Transformation Initiative

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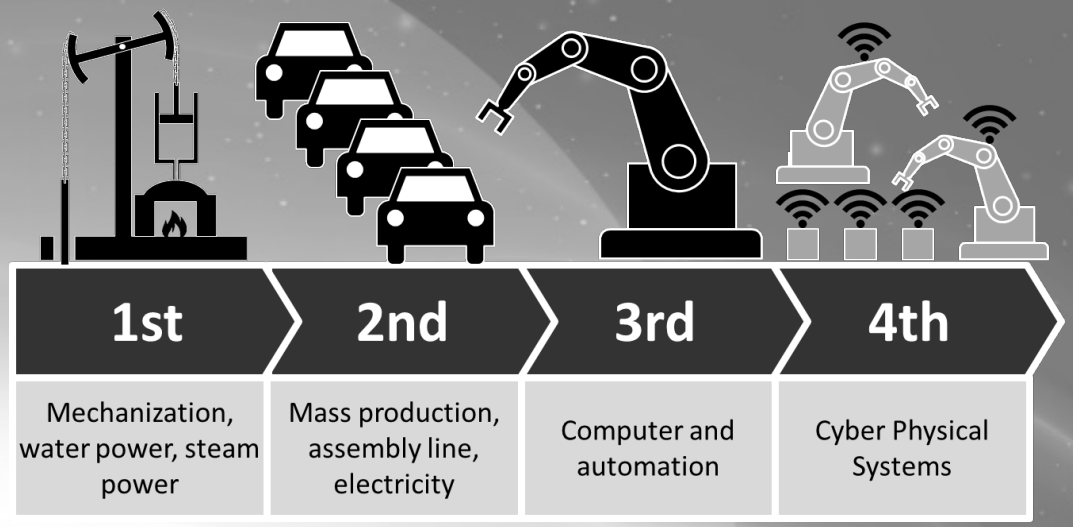


Digital Transformation

"The world is entering the Fourth Industrial Revolution. Processing and storage capacities are rising exponentially, and knowledge is becoming accessible to more people than ever before in human history. The future holds an even higher potential for human development as the full effects of new technologies such as the Internet of Things, artificial intelligence, 3-D Printing, energy storage, and quantum computing unfold."

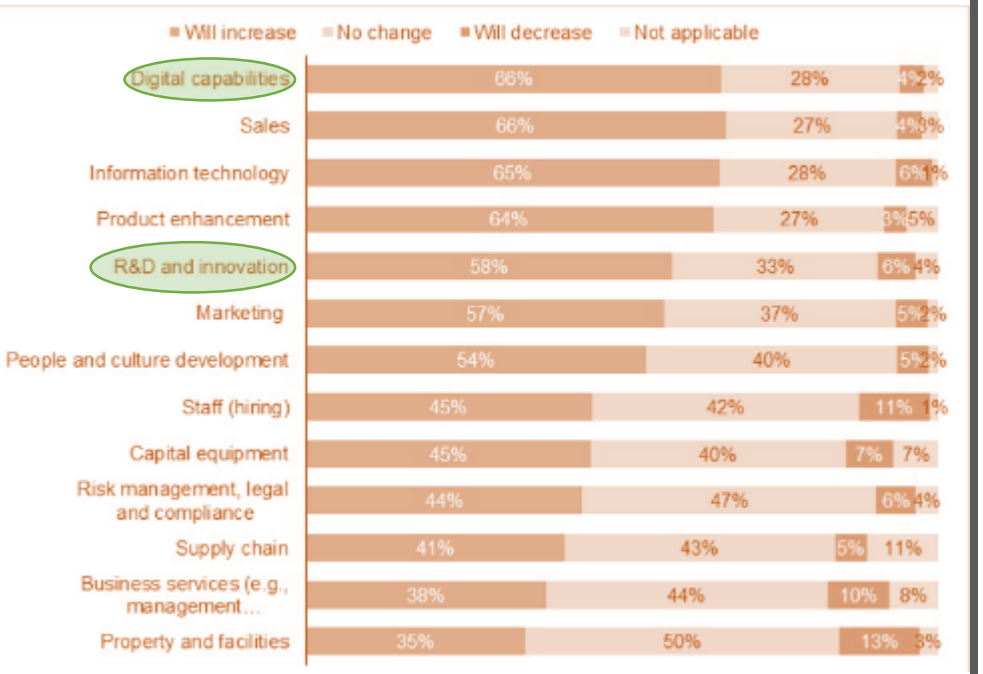
The Global Information Technology Report
Innovating in the Digital Economy - 2016
World Economic Forum

Deep Shift
Technology Tipping Points and Societal Impact

AI
Big Data
IoT
Digitization of Matter
HPC
Industry 4.0

Digital Transformation Survey Data

Digital Business Gains Executive Mindshare

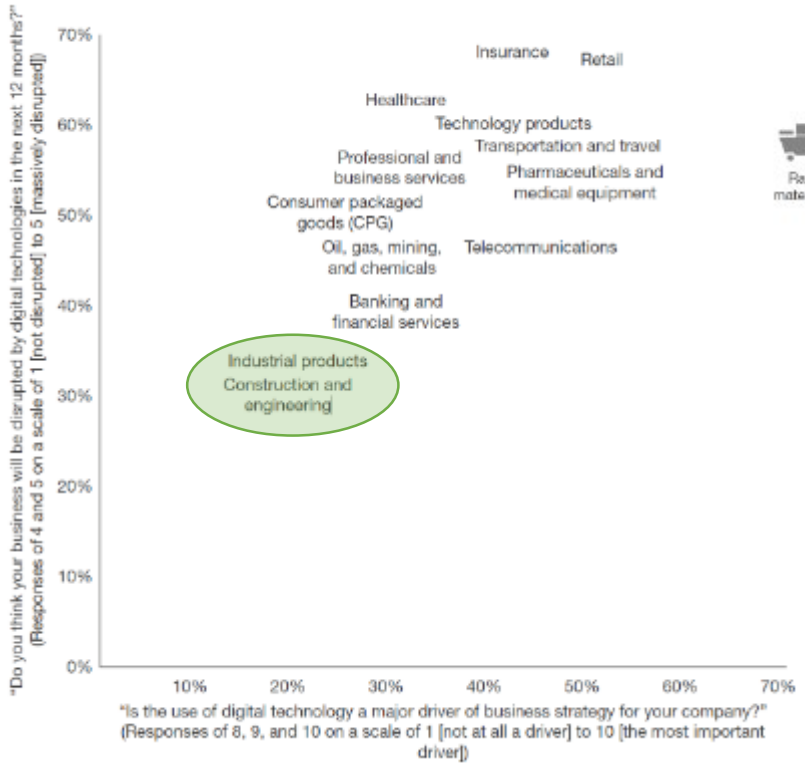


How will your organizations investments in the following areas change in fiscal year 2017?

Gartner

Gartner INCOSE International Workshop MBSE Workshop Presentation, January 2018

Digital Technology Drives Strategy and Disrupts Your Business



Digital Shifts from Linear Value Change to Digital Ecosystems

FORRESTER®

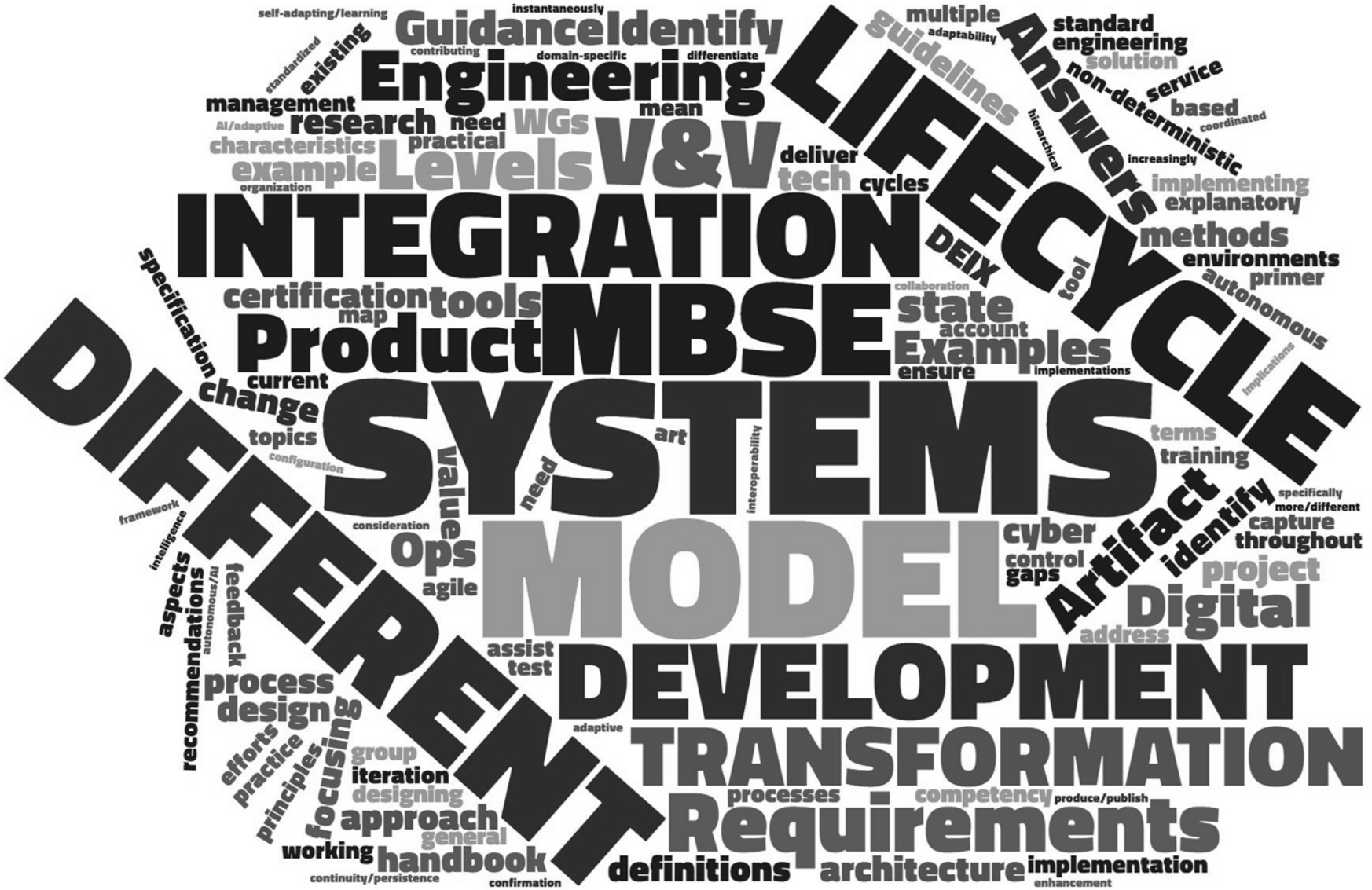
Schadler, Ted and Fenwick Nigel, The Digital Business Imperative, For eBusiness & Channel Strategy Professionals, Forrester, February 15, 2017

INCOSE Corporate Advisory Board Smart Goals

INCOSE International Council on Systems Engineering

CAB SMART Goals:
Top Work Uses

19 SYSTEMS
14 MODEL
13 DIFFERENT
12 LIFECYCLE
11 V-MODEL
11 MBSE
10 INTEGRATION
10 DEVELOPMENT
10 V&V
7 TRANSFORMATION



The Context: A Call to Action

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

"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]

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

Hyper-connectivity

System Elements & Interactions

External Elements & Interactions

Increased Density of System Elements & Interactions

Increased Density of System External Elements & Interactions

Increased Interactions Between External Elements

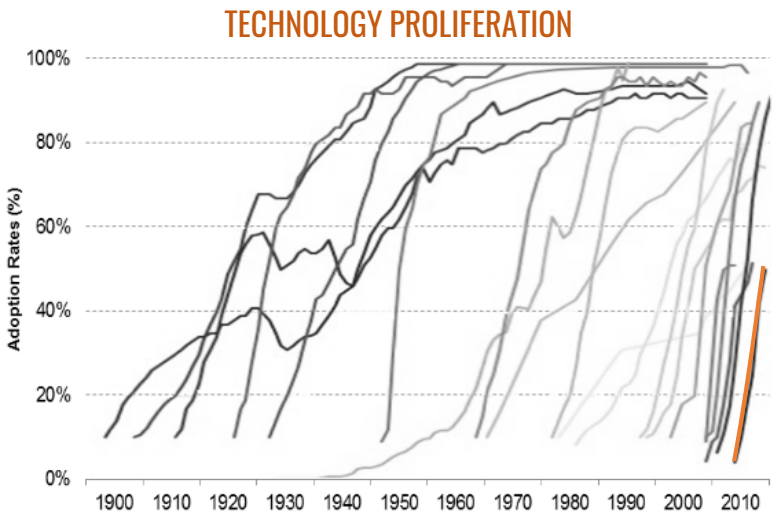
Expanding System Domain Boundary Increasing Interactions

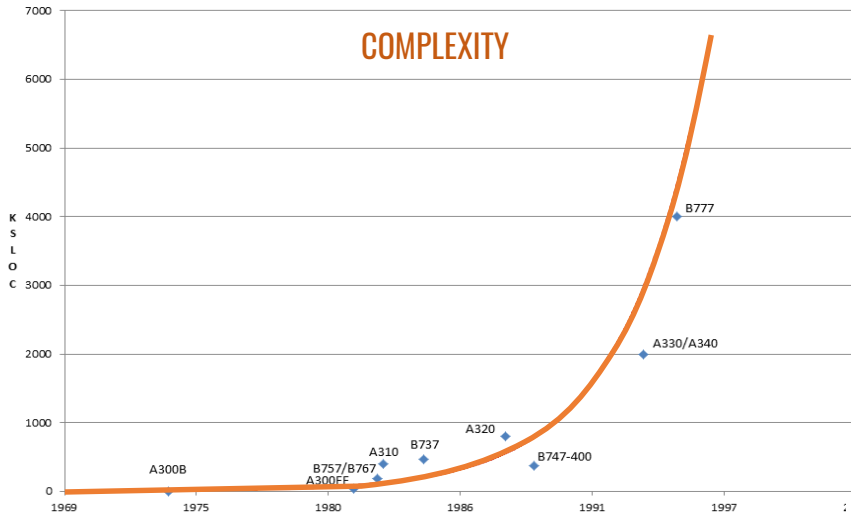
PL = N(N-1)/2
N=Nodes
PL=Potential Links
Potential System Configurations = 2^{PL}
N=20, PL =190, PSC = 2^{190*}

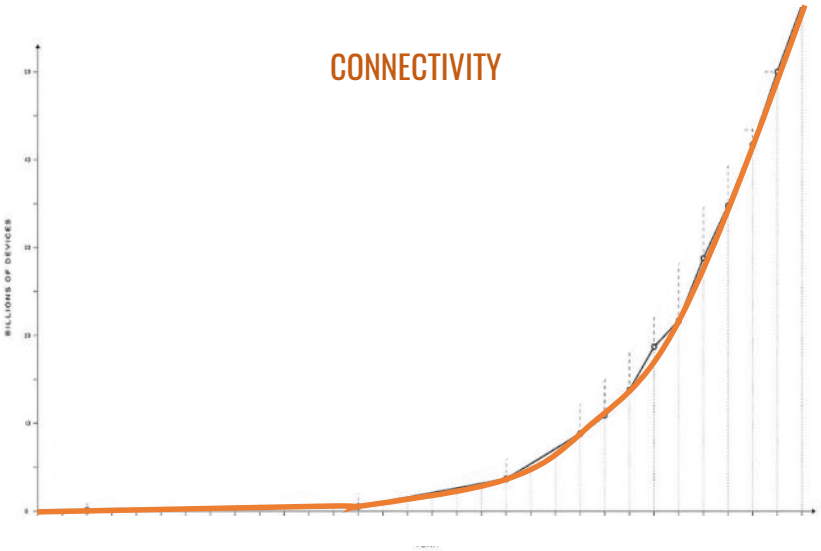
**Number of known atoms in the universe ~ 2^{158} and 2^{246}*

Exponential Growth and Solution Seeking

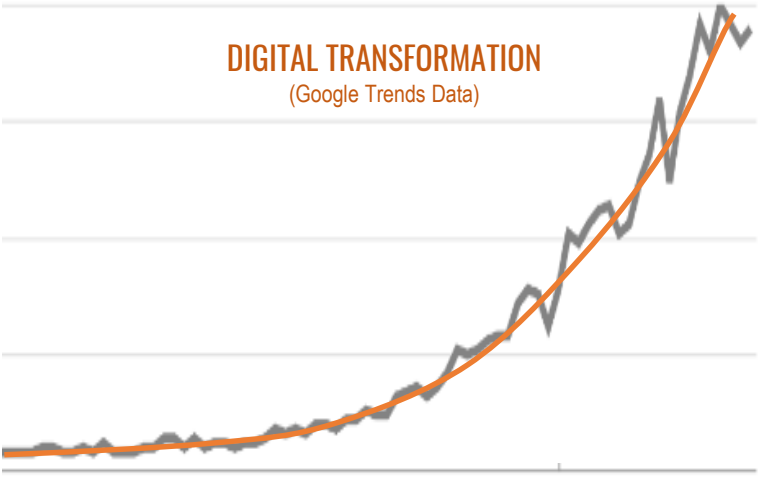
Contextual Challenges

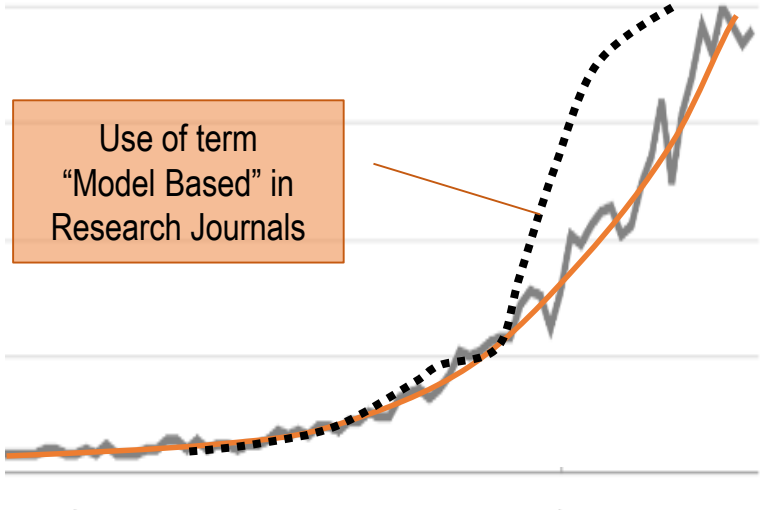


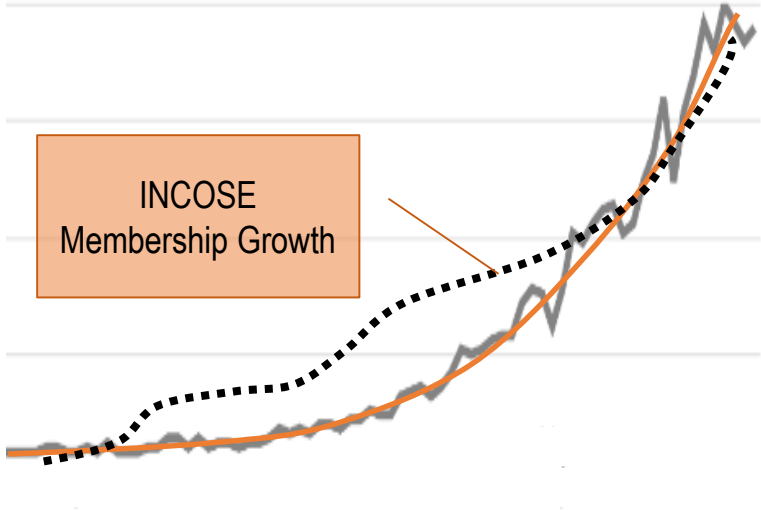




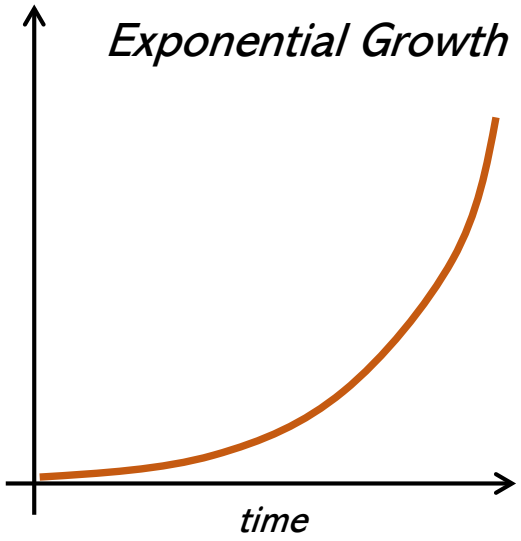
Solution Seeking

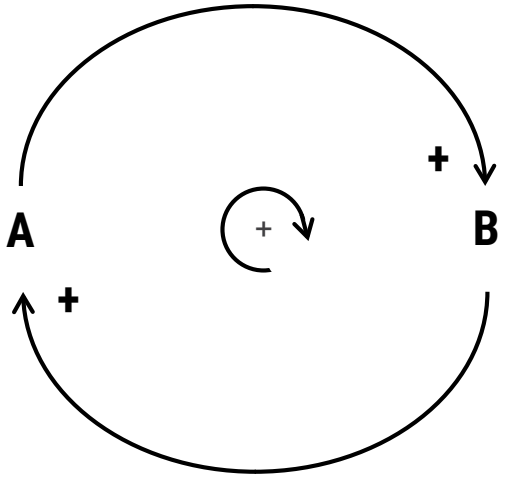






Characterizing Exponential Growth

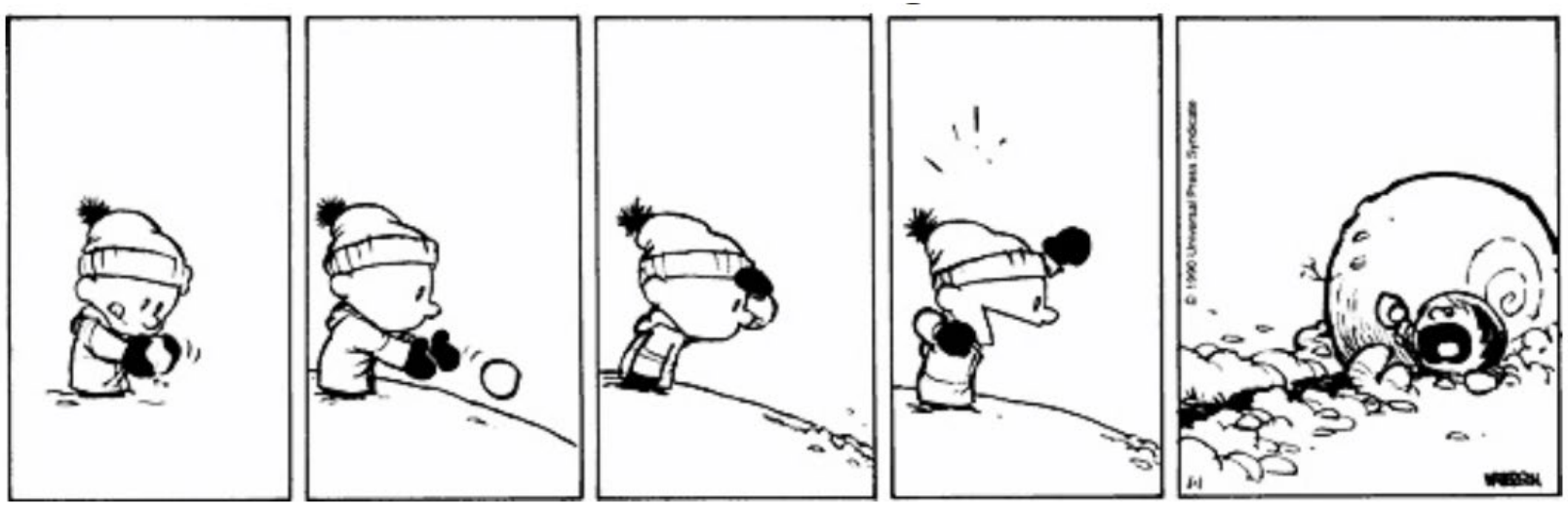




We routinely underestimate the power of exponential growth.

For example:
What is the thickness of a piece of paper after folding it 42 times?
What about 100 times?

42x = 440,000 km thick
*100x = 850T * distance to our sun*



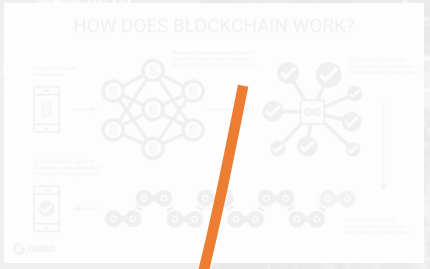
Mega Trends Shaping Society and How and What We Innovate

3D Printing

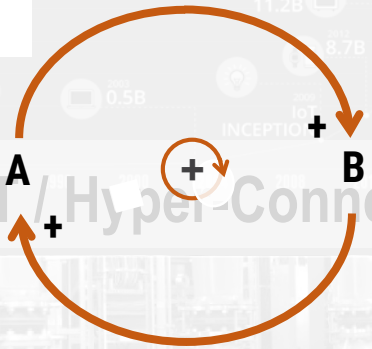
Blockchain

AGILE METHODS, APPLIED LEARNING, PATTERNS

NEW FEEDBACK MECHANISMS



ARTIFICIAL INTELLIGENCE & AUGMENTED INTELLIGENCE



Data Rich Environments

IoT/Hyper-Connectivity

Artificial Intelligence

ADVANCED MANUFACTURING & COMPRESSED DELIVERY TIMELINES

DIGITAL THREAD, DIGITAL TWIN, AUGMENTED REALITY, HPC

MODEL BASED METHODS

Industry 4.0

Digital Twin

High Performance Computing

The Power of Models, Feedback Loops and Learning for Orgs and Systems

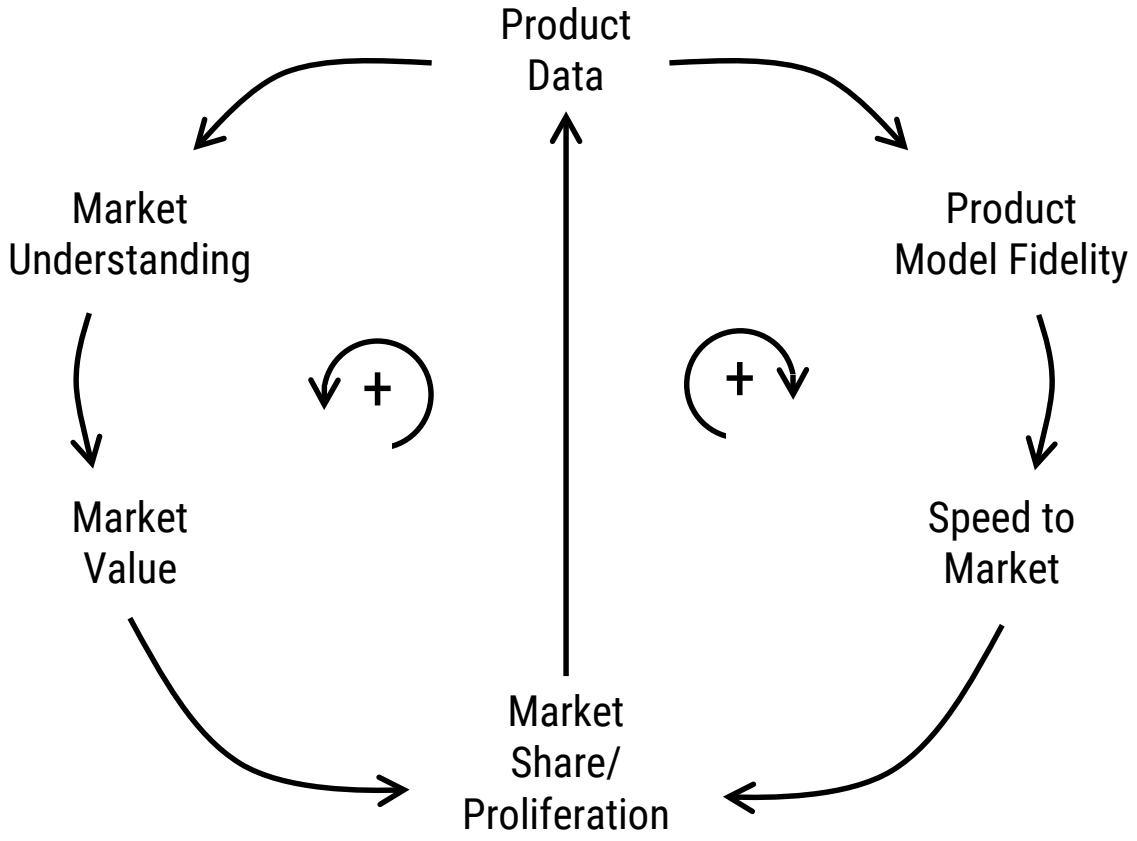
THE WALL STREET JOURNAL

Models Will Run the World

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

- There is no shortage of hype about artificial intelligence and big data, but models are the source of the real power behind these tools.
- Model based business products get better, allowing them to collect more data, which allows them to build better models, making their products better…
- Are there missing feedback loops, can we improve existing ones. Is there unnecessary delay in feedback?
- Exponential growth in speed, scale and complexity of operations requires exponential responses in how we innovate

What happens when our models are right?



What happens when our models are wrong?

Foundations: Knowledge Management - Central to Systems Engineering and Agile

Agreement Processes

- Acquisition Process (6.1.1)
- Supply Process (6.1.2)

Organization Project-Enabling Processes

- Life Cycle Model Management Process (6.2.1)
- Infrastructure Management (6.2.2)
- Project Portfolio Management (6.2.3)
- Human Resource Management (6.2.4)
- Quality Management (6.2.5)
- Knowledge Management Process (6.2.6)

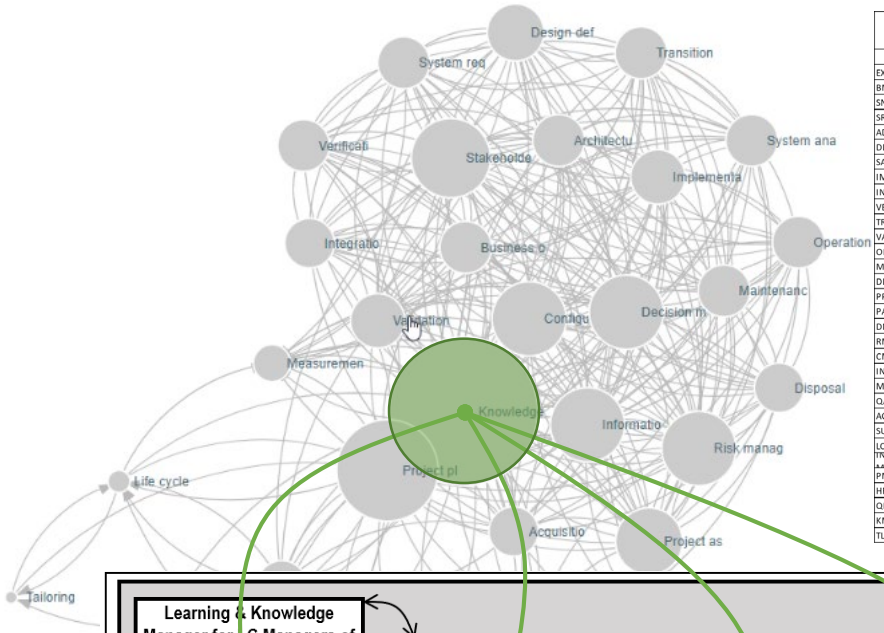
Technical Management Processes

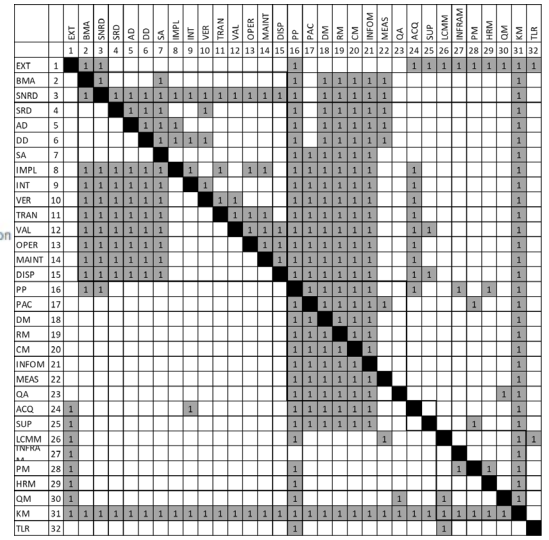
- Project Planning Process (6.3.1)
- Project Assessment and Control Process (6.3.2)
- Decision Management Process (6.3.3)
- Risk Management Process (6.3.4)
- Configuration Management Process (6.3.5)
- Information Management Process (6.3.6)
- Measurement Process (6.3.7)
- Quality Process (6.3.8)

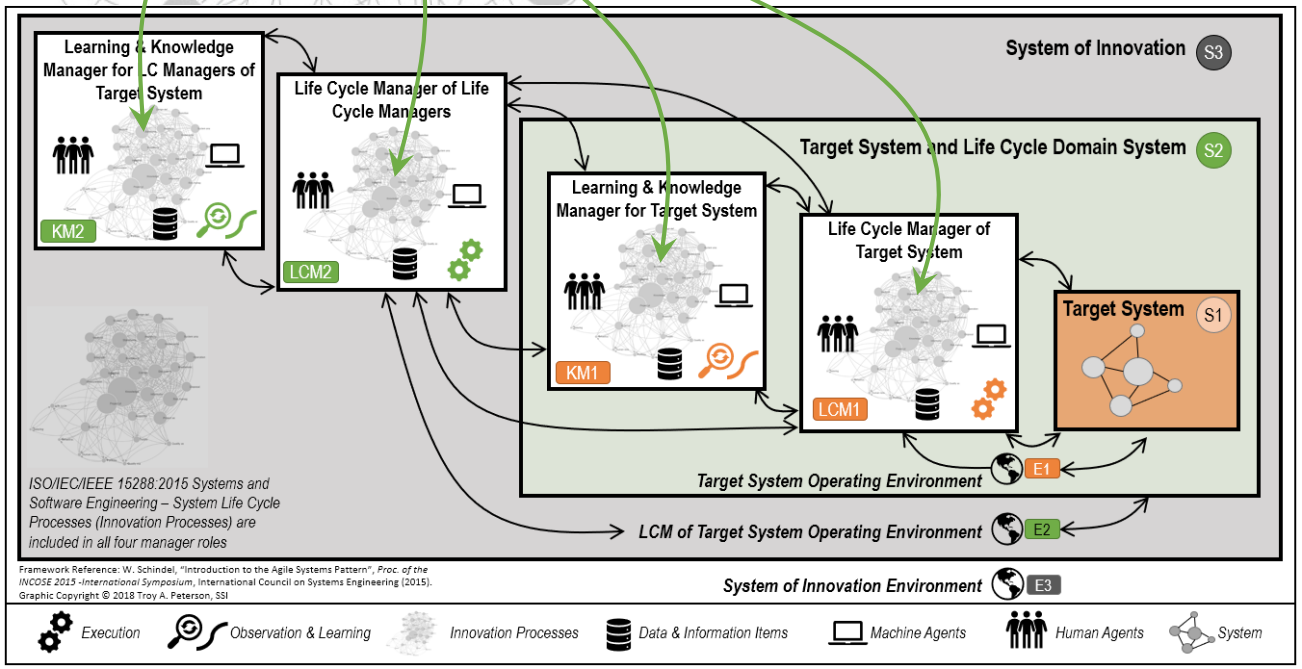
Technical Processes

- Business or Mission Analysis Process (6.4.1)
- Stakeholder Needs & Requirements Definitions Process (6.4.2)
- System Requirements Definition Process (6.4.3)
- Architecture Development Process (6.4.4)
- Design Definition Process (6.4.5)
- System Analysis Process (6.4.6)
- Implementation Process (6.4.7)
- Integration Process (6.4.8)
- Verification Process (6.4.9)
- Transition Process (6.4.10)
- Validation Process (6.4.11)
- Operation Process (6.4.12)
- Maintenance Process (6.4.13)
- Disposal Process (6.4.14)

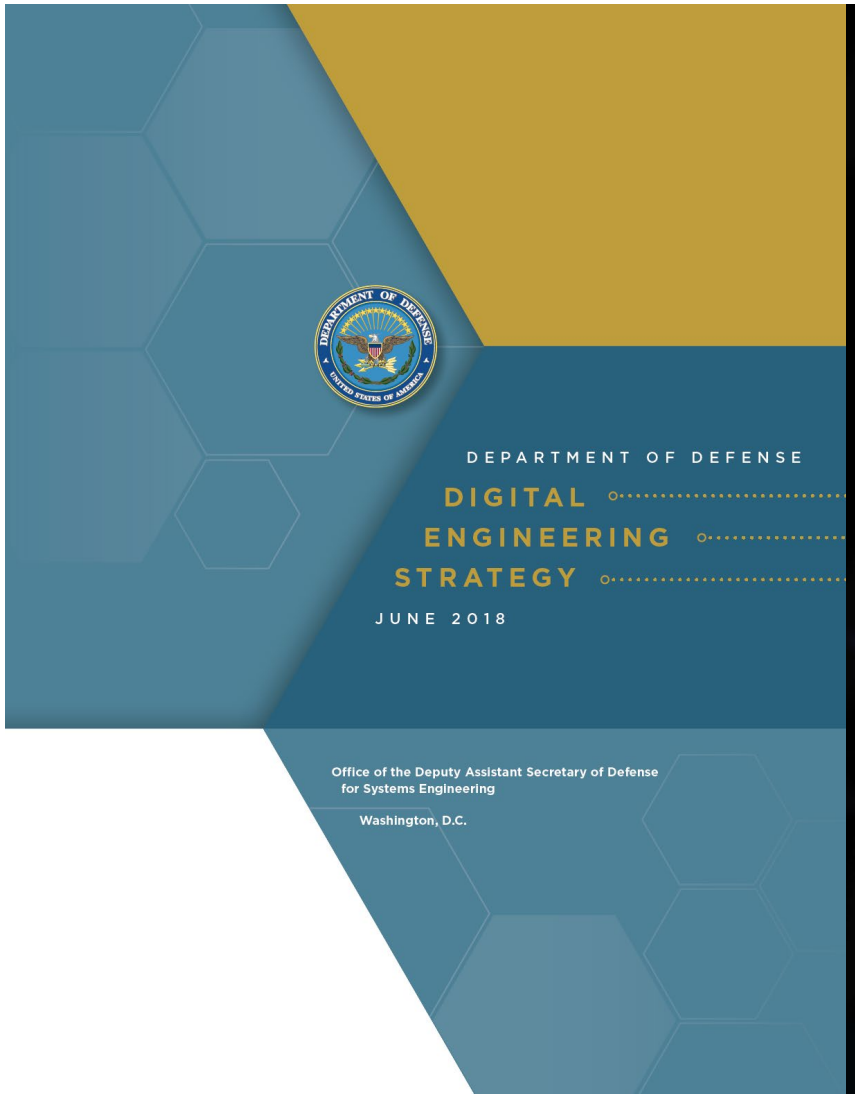
ISO 15288







Trends Toward MBSE/Digital Engineering: Professional Societies



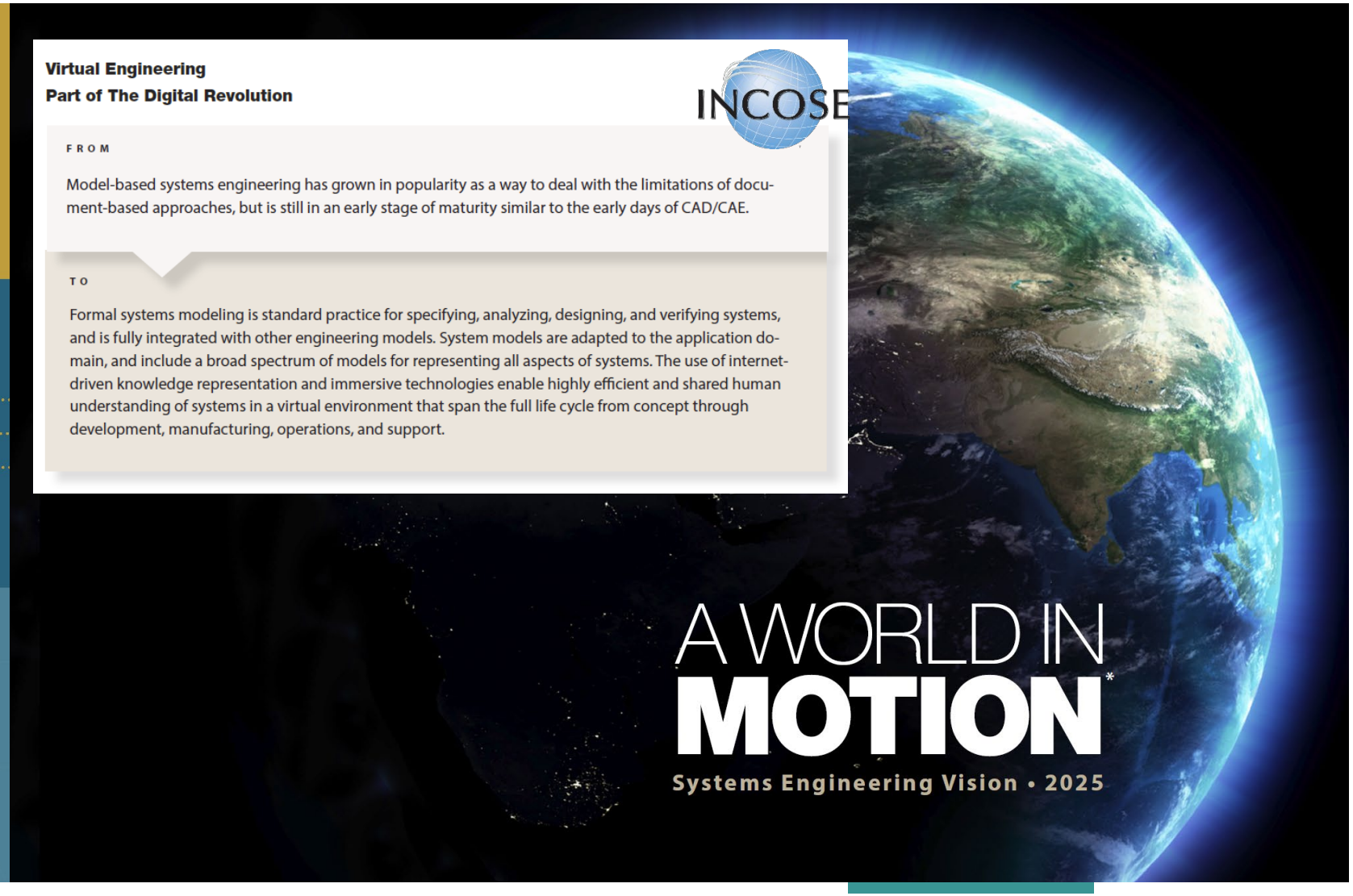
Virtual Engineering
Part of The Digital Revolution

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.



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

Transformation: INCOSE CAB 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

Findings from 2015 INCOSE International Workshop Corporate Advisory Board Breakout Sessions

MBSE Intiative -> Transformation Initiative / Incubator

Continuing to build upon INCOSE resources to build understanding of the practical implications of MBSE.

- INCOSE / OMG MBSE Wiki
  - Proceedings of ~10 years of the MBSE Workshop and IW content
  - Overviews/Summaries of MBSE methodologies
  - MBSE Challenge Teams addressing leading issues
  - MBSE related working groups and products

- SEBoK, SE Journal and INSIGHT
- INCOSE Event Proceedings
- INCOSE Community and more…

Challenge/Activity Team	Challenge/Activity Team Lead
Augmented Intelligence in Systems Engineering	Mark Petrotta
MBX Ecosystems	Russell Peak
Model-Based Engineering (MBE) Manifesto	Chris Schreiber
Model-Based Enterprise Capabilities Matrix	Joe Hale and Al Hoheb
Production and Logistics Systems Modeling	Tim Sprock
Telescope Modeling	Robert Karban

INCOSE FUTURE Strategic Objective

INCOSE FUTURE Strategic Objective:

INCOSE leads the community in shaping the future of systems engineering

- Engage with and Align FUTURE related INCOSE activities
  - Systems Engineering Vision
  - Future of Systems Engineering (FuSE)
  - MBSE Incubator
  - Transformation Initiative
  - Transformational Enablers
  - Strategic Integration
- Engage Larger External Community - Collaborate
- Cast Clear and Impactful Vision and Demonstrate It

INCOSE FuSE
Future of Systems Engineering

Systems Engineering: Cracking the Code of Digital Transformation

Unprecedented change and growing systems complexity is diving the need for digital transformation and most notably in how we innovate or perform systems engineering.

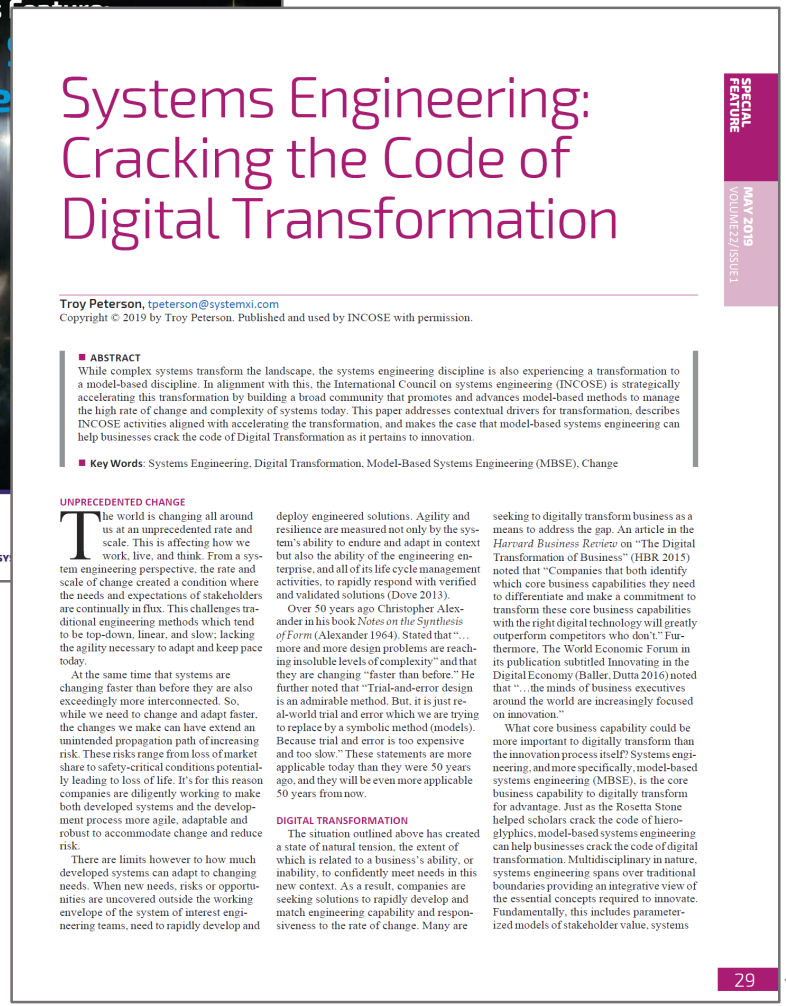
INCOSE is leading many activities to help accelerate the necessary transformation, some of these include:

- Transformation Initiative
- MBSE Incubator
- SysML v2
- Semantic Technologies for Systems Engineering
- MBSE Patterns Working Group (WG)
- Digital Engineering Information Exchange WG
- Augmented Intelligence for Systems Engineering Challenge Team (CT)
- Model Based X Ecosystem Challenge Team (CT)
- Model Based Enterprise Capabilities Matrix (CT)

What's Next:

- MBSE Foundations
- MBX Ecosystem
- Organizational Change

It is an exciting time for systems engineers and the discipline of systems engineering. We are at a tipping point, and a timely one.



Systems Engineering: Cracking the Code of Digital Transformation

SPECIAL FEATURE

MAY 2019 VOLUME 22 / ISSUE 1

Troy Peterson, tpeterson@systemxi.com

ABSTRACT
While complex systems transform the landscape, the systems engineering discipline is also experiencing a transformation to a model-based discipline. In alignment with this, the International Council on systems engineering (INCOSE) is strategically accelerating this transformation by building a broad community that promotes and advances model-based methods to manage the high rate of change and complexity of systems today. This paper addresses contextual drivers for transformation, describes INCOSE activities aligned with accelerating the transformation, and makes the case that model-based systems engineering can help businesses crack the code of Digital Transformation as it pertains to innovation.

Key Words: Systems Engineering, Digital Transformation, Model-Based Systems Engineering (MBSE), Change

UNPRECEDENTED CHANGE

The world is changing all around us at an unprecedented rate and scale. This is affecting how we work, live, and think. From a system engineering perspective, the rate and scale of change created a condition where the needs and expectations of stakeholders are continually in flux. This challenges traditional engineering methods which tend to be top-down, linear, and slow; lacking the agility necessary to adapt and keep pace today.

At the same time that systems are changing faster than before they are also exceedingly more interconnected. So, while we need to change and adapt faster, the changes we make can have extend an unintended propagation path of increasing risk. These risks range from loss of market share to safety-critical conditions potentially leading to loss of life. It's for this reason companies are diligently working to make both developed systems and the development process more agile, adaptable and robust to accommodate change and reduce risk.

There are limits however to how much developed systems can adapt to changing needs. When new needs, risks or opportunities are uncovered outside the working envelope of the system of interest engineering teams, need to rapidly develop and deploy engineered solutions. Agility and resilience are measured not only by the system's ability to endure and adapt in context but also the ability of the engineering enterprise, and all of its life cycle management activities, to rapidly respond with verified and validated solutions (Dove 2013).

Over 50 years ago Christopher Alexander in his book *Notes on the Synthesis of Form* (Alexander 1964). Stated that "… more and more design problems are reaching insoluble levels of complexity" and that they are changing "faster than before." He further noted that "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 (models). Because trial and error is too expensive and too slow." These statements are more applicable today than they were 50 years ago, and they will be even more applicable 50 years from now.

DIGITAL TRANSFORMATION

The situation outlined above has created a state of natural tension, the extent of which is related to a business's ability, or inability, to confidently meet needs in this new context. As a result, companies are seeking solutions to rapidly develop and match engineering capability and responsiveness to the rate of change. Many are seeking to digitally transform business as a means to address the gap. An article in the *Harvard Business Review* on "The Digital Transformation of Business" (HBR 2015) noted that "Companies that both identify which core business capabilities they need to differentiate and make a commitment to transform these core business capabilities with the right digital technology will greatly outperform competitors who don't." Furthermore, The World Economic Forum in its publication subtitled Innovating in the Digital Economy (Baller, Dutta 2016) noted that "…the minds of business executives around the world are increasingly focused on innovation."

What core business capability could be more important to digitally transform than the innovation process itself? Systems engineering, and more specifically, model-based systems engineering (MBSE), is the core business capability to digitally transform for advantage. Just as the Rosetta Stone helped scholars crack the code of hieroglyphics, model-based systems engineering can help businesses crack the code of digital transformation. Multidisciplinary in nature, systems engineering spans over traditional boundaries providing an integrative view of the essential concepts required to innovate. Fundamentally, this includes parameterized models of stakeholder value, systems

Systems Engineering Foundations

Many INCOSE resources exist to build an understanding of the practical implications of applying MBSE.

SysML v2 Objectives: Increase adoption and effectiveness of MBSE by enhancing…

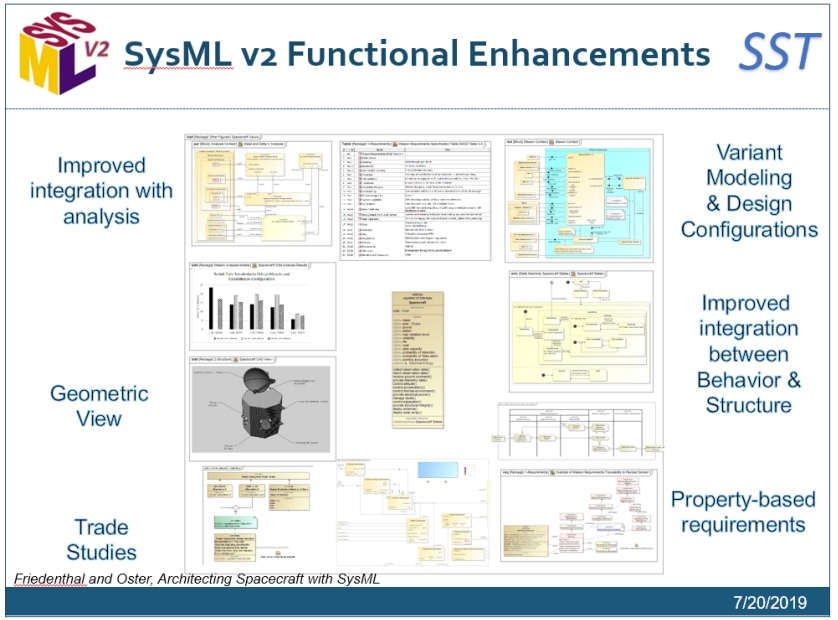
- Precision and expressiveness of the language
- Consistency and integration among language concepts
- Interoperability with other engineering models and tools
- Usability by model developers and consumers

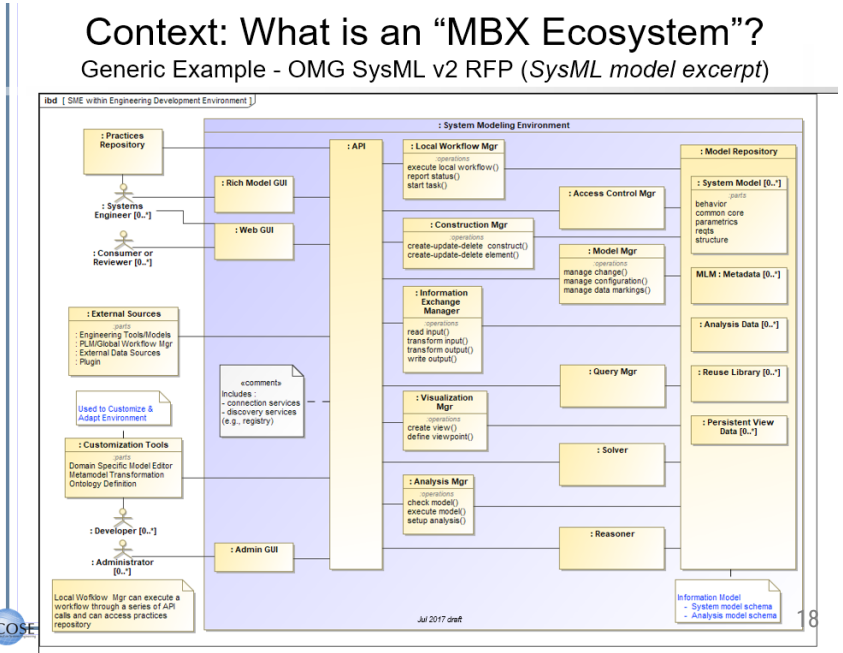
ST4SE / MBSE Patterns WG

- 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.

INCOSE Fellows Meetings and INCOSE Vision 2025/2030

- Ensuring the Systems Engineering discipline is has its roots in engineering and science principles – interactions, Hamilton's principle, systems phenomenology.

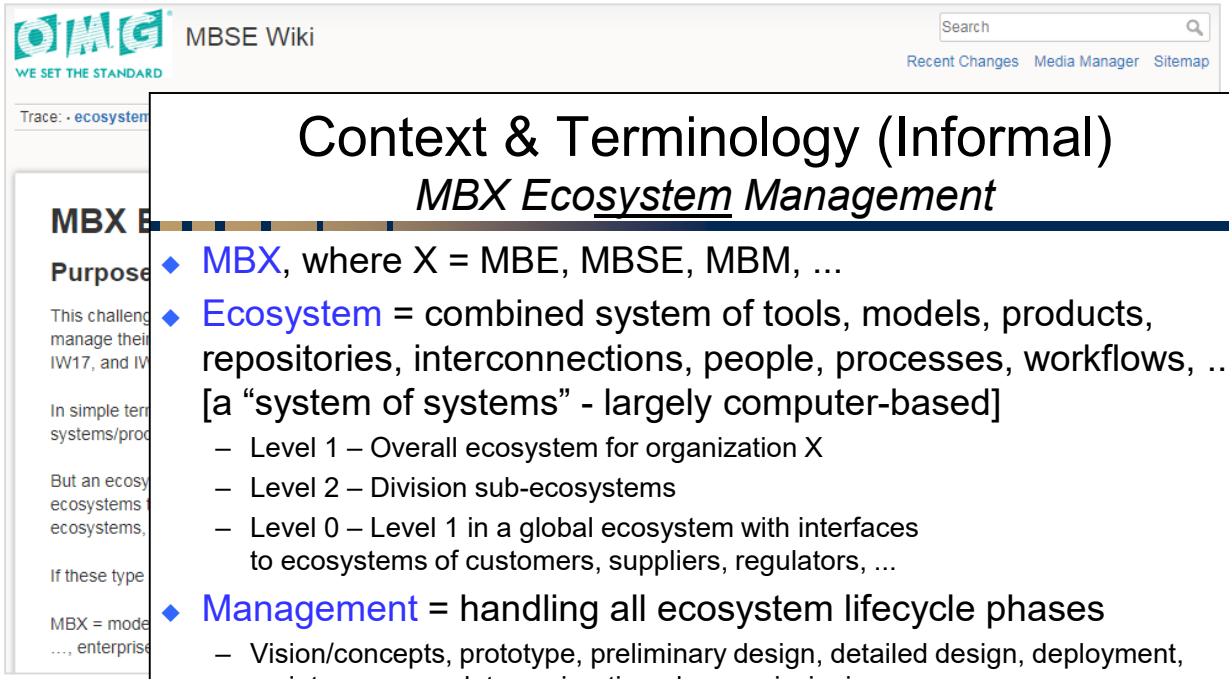




MBX Ecosystem

Challenge Team Wiki @ INCOSE/OMG Site

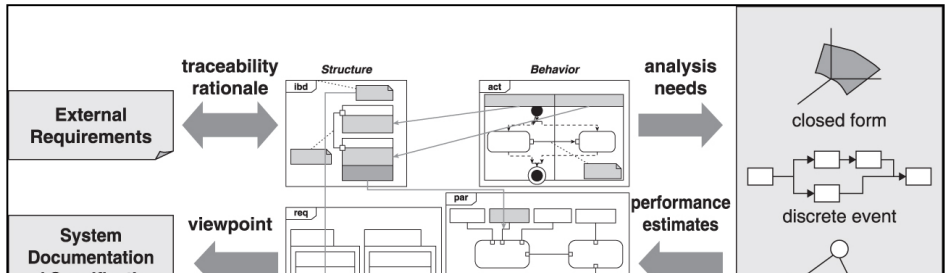
https://www.omgwiki.org/MBSE/doku.php?id=mbse:ecosystems

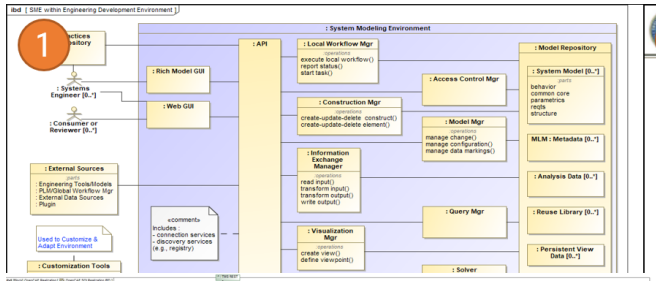


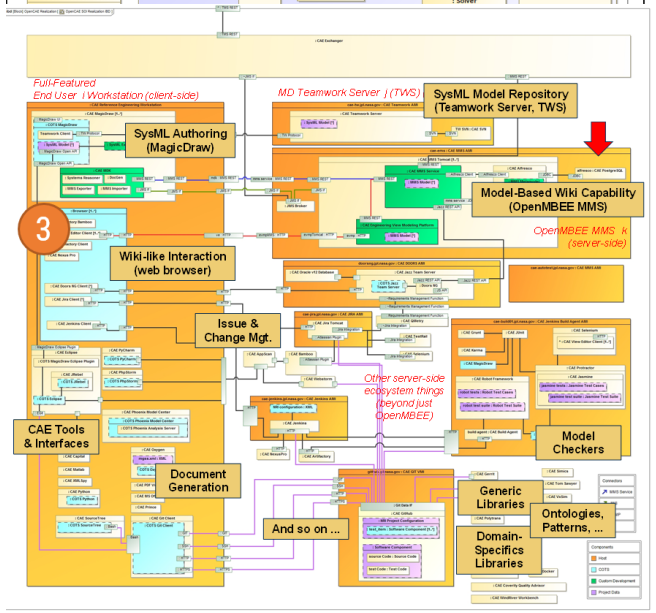
Context & Terminology (Informal)

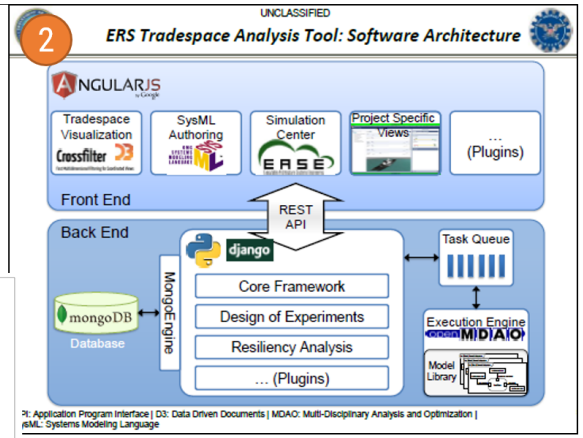
MBX Ecosystem Management

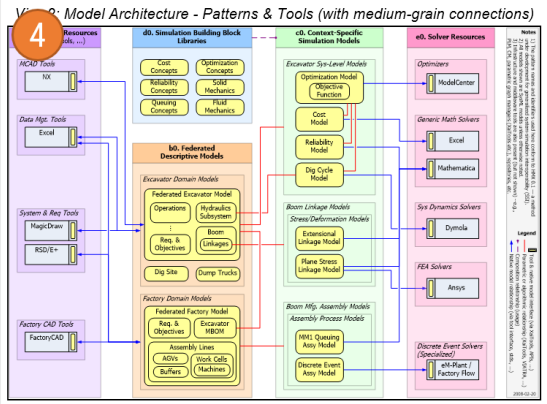
- MBX, where X = MBE, MBSE, MBM, ...
- Ecosystem = combined system of tools, models, products, repositories, interconnections, people, processes, workflows, ... [a "system of systems" - largely computer-based]
  - Level 1 – Overall ecosystem for organization X
  - Level 2 – Division sub-ecosystems
  - Level 0 – Level 1 in a global ecosystem with interfaces to ecosystems of customers, suppliers, regulators, ...
- Management = handling all ecosystem lifecycle phases
  - Vision/concepts, prototype, preliminary design, detailed design, deployment, maintenance, updates, migration, decommissioning
- Therefore, treat your MBX ecosystem as a system!
  - Apply systems engineering principles ("Alpo" approach) w/ ecosystem know-how
- Similar terms: system development environment, decision support system, modeling & simulation framework, ...



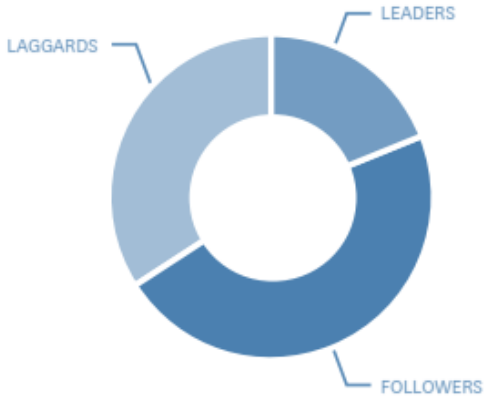


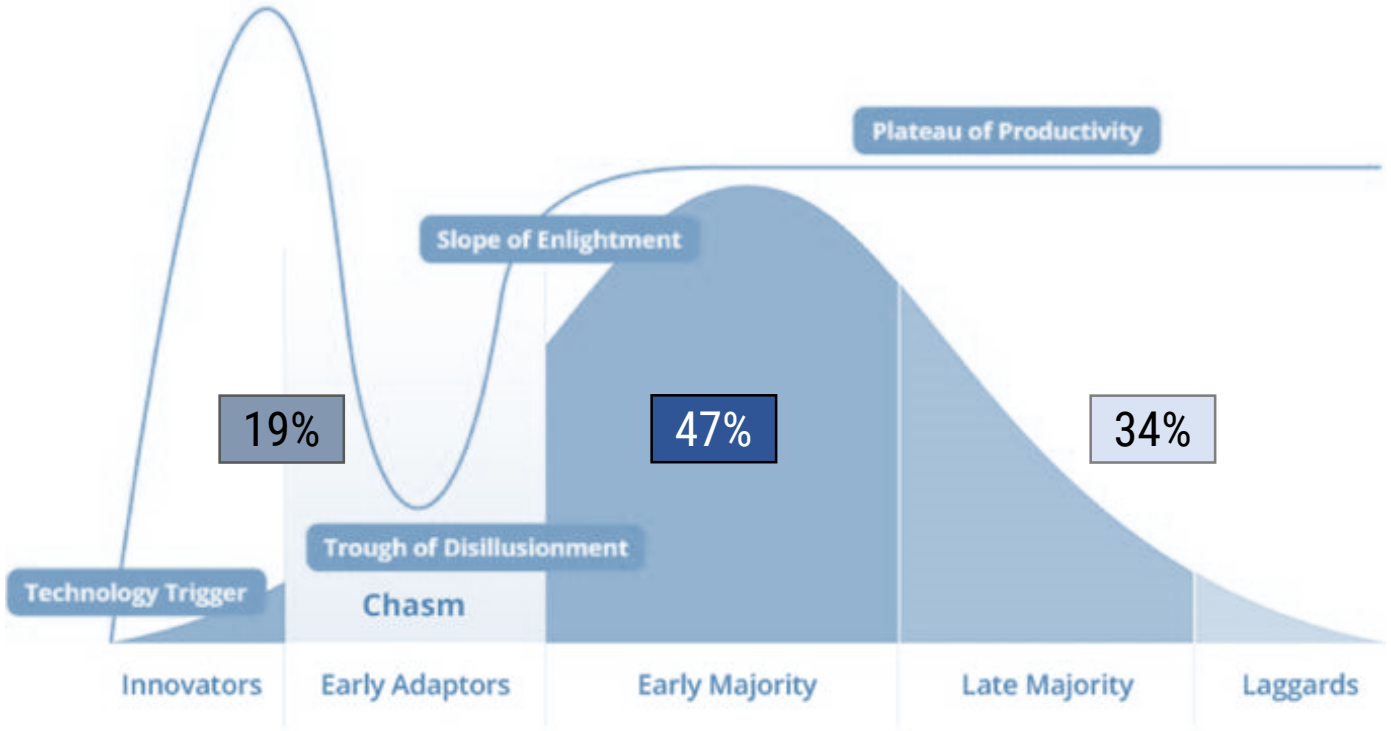






Accelerating: Technology Adoption – Hype and Chasm





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

More than 80% of respondents are either followers or laggards

Acceleration is very much about sharing, communicating and learning

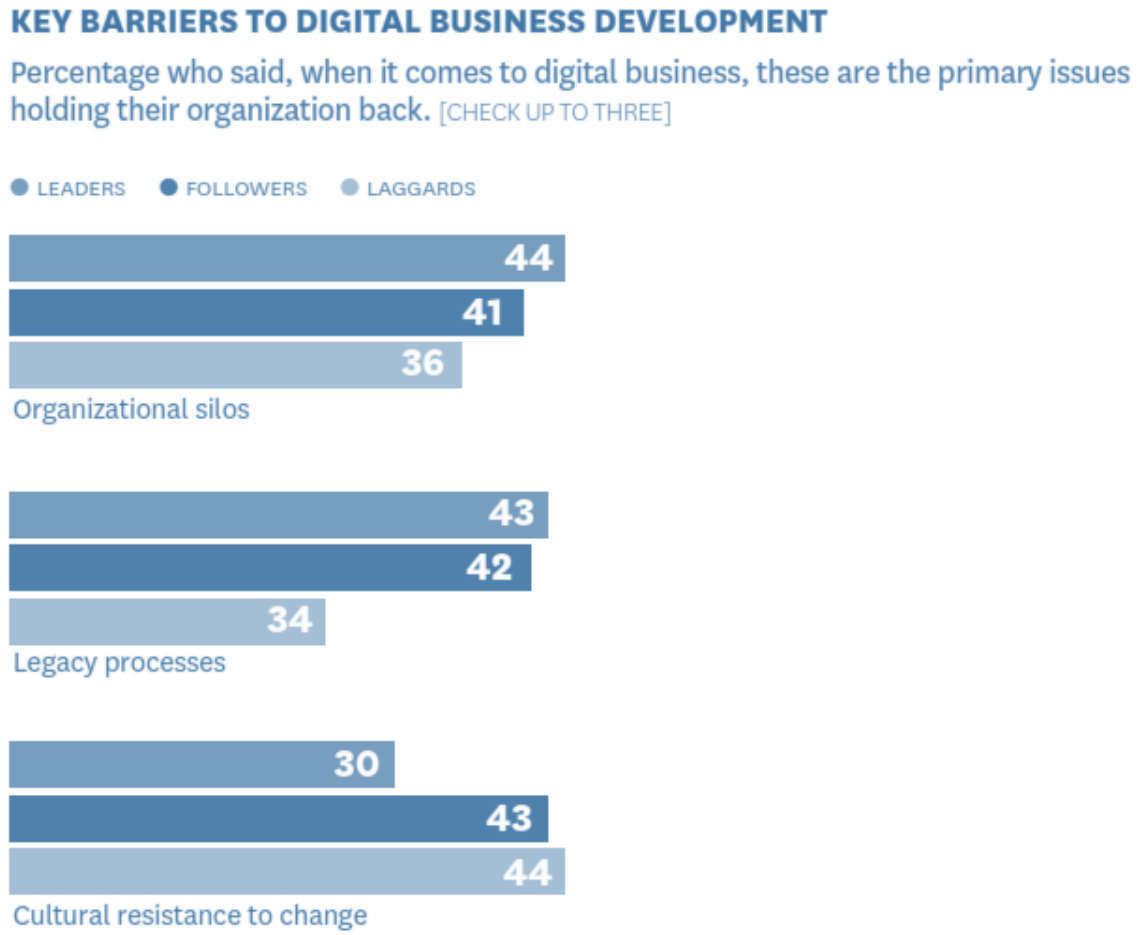
Where would you plot your organization today?

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: Driving Digital Transformation[1]

Keys to Digital Transformation (HBR Report)

- Start from the customers perspective
- Digital leadership starts at the top
- Engage in a discussion of trends
- Think about agile
- Use examples to make it real
- Need a foundation of trust
- Use KPIs for sharing knowledge
- Break down walls wherever possible
- Need digital coaches or maters
- Create appropriate learning forums



1. Driving Digital Transformation: New Skills for Leaders, New Role for the CIO, Harvard Business Review

Transformation: Change Management

Integrate dimensions of change

Addresses dimensions in parallel

Concurrency and dimensional trades

Build grass-roots ownership

Obtain top leadership support

Consider:

ABP = CM(OE + PR + IT)

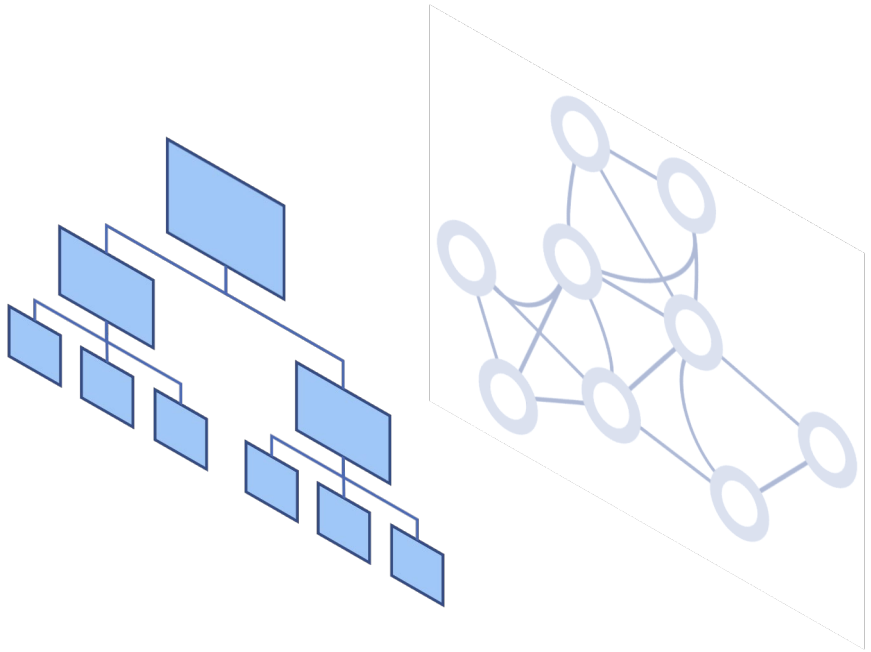
- ABP = Achieving Breakthrough Performance
- OE = Organizational Environment
- BPR = Business Process Reengineering
- IT = Information Technology
- CM = Change Management

Transformation is very much a people focused endeavor.

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

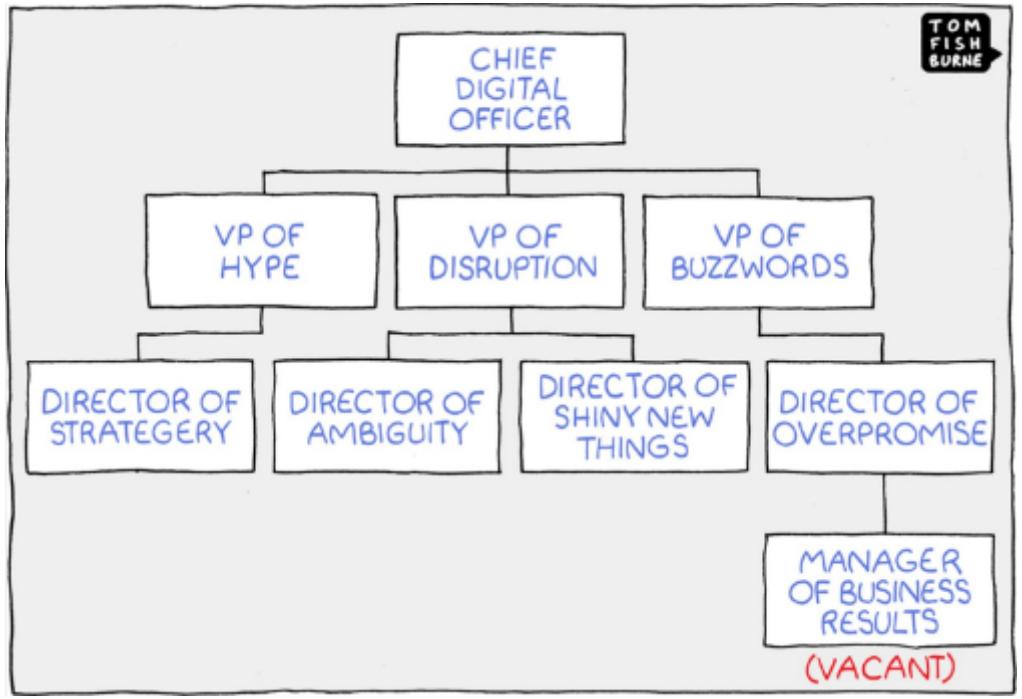


Accelerate: John P. Kotter
Kotter's new book *Accelerate* refines principals and adds the concept of a "dual operating system".

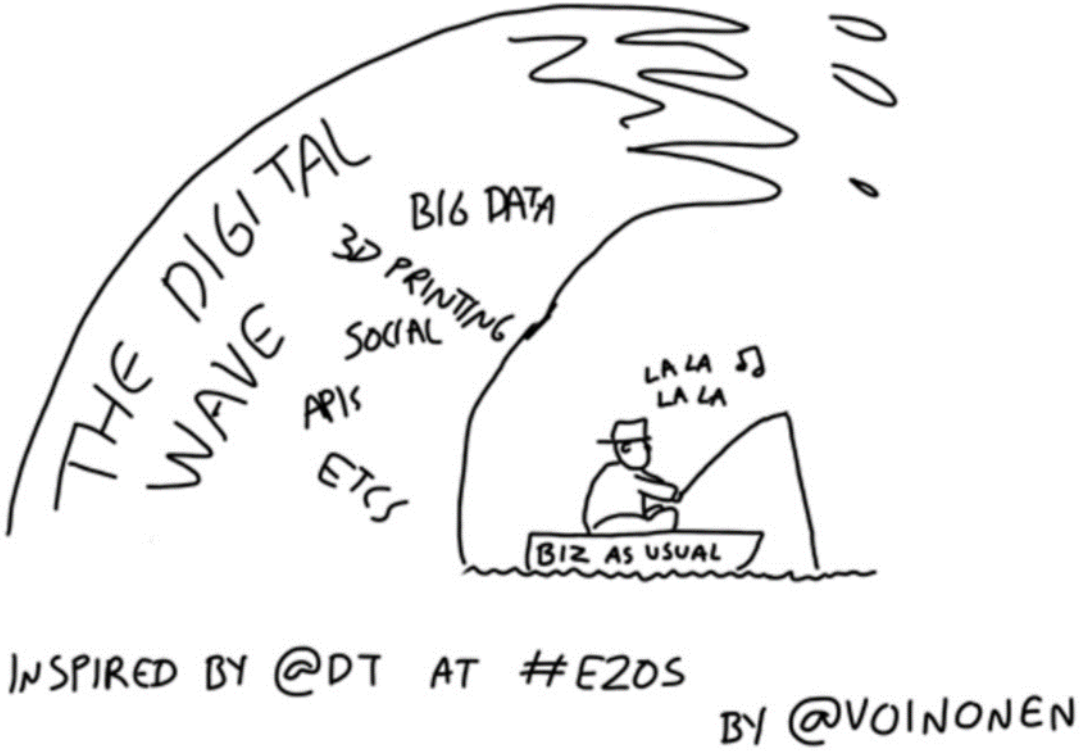
- One operating system is characterized by management, hierarchy and driven toward efficiency
- The other is characterized by leadership, networks, strategic acceleration and driven to innovate.
- Operating systems align nicely with the System of Innovation framework used in INCOSE's Agile and Patterns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

- It’s a paradigm shift
- The previous state is unrecognizable
- It doesn’t happen overnight, it takes time, and effort

States of Digital Transformation



Digitally Zealous



Digital Denial

model based

Systems Engineering

is the essential discipline for

Digital Transformation

“It is not necessary to change.
Survival is not mandatory.”

W. Edwards Deming

INCOSE’s Transformation Strategic Objective: http://www.incose.org/about/strategicobjectives/transformation

Q&A

About the Speaker

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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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