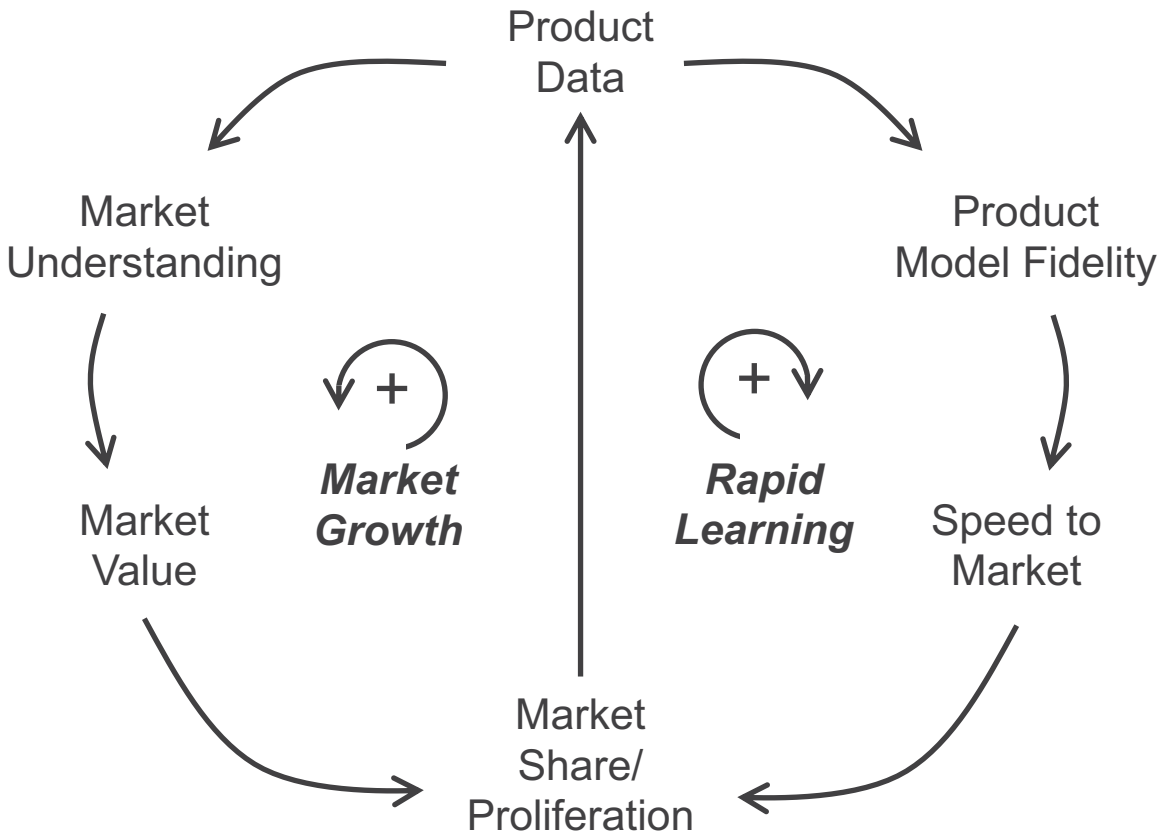
THE WALL STREET JOURNAL

Models Will Run the World

By Steven A. Cohen and Matthew W. Granade – August 19, 2018

- If software ate the world, models will run it.
- There is no shortage of hype about artificial intelligence and big data, but models are the source of the real power behind these tools.
- Their products get better, allowing them to collect more data, which allows them to build better models, making their products better, and onward.
- The software revolution has transformed business. What's next? Processes that constantly improve themselves without need of human intervention.

What happens when our models are right?



What happens when our models are wrong?

MBSE Evolution

SE Practices for Describing Systems

Past / Now

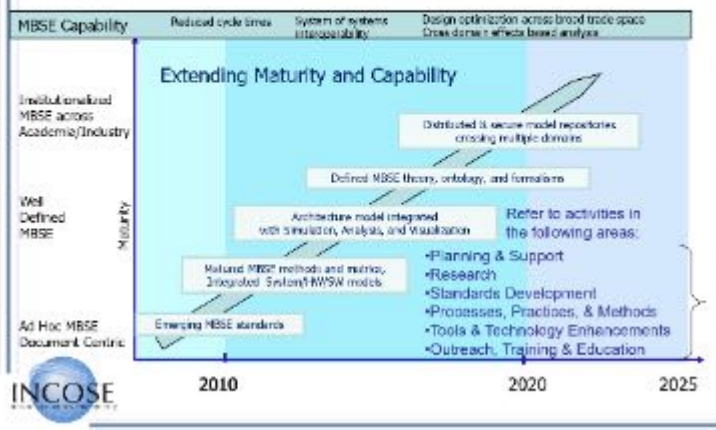
- Specifications
- Interface requirements
- System design
- Analysis & trade-off
- Test plans

Now / Future

- Moving from document-centric to model-centric (from PowerPoint/Excel/Word to SysML plus more)
- Analogy: Moving from physical drafting to 2D CAD to 3D feature-based CAD

INCOSE MBSE Roadmap

International Workshop
Jan 21–24, 2012
Jacksonville, FL USA



A MODEL-BASED ENGINEERING (MBE) MANIFESTO

PURPOSE: *To motivate the transformation to Model-Based Engineering.*

Faced with increasing system complexity, interdependencies, breakdown of document-based methods, and other challenges, MBE provides the transformation in which we value:

1. *Information over artifacts*
2. *Integration over independence*
3. *Expressiveness with rigor over flexibility*
4. *Model usage over model creation*

We value the items on the right, but not at the sacrifice of the items on the left.

WITH THESE PRINCIPLES:

On behalf of stakeholders, MBE increases emphasis on describing the nature and content of the information produced and consumed, compared to the traditional emphasis on engineering process and procedure.

We recognize that—independent of specific Information format, structure, language, syntax, the sequence or order of its production and consumption, and the domains and environments of our projects—the underlying nature (semantics) of the essential information we seek to discover and produce is invariant because of the very nature of engineering.

An essential and dynamically changing property of model information is its credibility to those people and processes which will consume that information. The critical nature of some intended uses of model information sets a higher bar on required investment in model verification, validation and uncertainty quantification.

Principles of human-machine interaction applied to the targeted stakeholders are vital to success. Application of advanced visualization methods and augmented intelligence capabilities can advance that success.

We seek an extended team across engineering disciplines with common and integrated understanding of the identity and nature of the model information as well as its content.

We seek effective enterprise-wide reuse of model-based information to more fully leverage past individual or local learning.

Systems engineering performed according to the above principles is required for the Engineering System itself, a complex and evolving system.

THE TEAM:

The team was assembled by invitation, intentionally drawing together different perspectives.

Ed Carroll
Team lead-Sandia National Laboratories – Engineering Methods Research

Nancy Hayden
SNL – Autonomous Systems/ Engineering Policy

Sharon Trauth
SNL-Systems Engineering/ MBSE Practice

Dana Grisham
SNL-Data Governance/Agile Methods

Chris Schreiber
Lockheed Martin Space Systems-Systems Engineering Modernization

Bill Schindel
ICTT Systems Sciences Systems Sciences

ENGILITY
Frank Salvatore
Engility Corp-Systems Engineering/ Data Taxonomy

Eliot Rich
Univ at Albany, SUNY-System Dynamics

Teleconference participation from:

Steve Jenkins
JPL-Systems Engineering

Anne O'Neil
Anne O'Neil Consulting-Organizational Transformation

Shifting our focus to System Information

1 Content

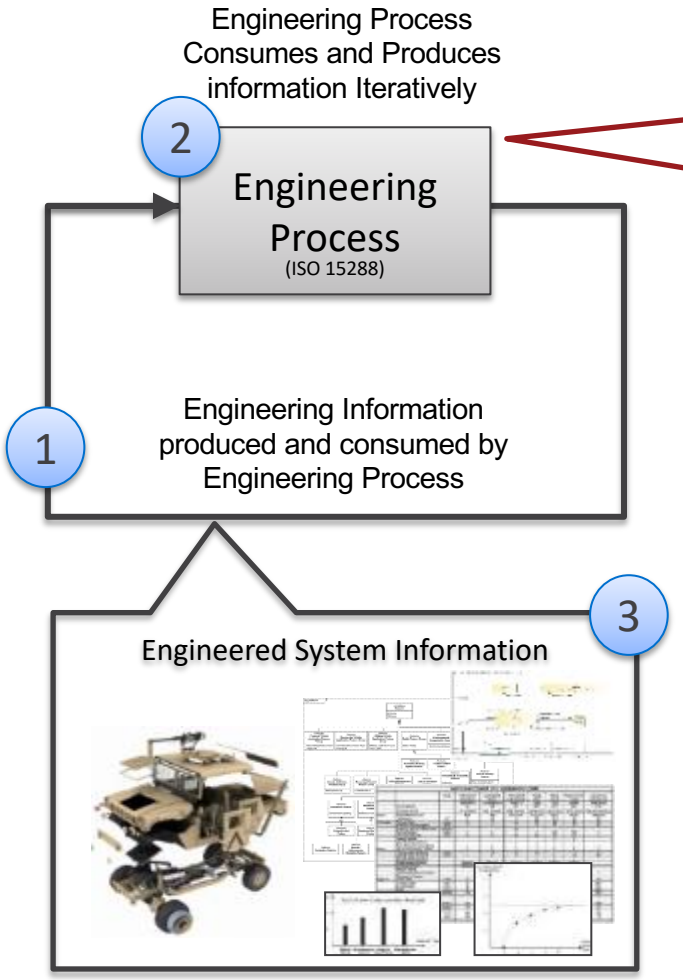
Key system information that must be produced, consumed and maintained consistently across the life cycle

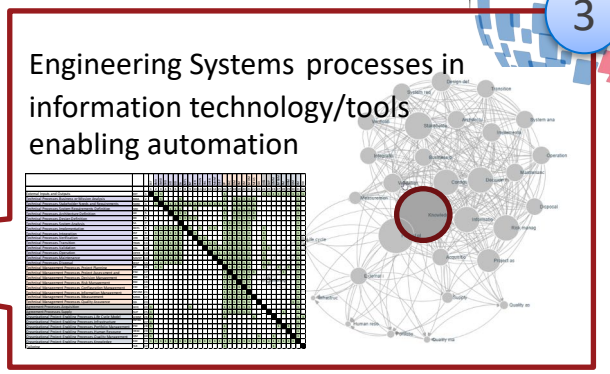
2 Process

Interrelated activities that direct what information goes where, when and to whom

3 Automation

Digital federation, integration, automation through the use of tooling, standards, common interfaces etc.





2. Processes

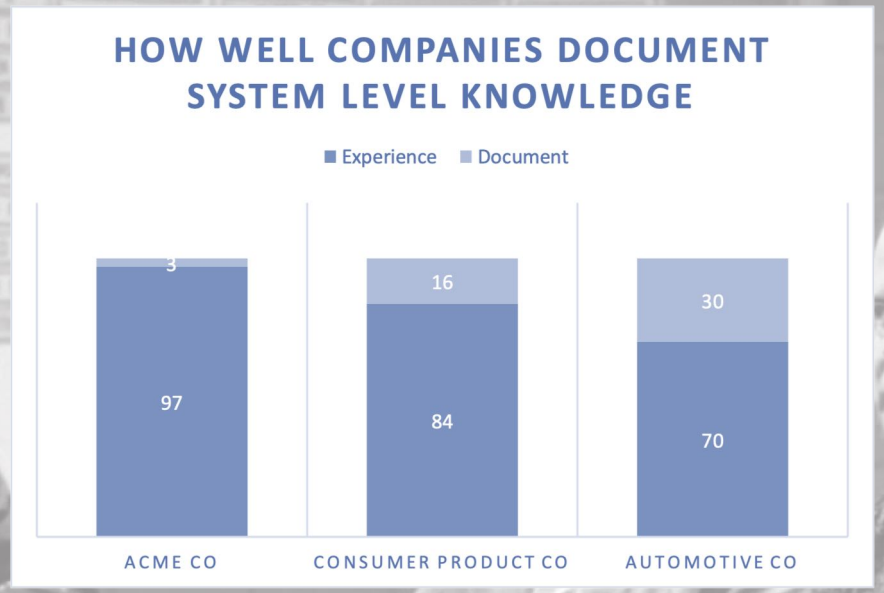
- Leverage existing ISO 15288 Systems Engineering Life Cycle Management Processes
- Design and modeling the Systems Engineering Process and Environment for MBSE.

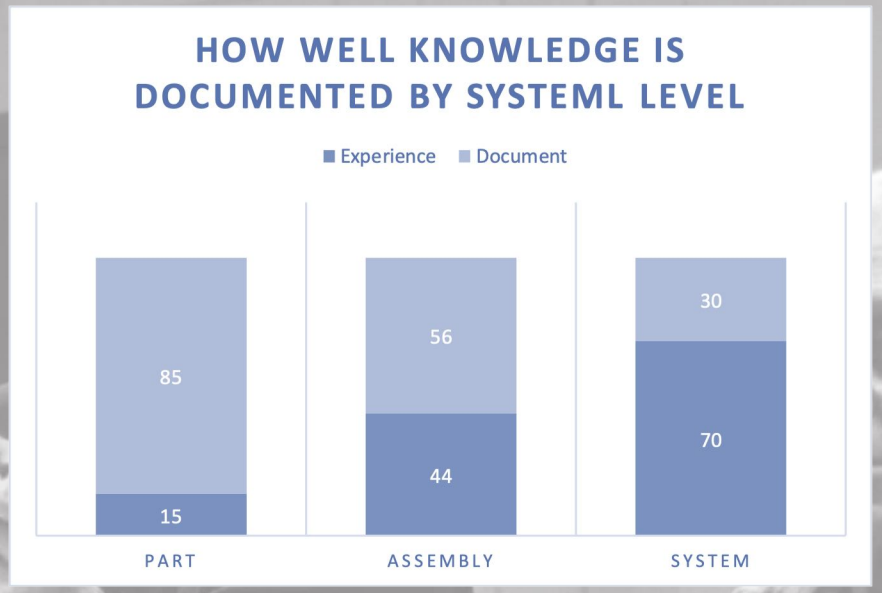
1. System Information

- A strong underlying metamodel
- Ensuring the essential system concepts underpin our models
- Science, Engineering, Math…

http://www.omgwiki.org/MBSE/doku.php?id=mbse:pbse

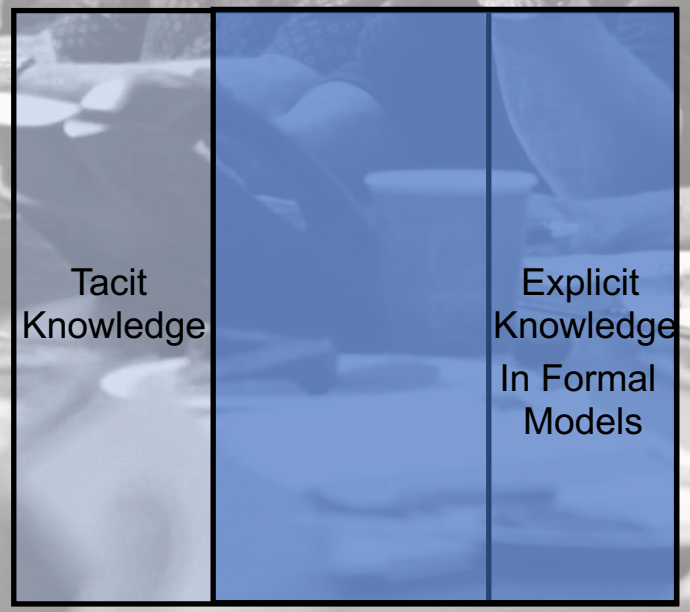
How Well Does Your Engineering Enterprise Capture, Model and Manage Knowledge?

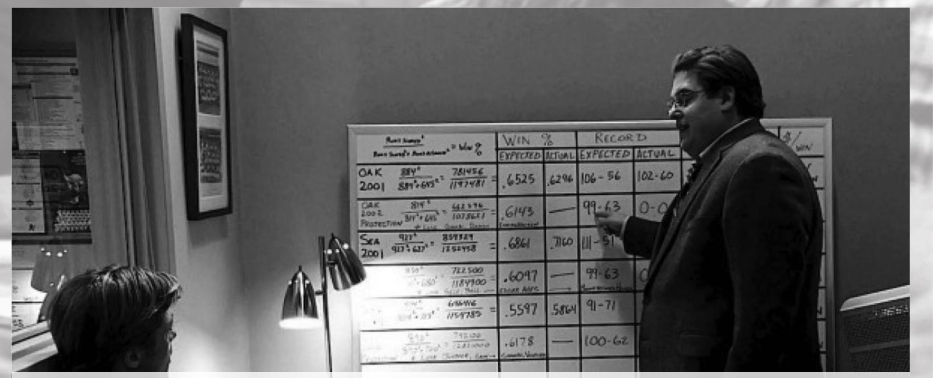




Knowledge Documentation Data from MIT Systems Engineering ESD.33 June 2010

“Domain experts” internalize patterns:
Human experts influence our projects, using their experience, intuition, informed judgment.





Engineers explicitly model knowledge

Data, information and knowledge used to overcome bias and identify opportunities.

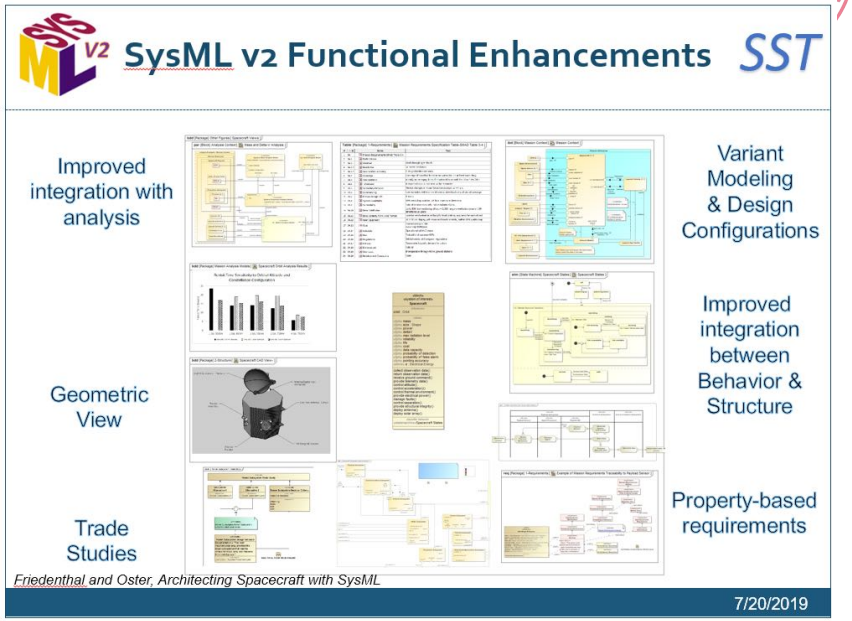
Lewis, Michael. Moneyball: The Art of Winning an Unfair Game. 2003. | Movie: Moneyball, Columbia Pictures presents ; Michael de Luca Productions Culver City, CA : Sony Pictures Home

MBSE Foundational Activities

SysML v2 Objectives:

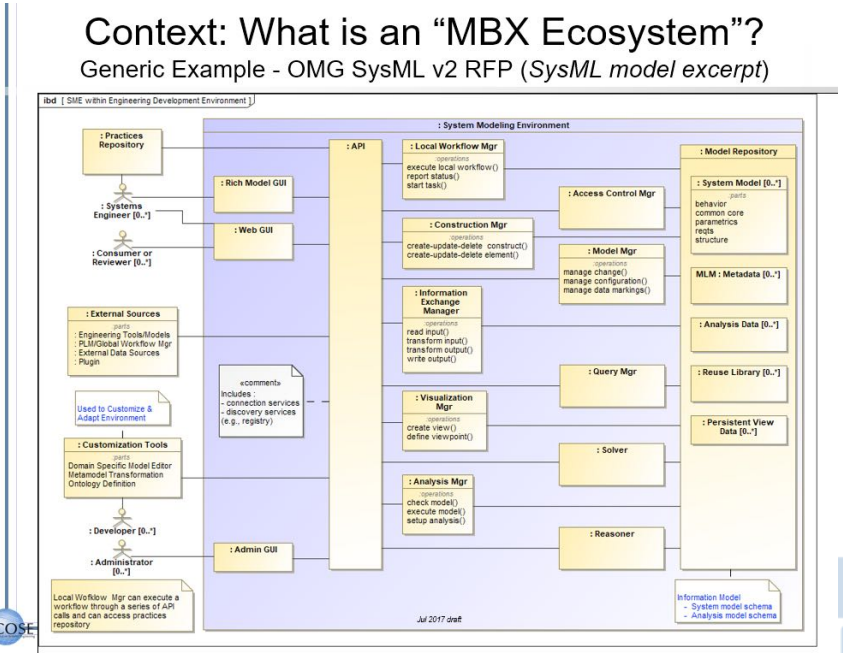
Increase adoption and effectiveness of MBSE by enhancing…

- Precision and expressiveness of the language
- Consistency and integration among language concepts
- Interoperability with other engineering models and tools
- Usability by model developers and consumers



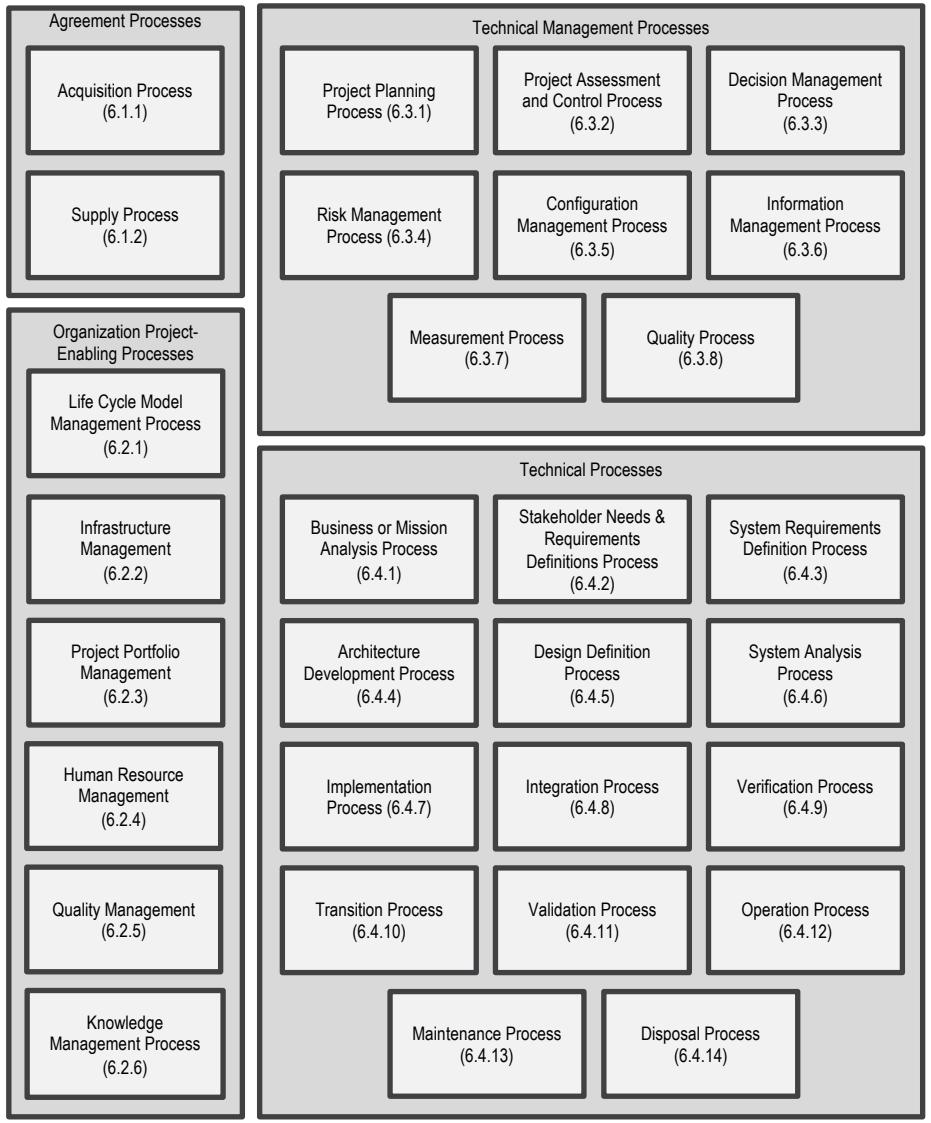
ST4SE / MBSE Patterns WG

- Improve shared systems engineering community-wide knowledge for more effective life cycle engineering of systems, through the identification, availability and distribution, and use of model-based ontological patterns and related semantic web technologies.

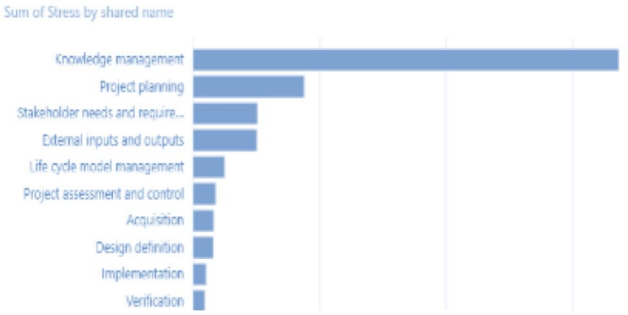


Enabling MBX Ecosystems

A Known Framework Systems Engineering Knowledge

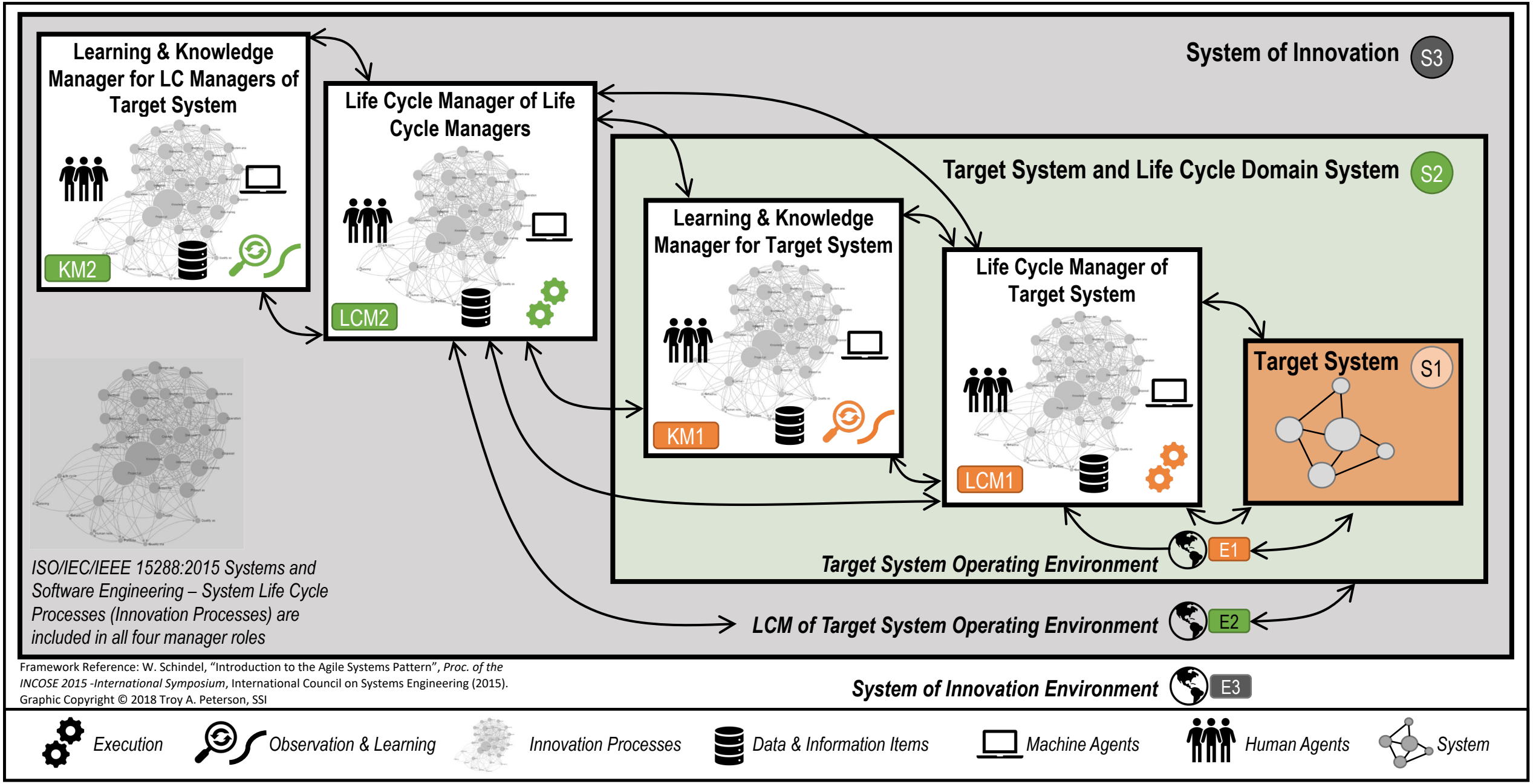


ISO 15288



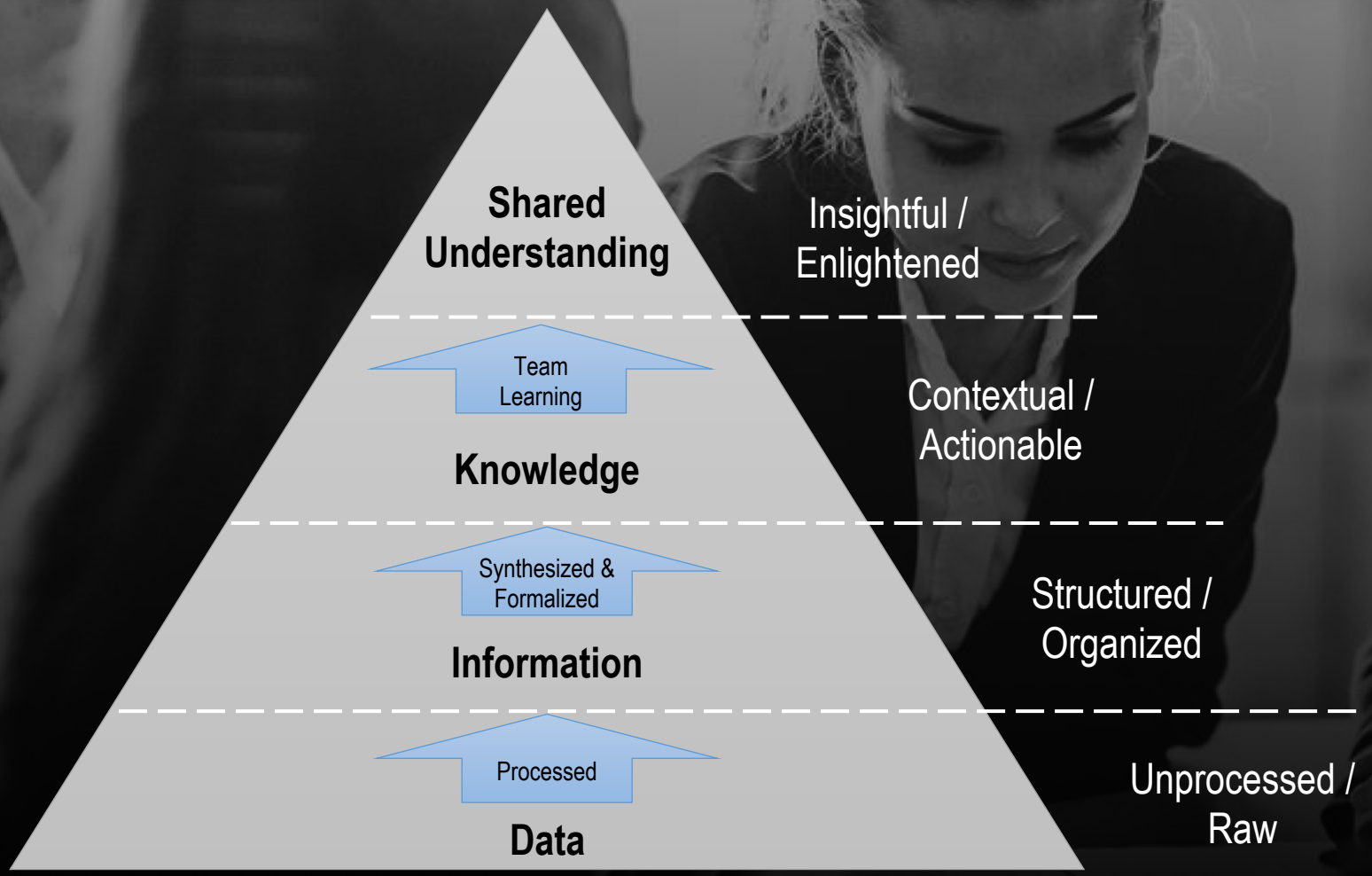
ISO 15288 Process Area interactions from INCOSE Handbook N²

Agile Systems Engineering Life Cycle Management Model



Framework Reference: W. Schindel, "Introduction to the Agile Systems Pattern", *Proc. of the INCOSE 2015 -International Symposium*, International Council on Systems Engineering (2015).

Model Based Methods Improve Shared Understanding



Virtual Engineering
Part of The Digital Revolution

Vision25 Systems Engineering
INCOSE International Council on Systems Engineering
A WORLD IN MOTION
Systems Engineering Vision • 2025

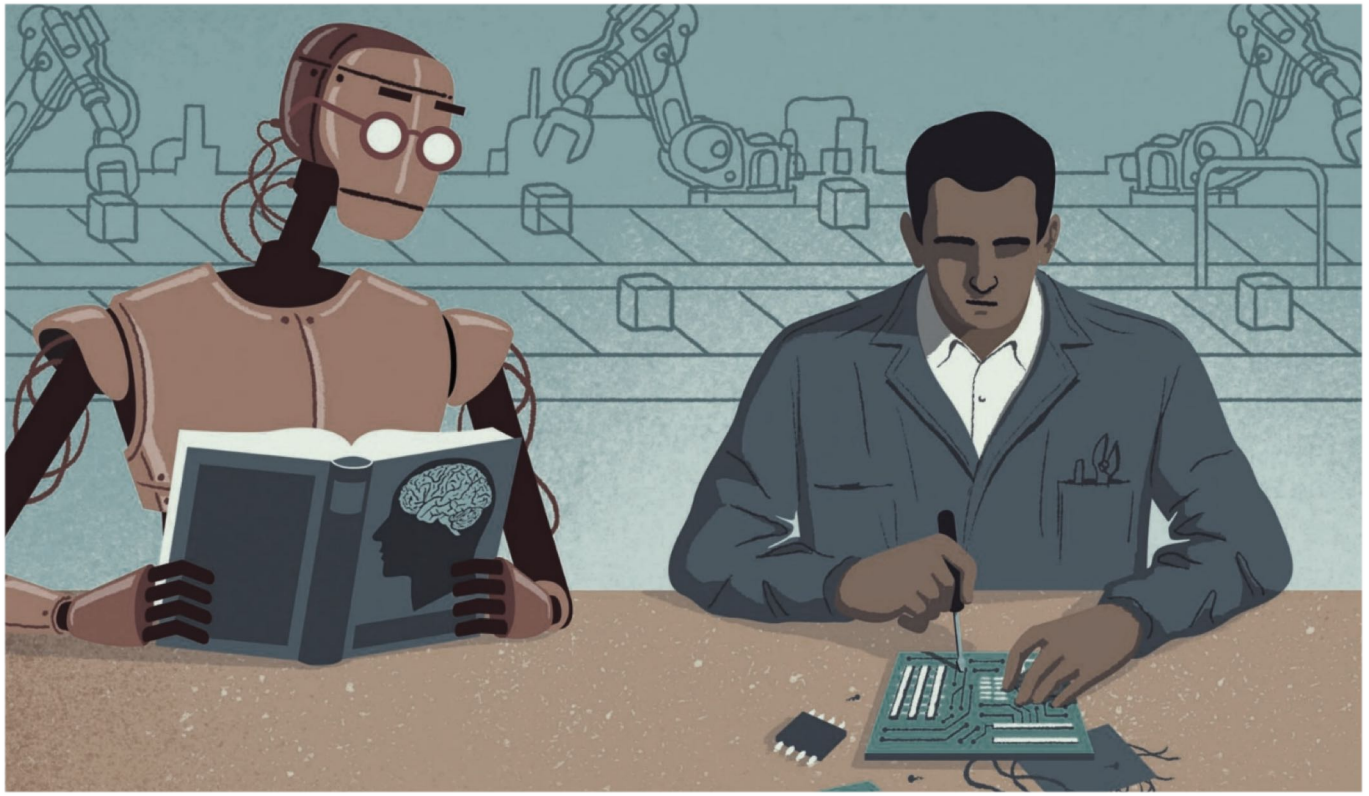
From: …Limitations of document-based approaches, but is still in an early stage of maturity similar to the early days of CAD/CAE.

To:…The use of internet-driven knowledge representation and immersive technologies enable highly efficient and **shared human understanding** of systems in a virtual environment that span the full life cycle from concept through development, manufacturing, operations, and support.

Employ Augmented Intelligence (AuI)

- Reinforce knowledge in formal models and pattern based methods with AuI
- Maximize Human + Machine Collaboration
- Allocate work based on strengths
- The Human + Machine combined "team" is more effective than either in isolation.

Remember: AuI = Human + AI
AuI > Human
AuI > AI



Kasparov's Law

weak human + machine + better process
beats
strong human + machine + inferior process.

Imperative: Use Models to Improve Outcomes

"Would you tell me, please," Alice asks the cat, "which way I ought to go from here?"

"Well", responds the Cheshire Cat, "That depends a good deal on where you want to get to."

"Oh, I don't much care where –" says Alice.

The Cheshire Cat responds "If you don't care where you are going, then it really doesn't matter which way you go."

Have a Goal
Know where you want to go…

The model is not the end game
Improved outcomes are…

Poor SE dooms MBSE
MBSE multiplies good SE

Lesson: Don't be Alice & Remember: Automating junk makes more junk automatically!

Imperative: Seek and Economical Description

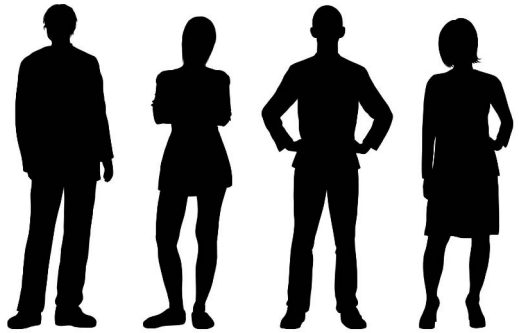
"…All models are wrong, but some are useful"

"Since all models are wrong the scientist cannot obtain a "correct" one by excessive elaboration. On the contrary following William of Occam he should ***seek an economical description*** of natural phenomena. Just as the ability to devise simple but evocative models is the signature of the great scientist so ***overelaboration and over parameterization*** is often the mark of mediocrity."

George E. P. Box

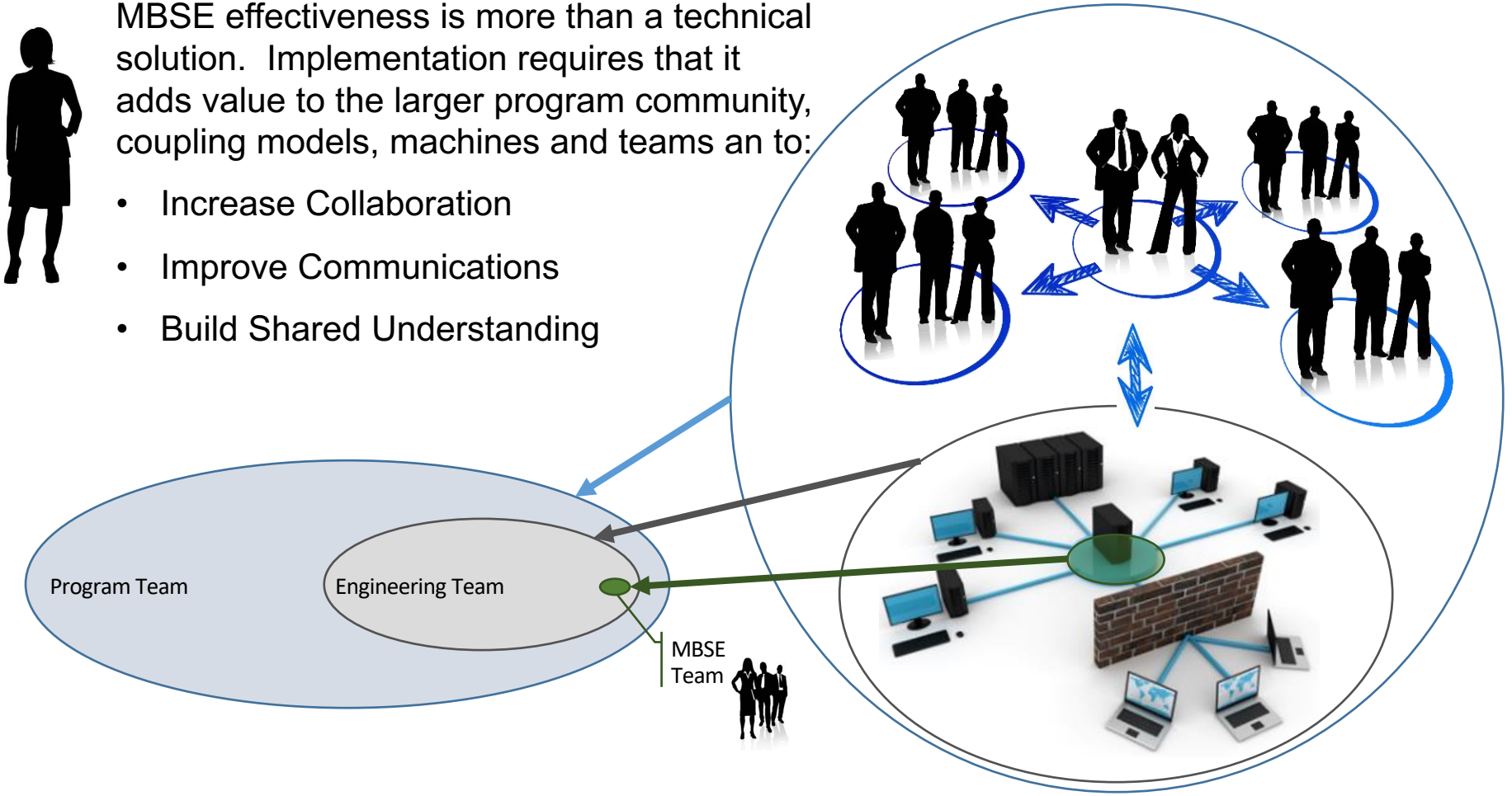
"…seek an economical description…"

Imperative: Add Value to the Larger Stakeholder Community



MBSE effectiveness is more than a technical solution. Implementation requires that it adds value to the larger program community, coupling models, machines and teams an to:

- Increase Collaboration
- Improve Communications
- Build Shared Understanding

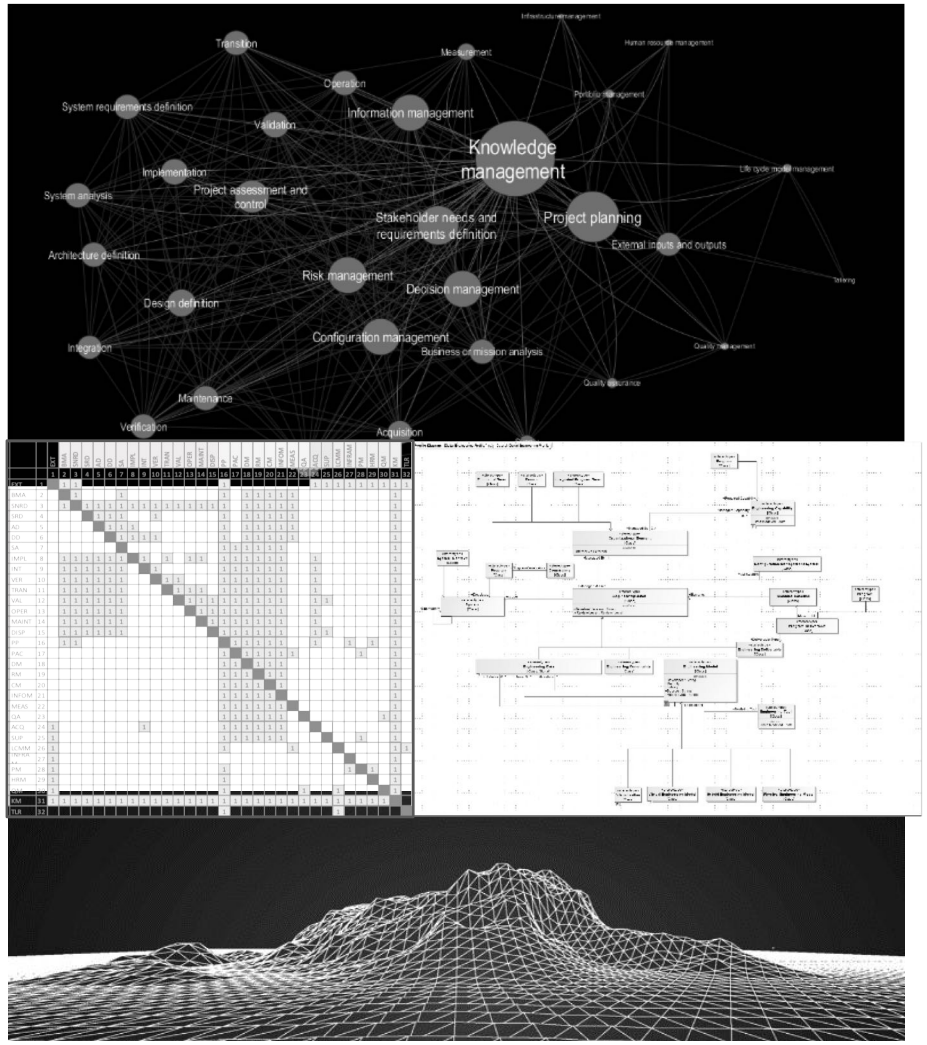


Imperative: Use Multiple Models

Evidence shows that people who think with models consistently outperform those who don't. And, moreover people who think with lots of models outperform people who use only one.

Scott E. Page "Model Thinking" Course Description

Models are powerful; they help us understand the world, they provide a path forward for our ideas, and they invoke action.



INCOSE Transformation Developments and Outcomes

Outcomes Achieved

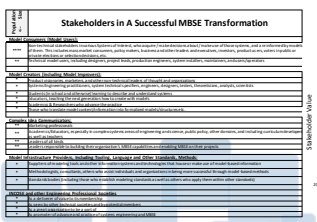
- **Supported incubation of >7 Challenge Teams/WGs**
- **Provided >35 INCOSE Transformation briefings**
- **INCOSE IS and IW MBSE Lightening Rounds**
- Model Wrapper / Features Packaging Framework
- Model Based Assessment Roadmap
- Model Based Stakeholder List
- Model Based Enablers & Roadblocks
- INCOSE Transformation Webinar
- Strategy & Action Plan
- Transformation website created
- Many Transformation Briefings

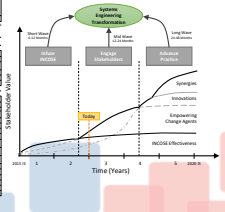
New/Related Developments

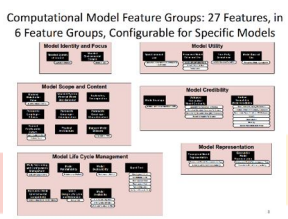
- Challenge Teams as Innovation Incubators
- Collaborative V&V of models with ASME
- Expanding and Developing new MOUs
- Supporting OCM effort within INCOSE
- MBSE FAQs Development
- Model Based Exemplars
- INCOSE MBSE Primer
- Model Based Value Briefing
- Supporting ST4SE: Semantic Technologies
- INCOSE Assessment Roadmap completion

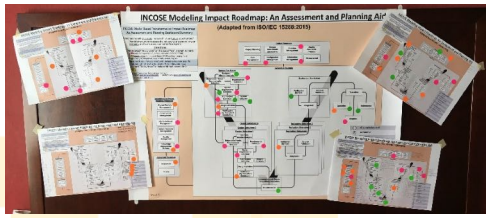
Next Steps

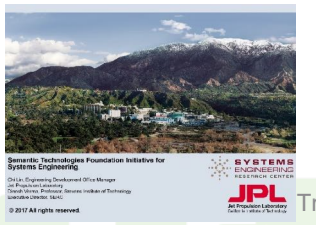
- Kickstart and Support Transformative INCOSE Activities
- Infuse Change Management principles across INCOSE
- Collaborate with FUSE, Vision etc.
- Establish a Sector Ambassador program to extend reach
- Improve communications (INSIGHT Transformation Corner Update webpage on incose.org)
- Update and refine metrics on Strategy
- Continue Working Standards review for changes related to model based

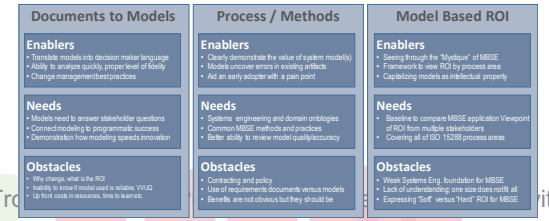


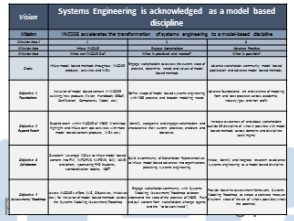












Systems Engineering Transformation Observation

A fundamental shift in the questions about MBSE has occurred over the last two years – from

Why & ROI?

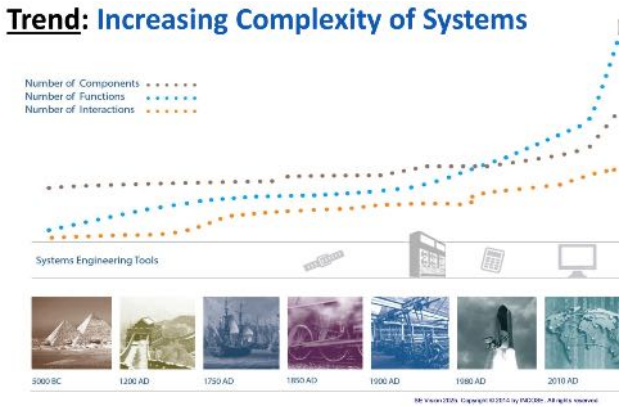
to

***Now* & How?**

INCOSE FUTURE Strategic Objective

- FuSE
- Transformation Initiative
- Organizational Change Management
- MBSE Incubator
- OCM to support Technical Product Adoption
- MBSE Benchmarking Study
- Virtual Models Community Network
- Modeling of ISO 15288 and availability
- Modeling of INCOSE and Products
- MBSE Value Briefing

INCOSE FuSE
Future of Systems Engineering



A Systems Community Initiative


Trouble
understanding
systems?
Model them

Facilitated Discussion

29th Annual INCOSE international symposium

Orlando, FL, USA

July 20 - 25, 2019

www.incose.org/symp2019

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Troy Peterson, SSI Vice President, and INCOSE Transformation lead is a recognized leader in developing model based solutions to speed innovation and solve complex systems challenges. He has led the delivery of numerous complex systems and methodologies while at SSI, Booz Allen and Ford Motor Company. His experience spans academic, non-profit, commercial and government environments across all lifecycle phases. Troy received a BS in Mechanical Engineering from Michigan State University, an MS in Technology Management from Rensselaer Polytechnic Institute and an advanced graduate certificate in Systems Design and Management from Massachusetts Institute of Technology. He also holds INCOSE CSEP, PMI PMP, and ASQ Six Sigma Black Belt Certifications.

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