The Essential Discipline for Digital Transformation

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Digital Transformation & the Forth Industrial Revolultion

"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
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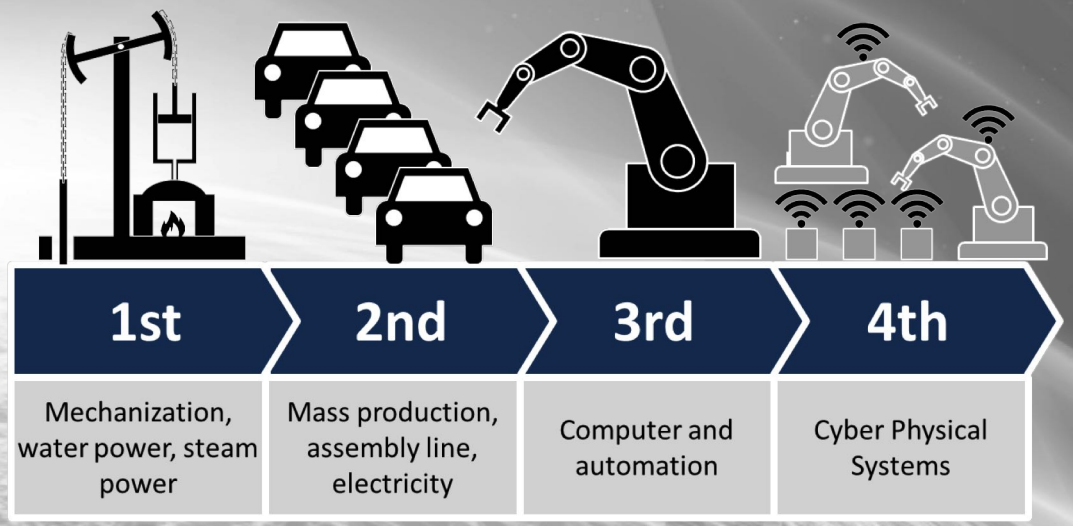


What is the role of Systems Engineering in the next Industrial Revolution

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

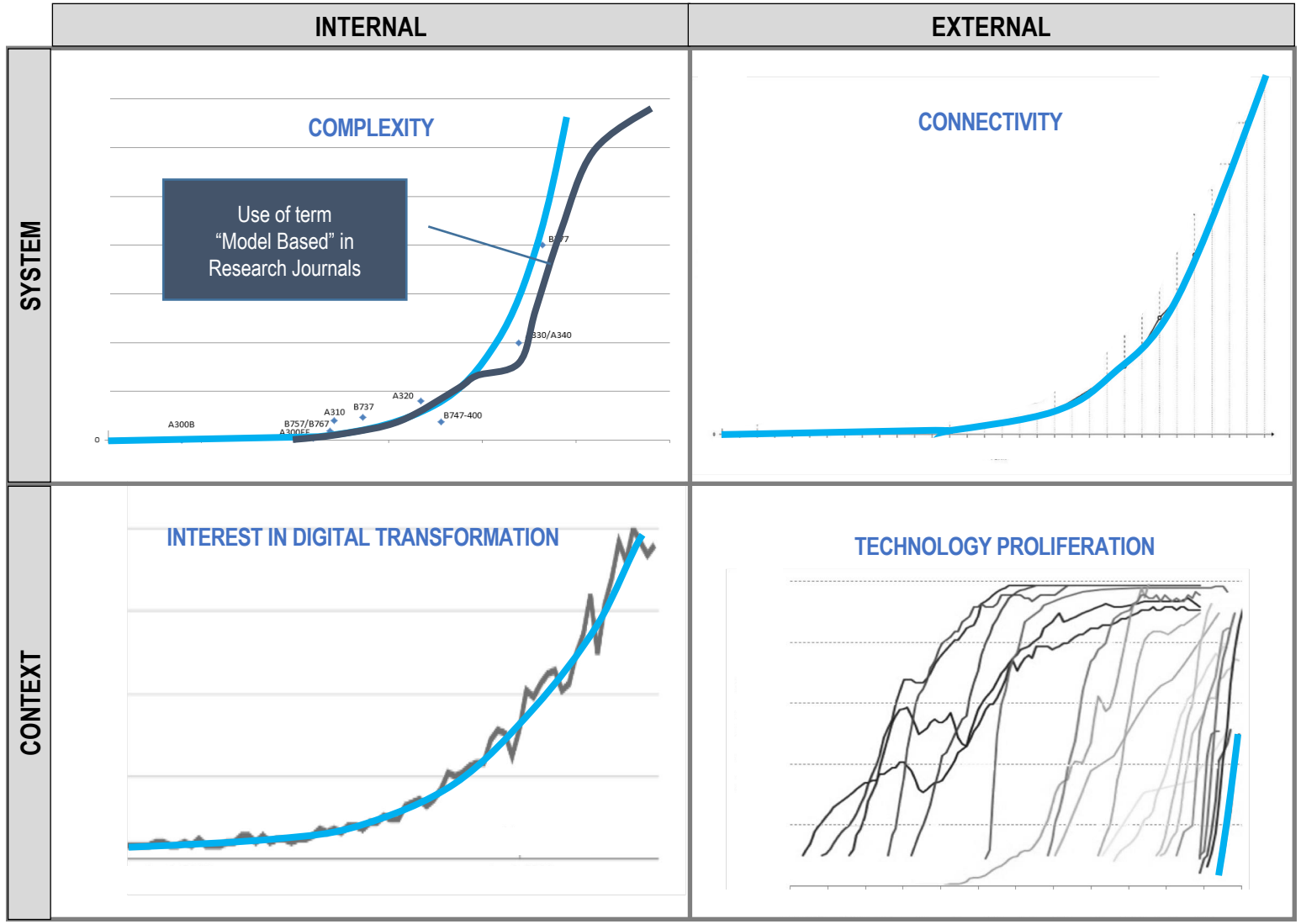
Jack Welch

How should we address rapid rates of change?

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

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

"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."



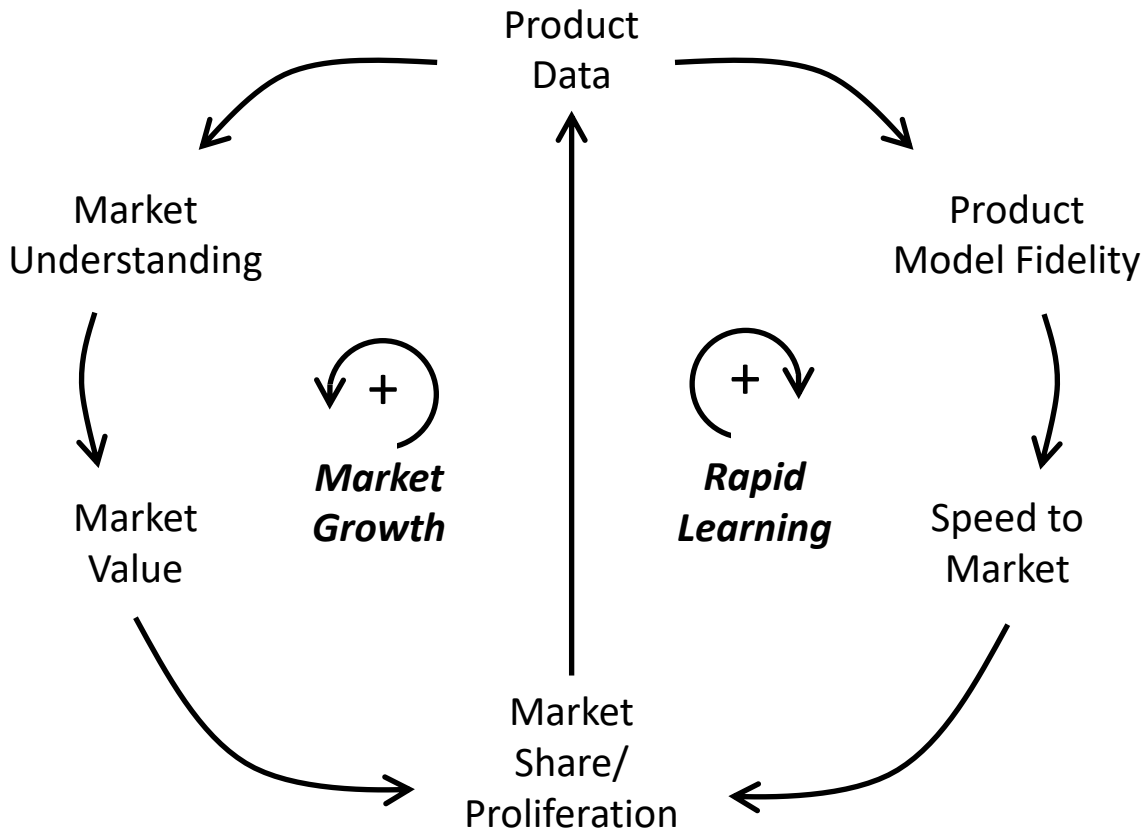
1. Christopher Alexander, "Notes on the Synthesis of Form" Harvard University Press, Cambridge Massachusetts, 1964

Wall Street Journal

Models Will Run the World

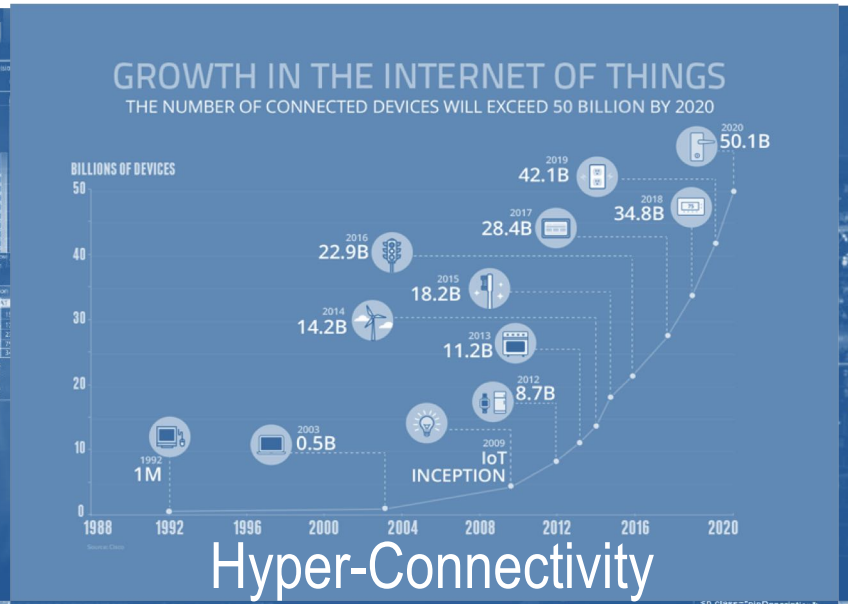
By Steven A. Cohen and Matthew W. Granade – August 19, 2018

- 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.



How Well Have We Taken Advantage of the Latest Technologies and Trends?

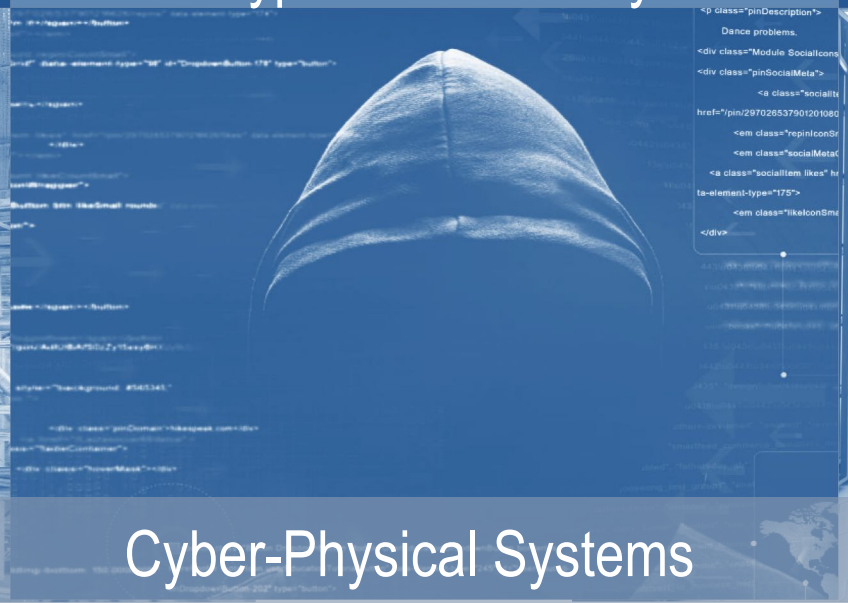
Data Rich Environments



Hyper-Connectivity

Artificial Intelligence

Industry 4.0



Cyber-Physical Systems

High Performance Computing

Shifting our focus to System Information

1 Content

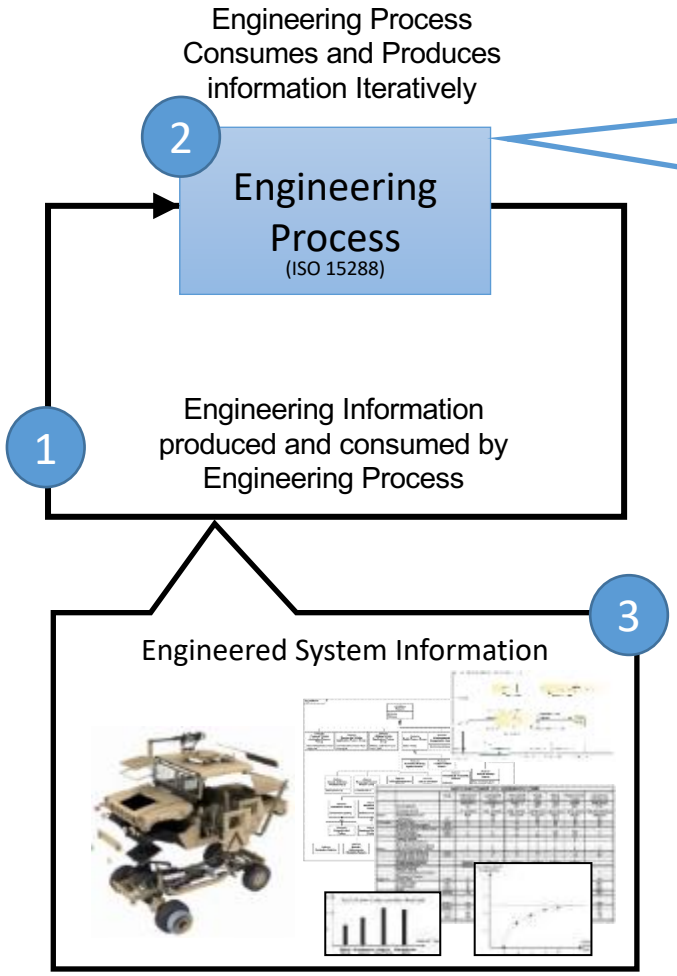
Key system information that must be produced, consumed and maintained consistently across the life cycle

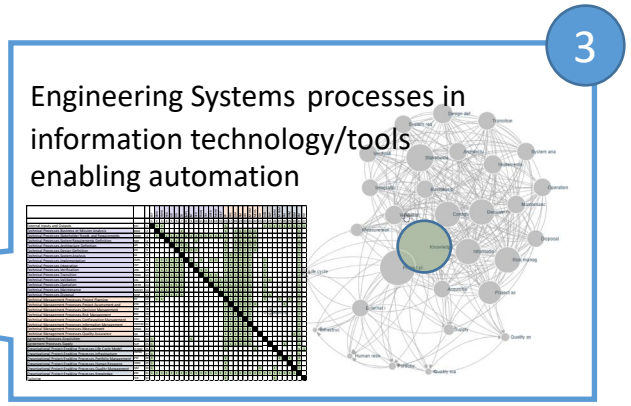
2 Process

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.

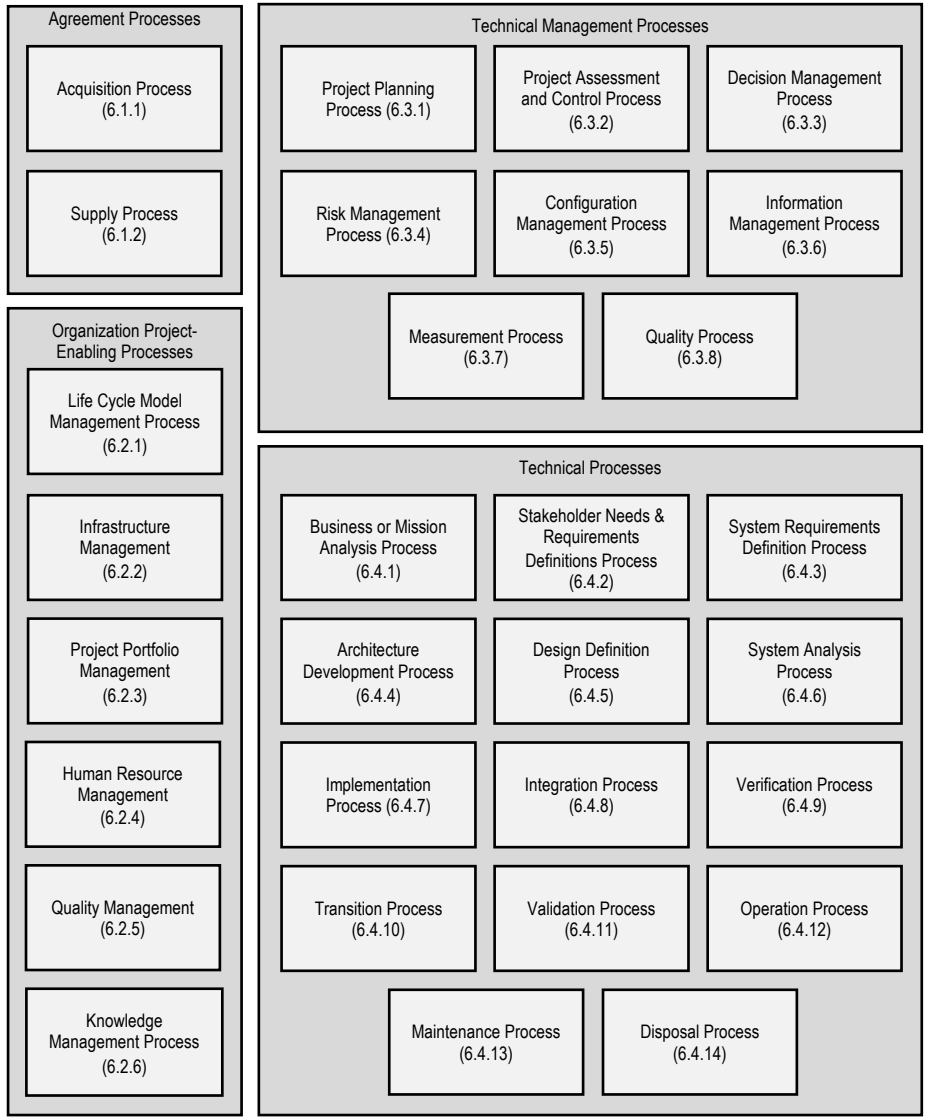
1. System Information

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

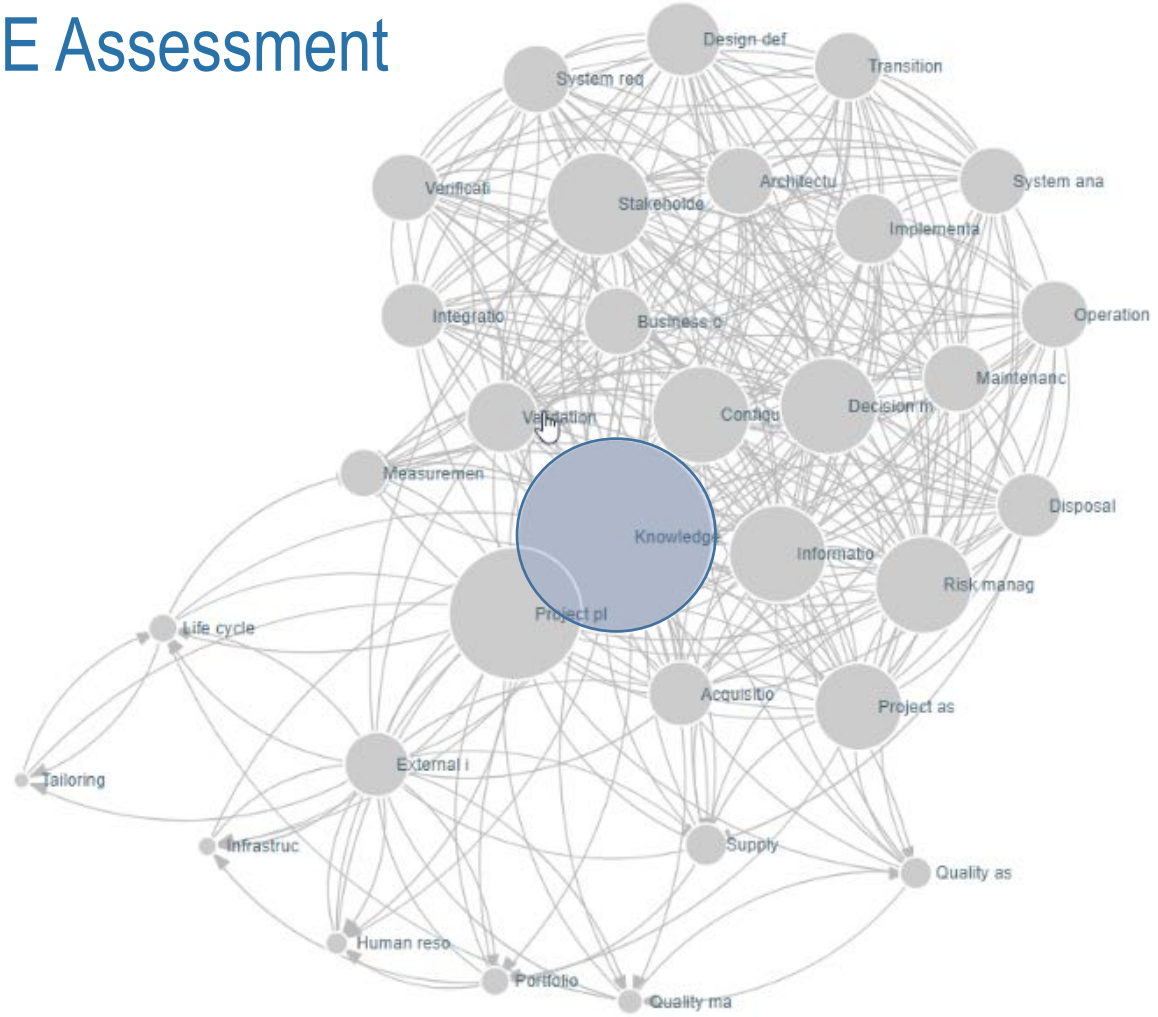
http://www.omgwiki.org/MBSE/doku.php?id=mbse:pbse

Remember: Automating junk, makes more junk automatically

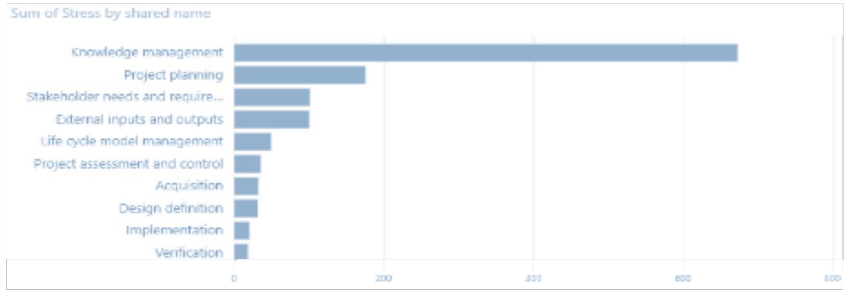
ISO 15288 as a Framework for MBSE Assessment



ISO 15288

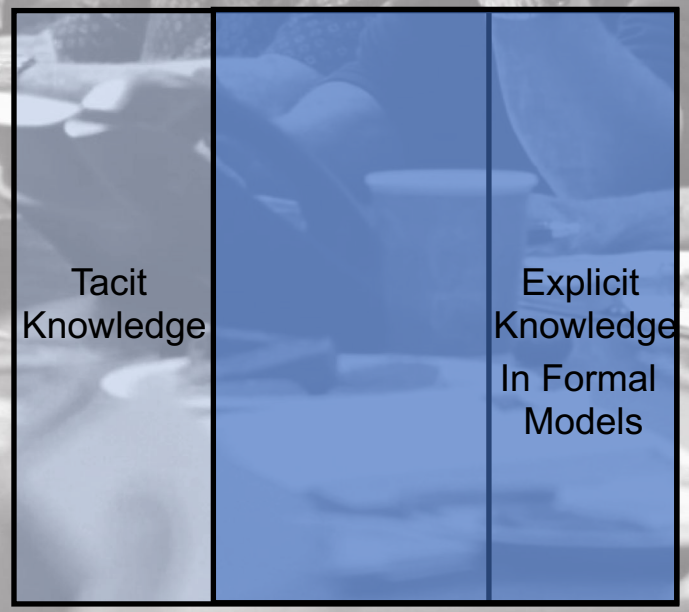


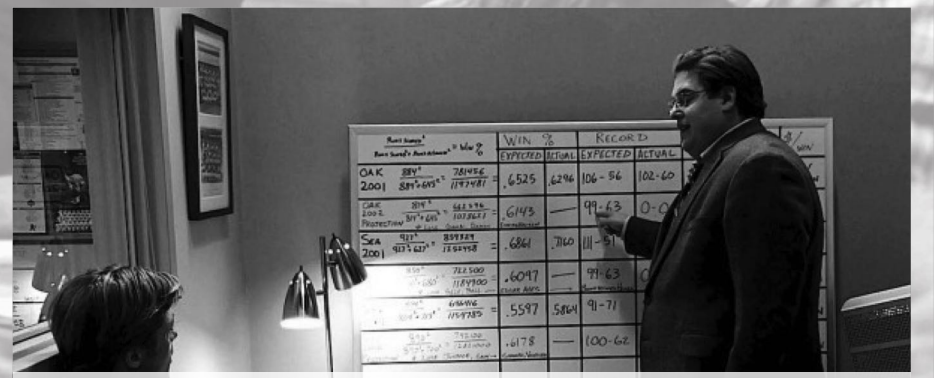
ISO 15288 Process Area interactions from INCOSE Handbook N^2



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

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



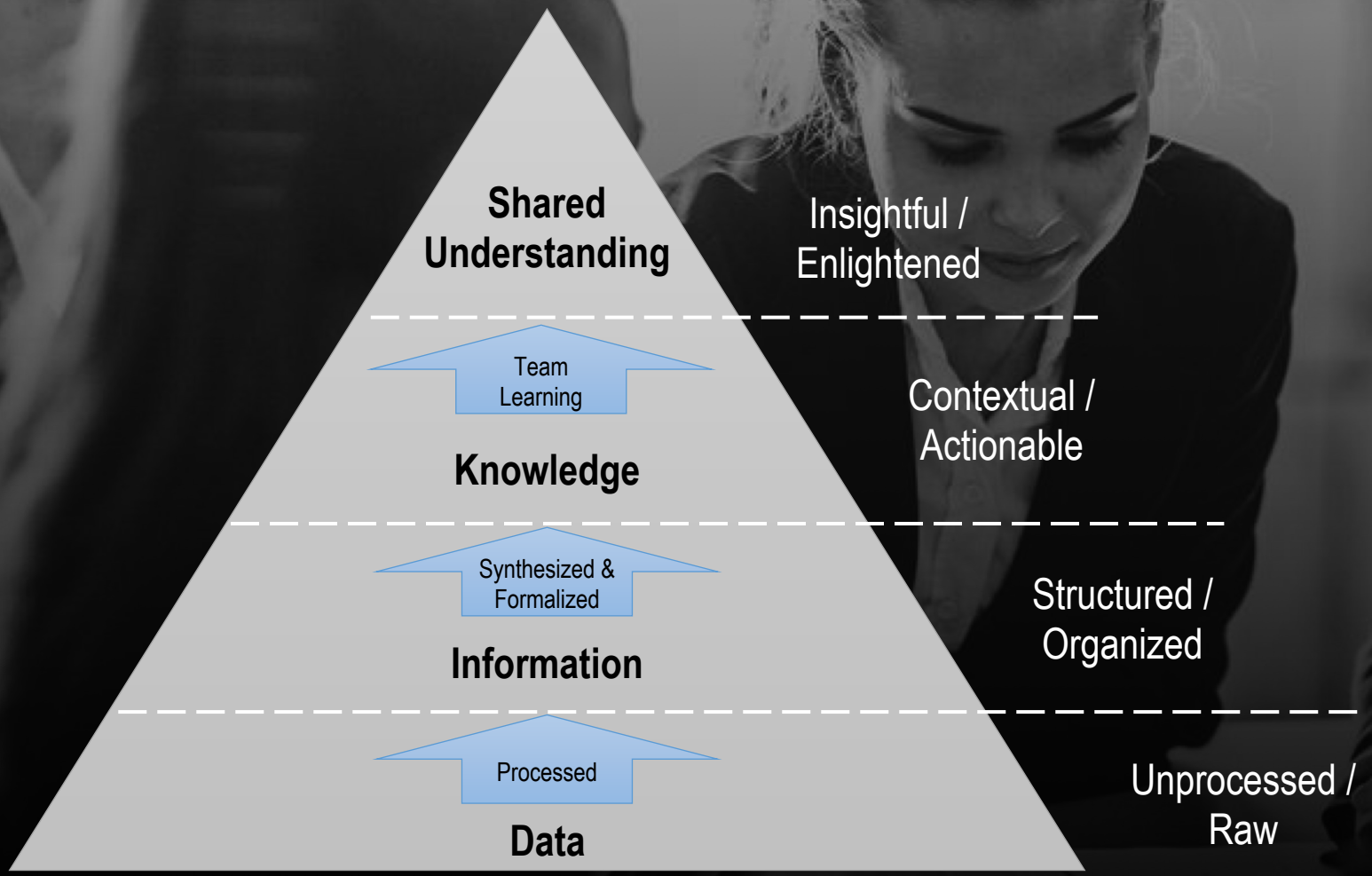


Engineers explicitly model knowledge

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

Model Based Methods Improve Shared Understanding



Vision25 Systems Engineering

INCOSE International Council on Systems Engineering

A WORLD IN MOTION

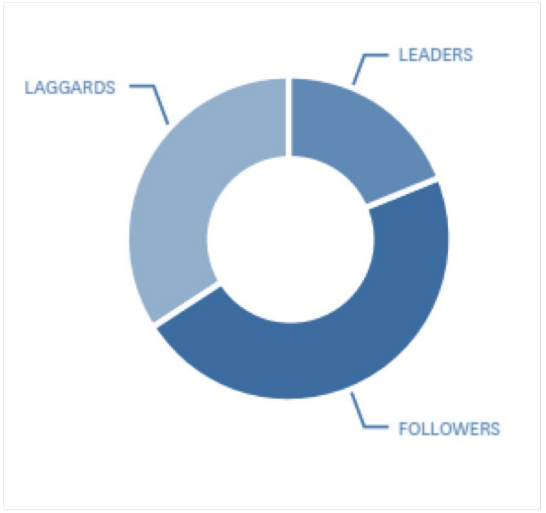
Systems Engineering Vision • 2025

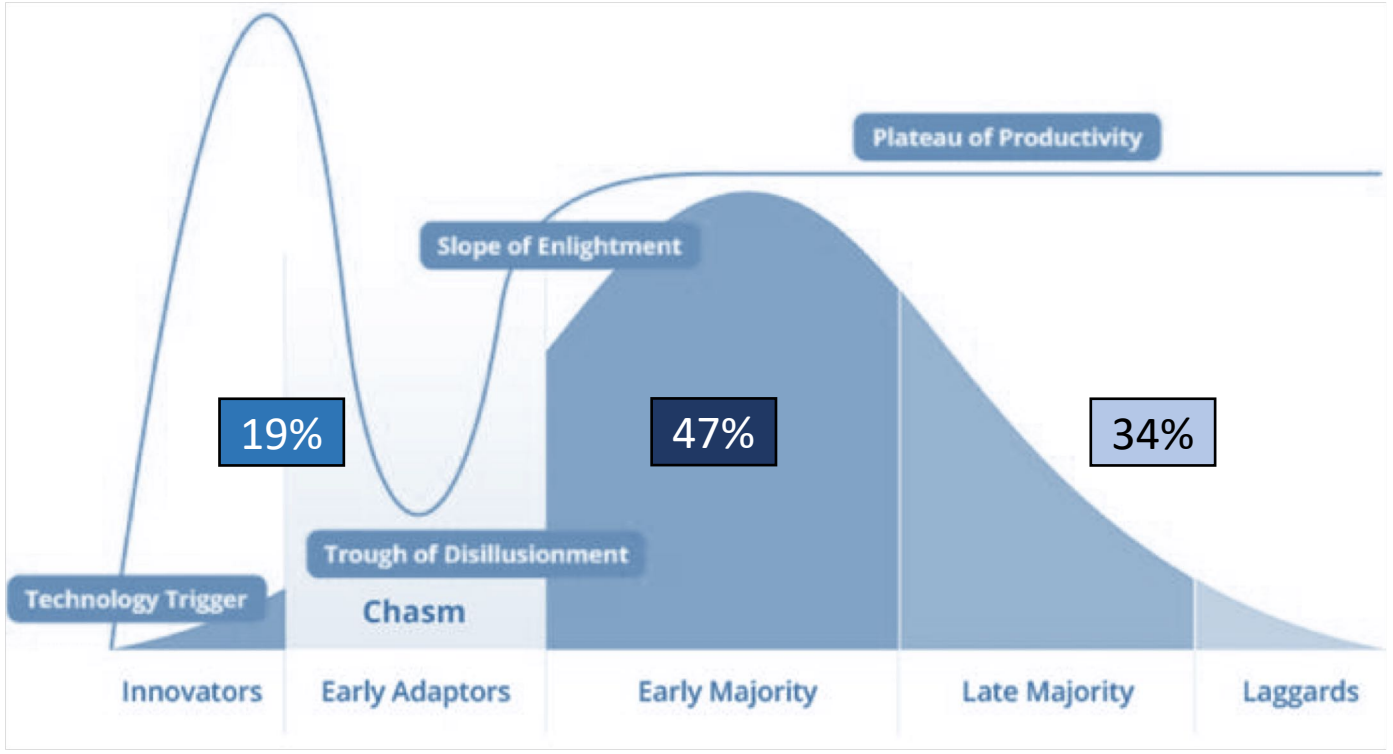
From: …Limitations of document-based approaches, but is still in an early stage of maturity similar to the early days of CAD/CAE.

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.

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

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

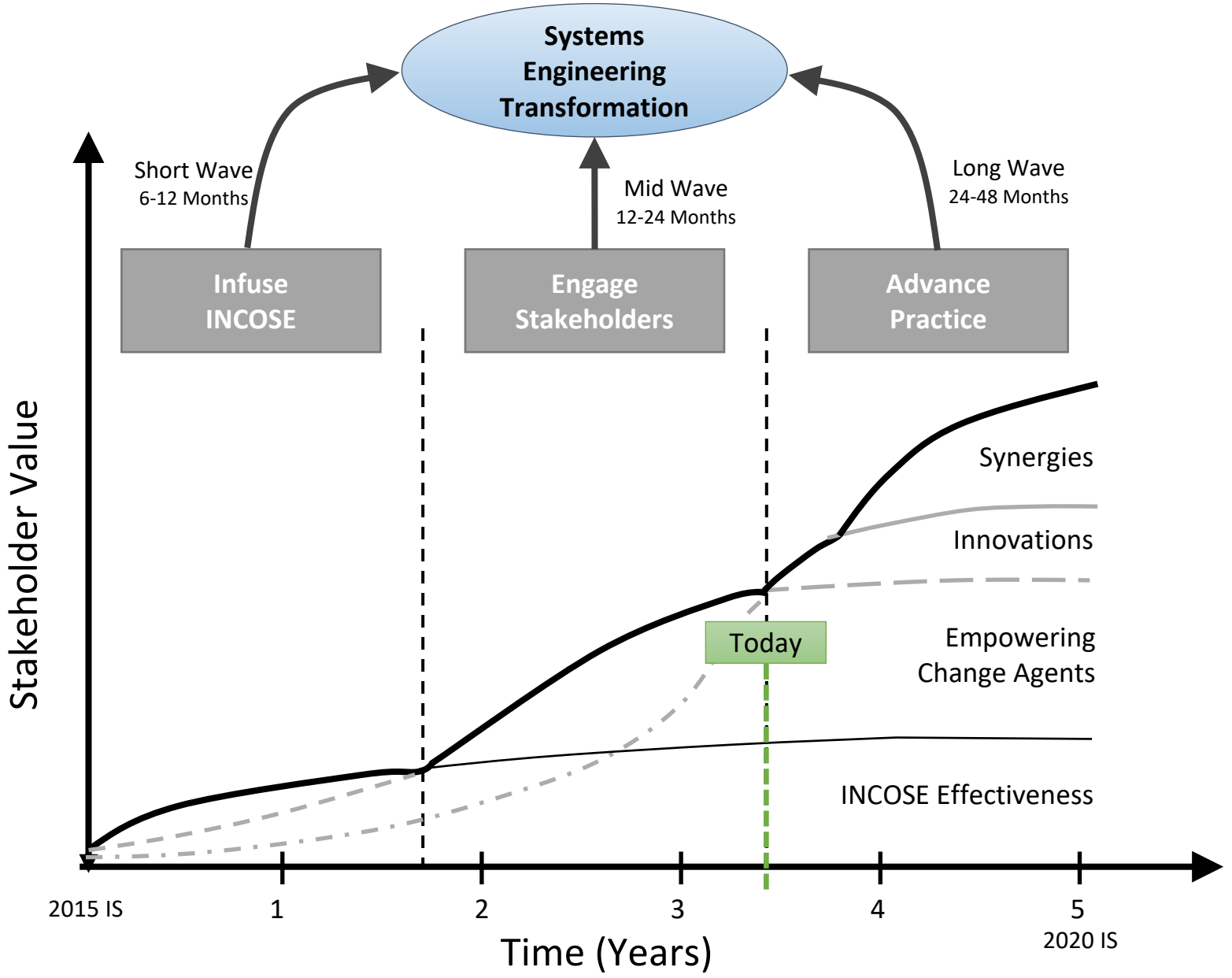
Transformation Strategy Overview

- Vision
- Mission
- Mission Areas
- Goals
- Objectives

Vision	**Systems Engineering is acknowledged as a model based discipline**		
Mission	**INCOSE accelerates the transformation of systems engineering to a model-based discipline**		
Mission Area #	**1**	**2**	**3**
Mission Area	**Infuse INCOSE**	**Engage Stakeholders**	**Advance Practice**
Mission Area	**What can INCOSE Do?**	**What is practiced and needed?**	**What is possible?**
Goals	Infuse model based methods throughout INCOSE products, activities and WGs	Engage stakeholders to assess the current state of practice, determine needs and values of model based methods	Advance stakeholder community model based application and advance model based methods.
Objective 1 Foundations	Inclusion of model based content in INCOSE existing/new products (Vision, Handbook, SEBoK, Certification, Competency Model, etc.)	Define scope of model based systems engineering with MBE practice and broader modeling needs	Advance foundational art and science of modeling from and best practices across academia, industry/gov. and non profit.
Objective 2 Expand Reach	Expand reach within INCOSE of MBSE Workshop; highlight and infuse tech ops activities with more model based content (products, WGs etc.)	Identify, categorize and engage stakeholders and characterize their current practices, enablers and obstacles	Increase awareness of and about stakeholders outside SE discipline of what is possible with model based methods across domains and disciplines (tech/mgmt)
Objective 3 Collaborate	Outreach: Leverage MOUs to infuse model based content into PMI, INFORMS, NAFEMS, BIM, ASME and others, sponsoring PhD Students, standardization bodies, ABET	Build a community of Stakeholder Representatives to infuse model based advances into organizations practicing systems engineering.	Initiate, identify and integrate research to advance systems engineering as a model based discipline
Objective 4 Assessment/ Roadmap	Assess INCOSE's efforts (WG, Objectives, Initiatives etc.) for inclusion of model based methods across the Systems Modeling Assessment/Roadmap	Engage stakeholder community with Systems Modeling Assessment/ Roadmap to better understand the state of the practice of MBSE. Push and pull content from stakeholders (change agents and the "to be convinced")	Provide baseline assessment framework, Systems Modeling Roadmap, to create a concrete measure of current state of the art of what's possible/what's the potential.

Strategy Notional Timeline

- Mission Areas
- Internal Short Wave
- External Mid Wave
- Advancing Long Wave
- Waves Run Concurrently
- Activities build on each other
- Important to fully engage stakeholder this next year. Pilot Assessment & Roadmap this CY and kick-off more broadly at 2017 IW.



Transformation Developments and Outcomes

Outcomes Achieved

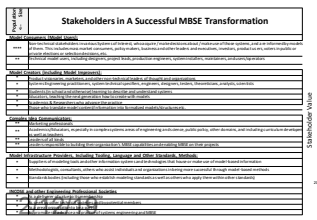
- **Supported incubation of >7 Challenge Teams/WGs**
- **Provided >35 INCOSE Transformation briefings**
- **INCOSE IS and IW MBSE Lightening Rounds**
- Model Wrapper / Features Packaging Framework
- Model Based Assessment Roadmap
- Model Based Stakeholder List
- Model Based Enablers & Roadblocks
- INCOSE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

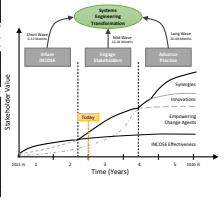
New/Related Developments

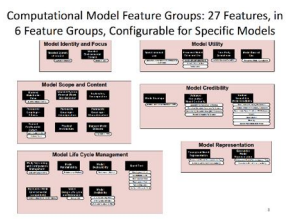
- Challenge Teams as Innovation Incubators
- Collaborative V&V of models with ASME
- Expanding and Developing new MOUs
- Supporting OCM effort within INCOSE
- MBSE FAQs Development
- Model Based Exemplars
- INCOSE MBSE Primer
- Model Based Value Briefing
- Supporting ST4SE: Semantic Technologies
- INCOSE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

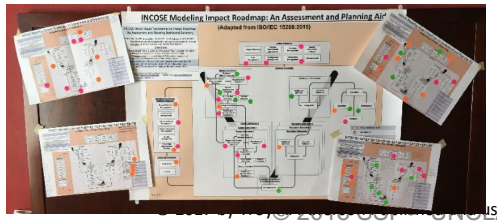
Next Steps

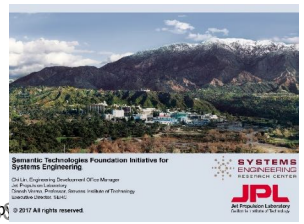
- Kickstart and Support Transformative INCOSE Activities
- Infuse Change Management principles across INCOSE
- Collaborate with FUSE, Vision etc.
- Establish a Sector Ambassador program to extend reach
- Improve communications (INSIGHT Transformation Corner Update webpage on incose.org)
- Update and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

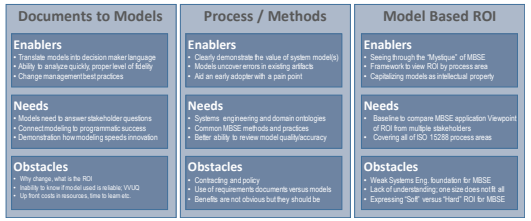


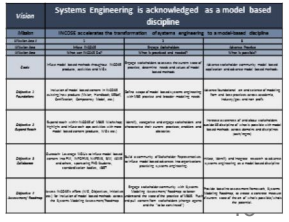












Transformation, Change and Trust – Speed Depends on Relationships

Leading Change: John P. Kotter

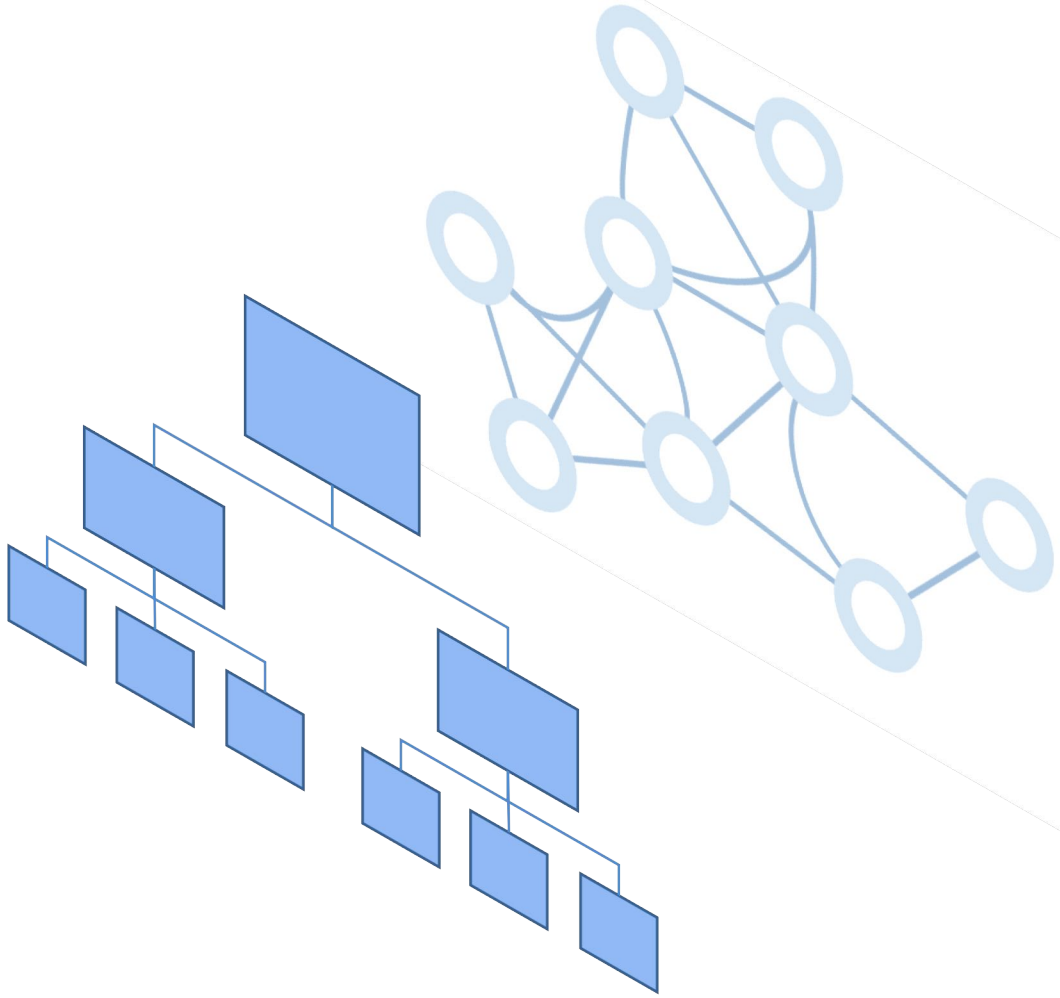
Eight-Step Process for undertaking major change.

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, relationships, strategic acceleration and driven to innovate.



Assertion

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

Engage as a Transformation Stakeholder Representative, visit:
http://www.incose.org/about/strategicobjectives/transformation

Are we nearing a Tipping Point? Are Models the Obvious Path Foward

Is the tide changing? Are we moving from:

Why & ROI

to

Now & How

Having Trouble Understanding your Systems?

Model Them!

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}*

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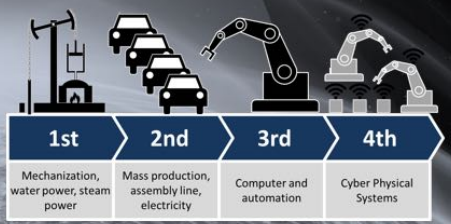

Systems Engineering

The Essence of the Next Industrial Revolution

25 January 2019

Complexity and Rate of Change

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

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

"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."

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

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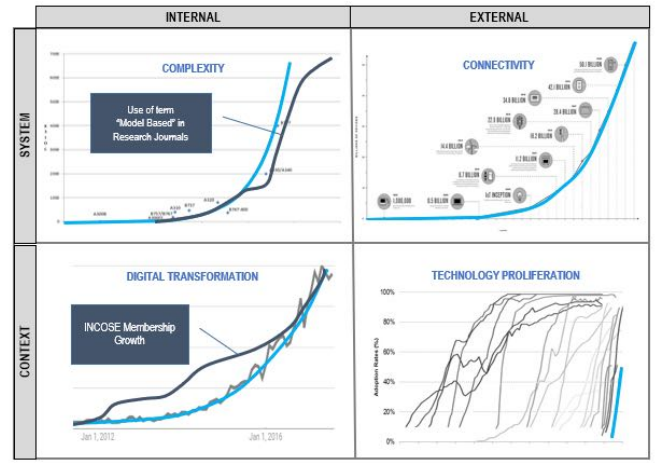
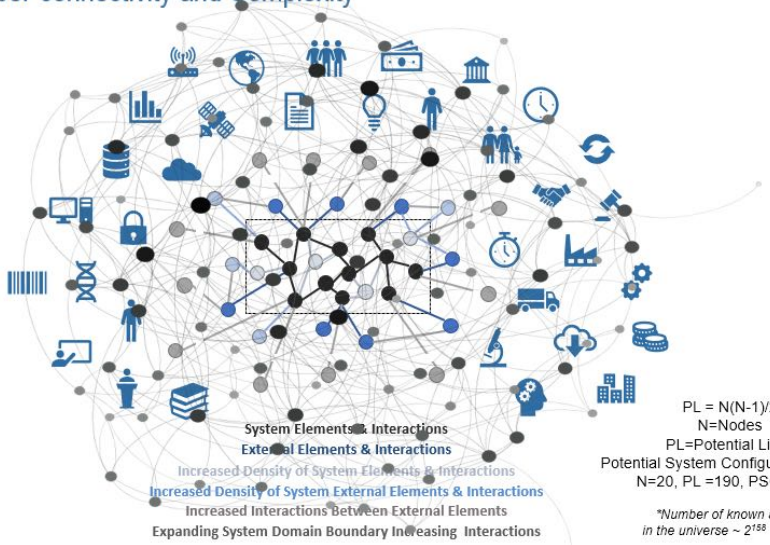


3

Hyper-connectivity and Complexity



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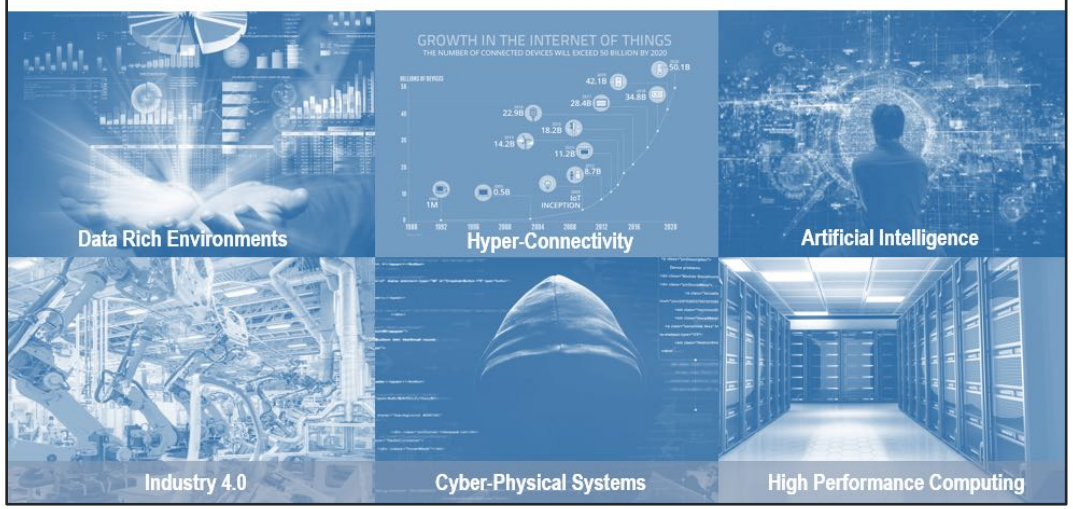

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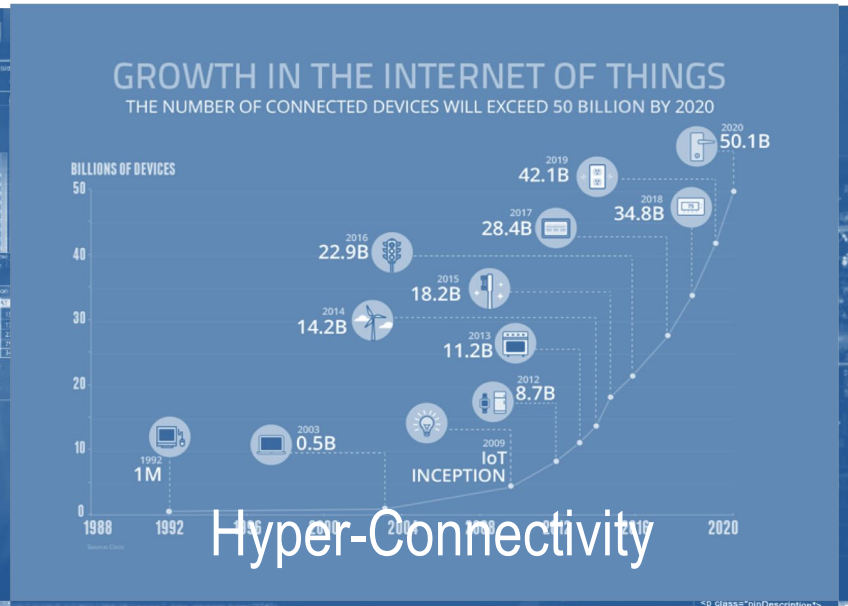
What is the role of Systems Engineering with latest Technologies and Trends?

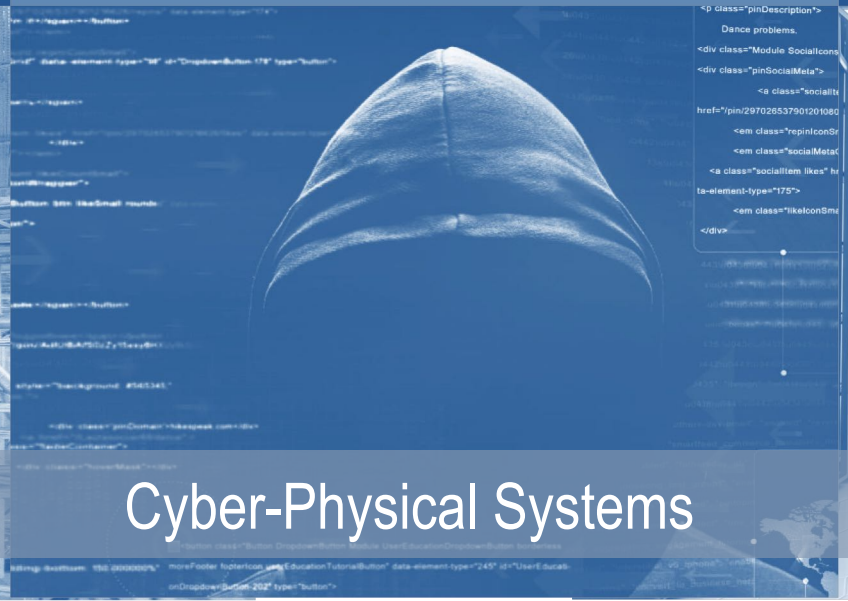
Data Rich Environments



Hyper-Connectivity

Artificial Intelligence

Industry 4.0



Cyber-Physical Systems

High Performance Computing

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 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

Transformation: Change Management and Leadership

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.

Why We Must Rapidly Modify and Adapt our Systems?

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

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

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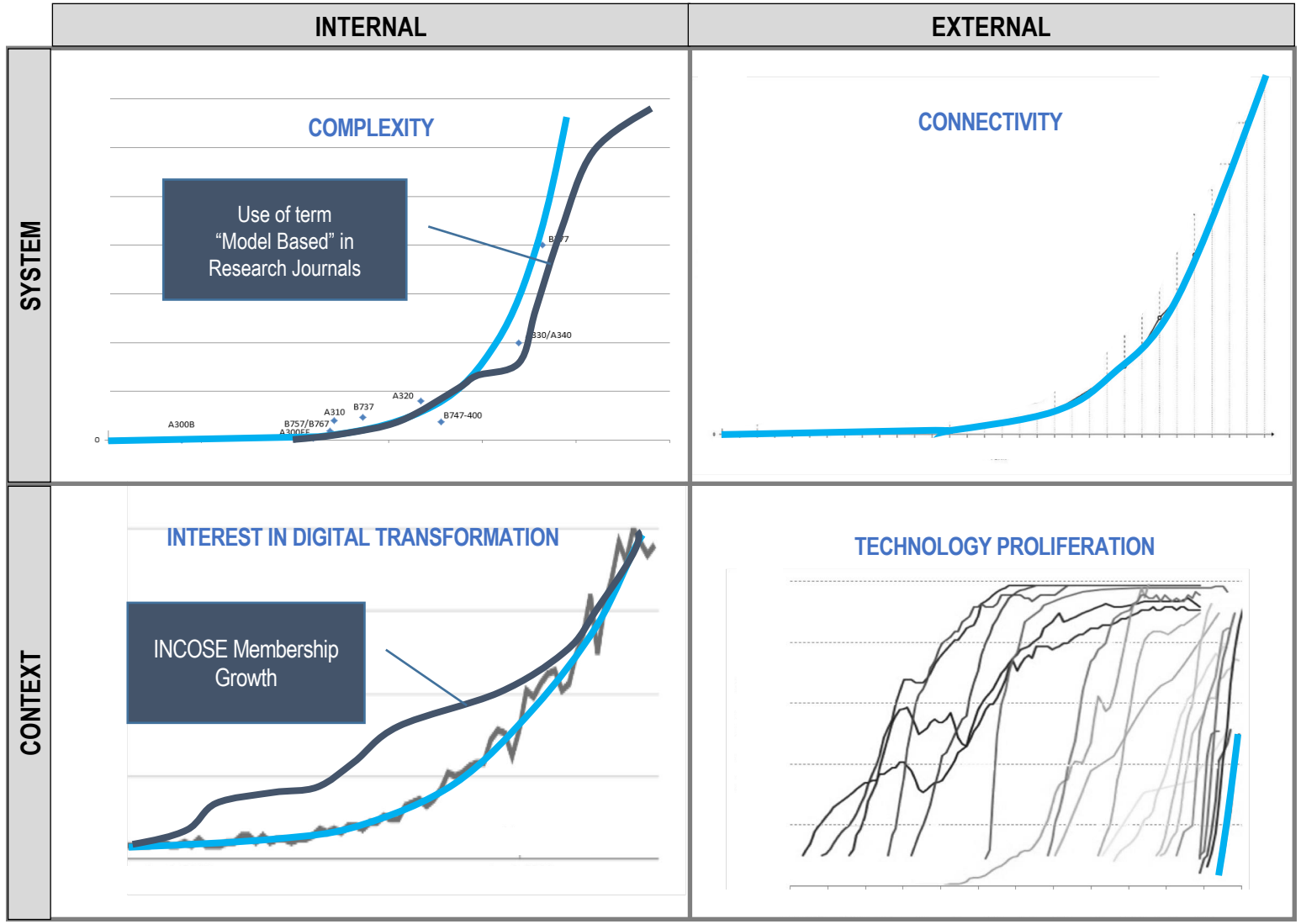


Transforming Systems Engineering

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.

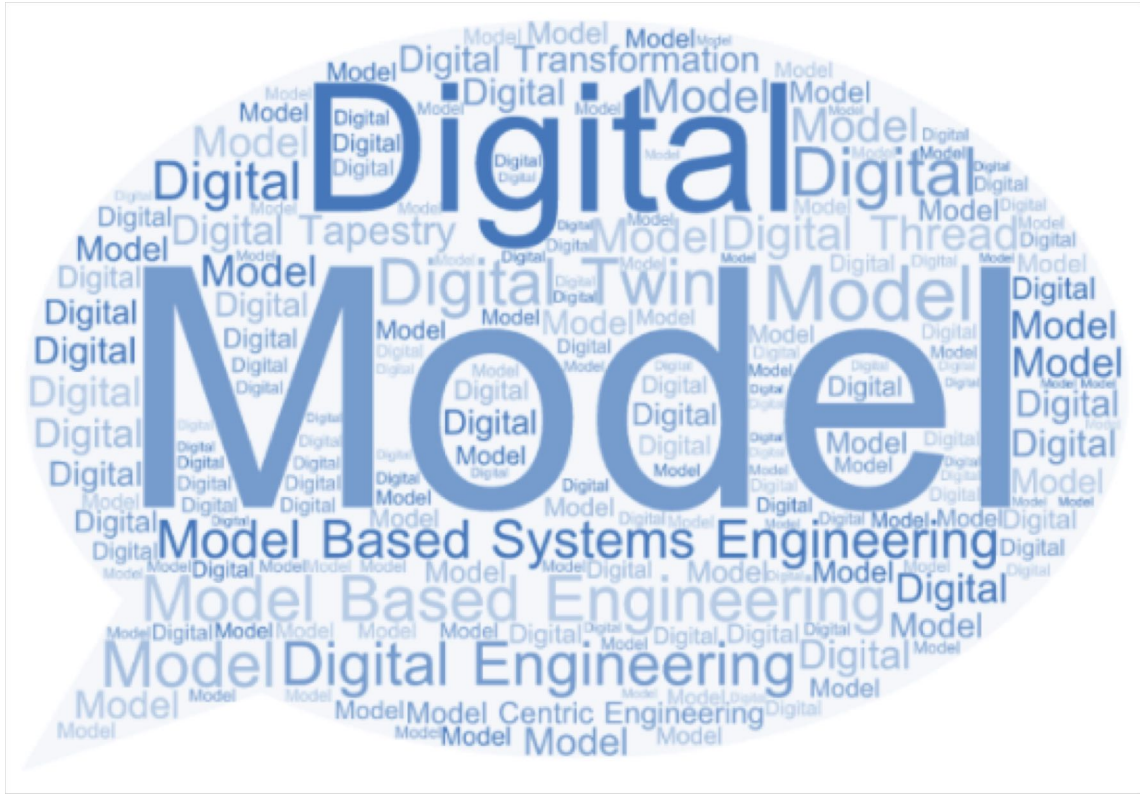
Composable design methods in a virtual environment **support rapid, agile and evolvable designs of families of products**. By combining formal models from a library of component, reference architecture, and other context models, different system alternatives can be quickly compared and probabilistically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

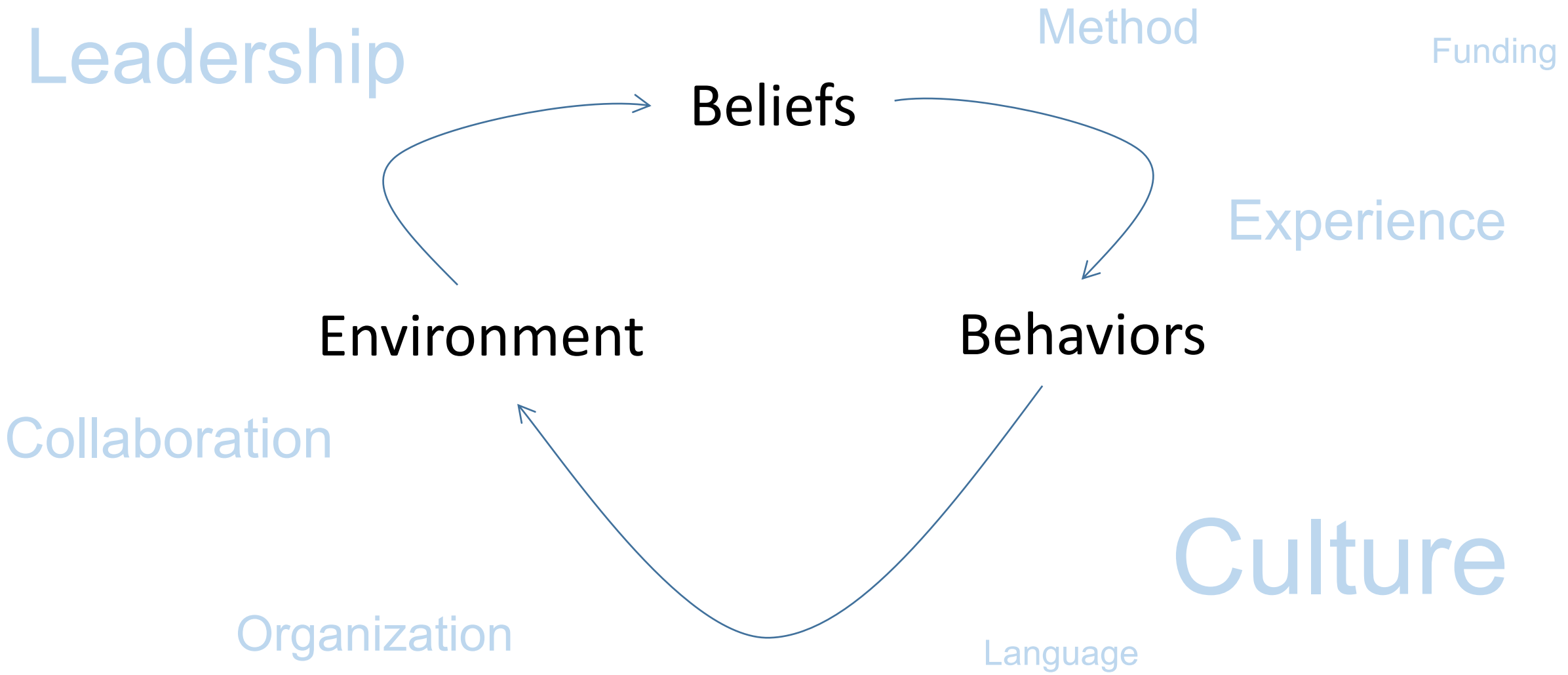
To: Formal systems modeling is standard practice for specifying, analyzing, designing, and verifying systems, and is fully integrated with other engineering models. System models are adapted to the application domain, and include a broad spectrum of models for representing all aspects of systems. The 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.

What is Model-Driven, MBSE, DE?

- What do we mean by:
  - Model Based Systems Engineering
  - Model Based Engineering
  - Model Based Development
  - Model Based Design
  - Model Centric Engineering
  - Model Based Methods
  - Digital Engineering
  - Digital Design
  - Digital Thread
  - Digital Twin
  - Digital Tapestry
  - Et al.

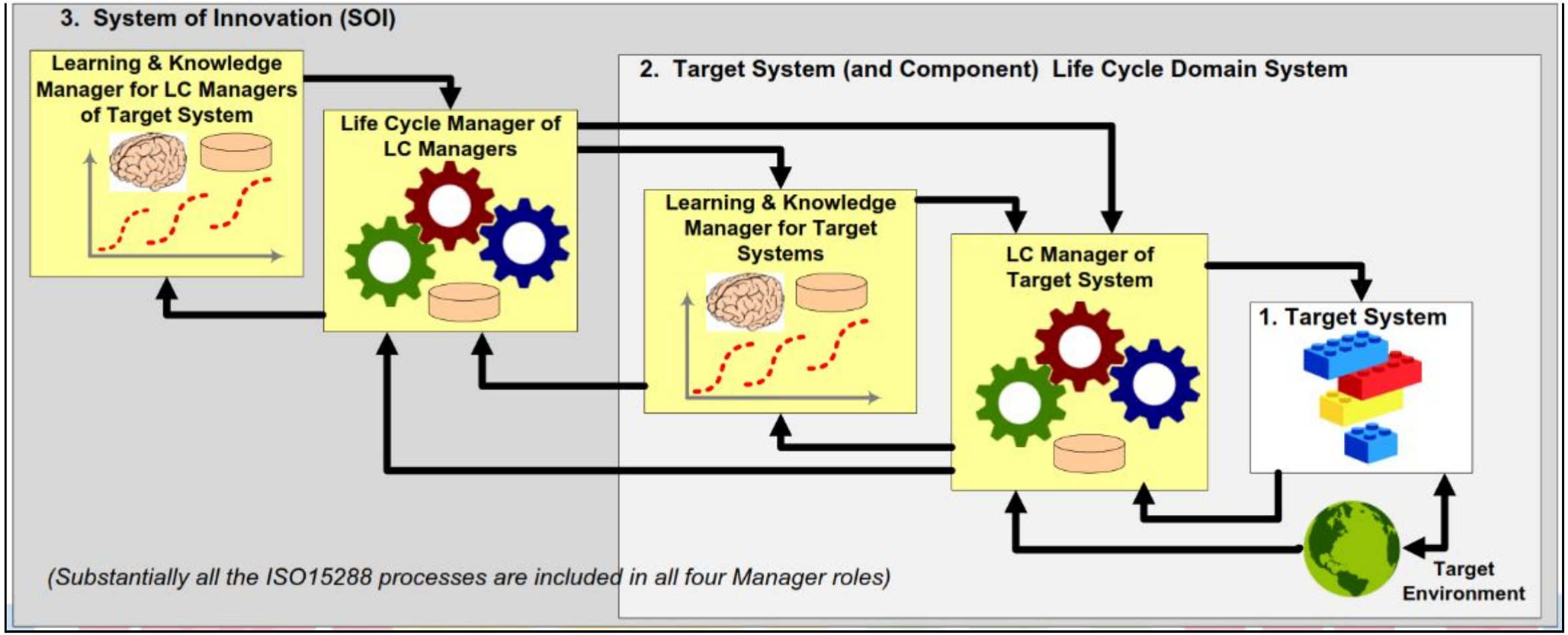


Transformation: Change Beliefs to affect Outcomes



Innovation - Management of Change - Transformation

Agile Systems Engineering Life Cycle Management Pattern



System of Innovation Environment

Who is applying Systems Engineering to the greatest extent possible today

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

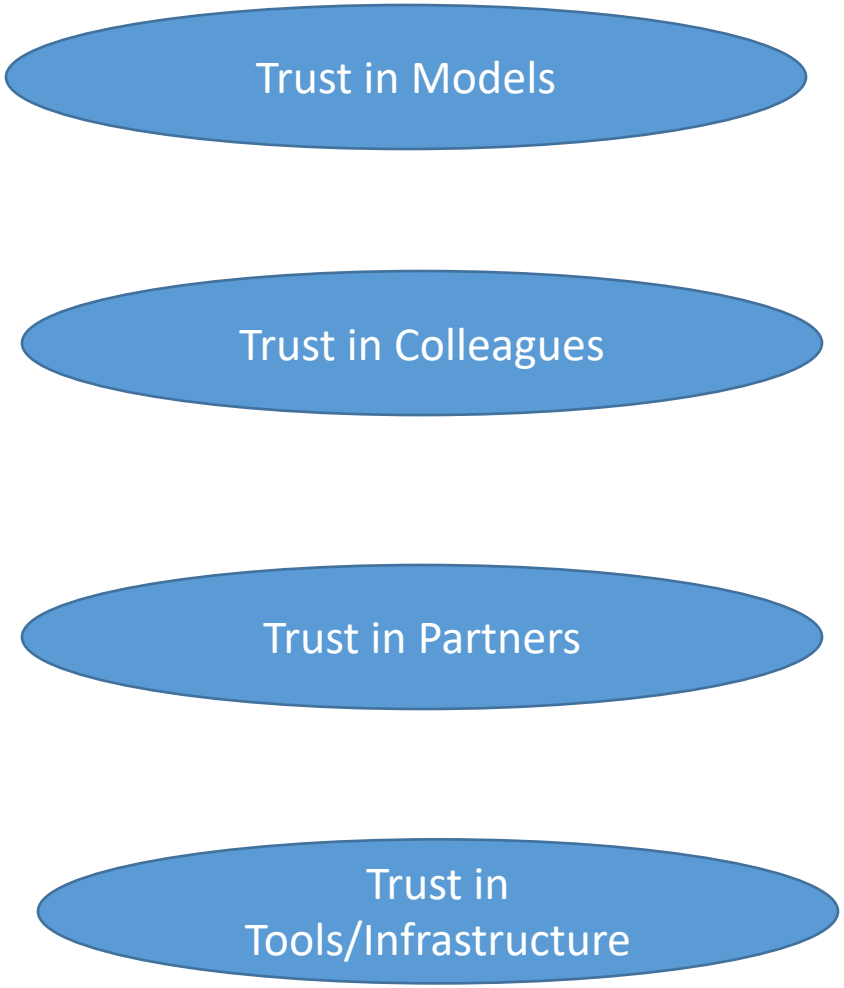
Jack Welch

Ultimately we are talking about speed

- What is required for speed?

TRUST

- At every level



- AI (across lifecycle) 3d printing (late), Concepts (early),
- Models Underpinning all
- Systems Principles Underpinning all

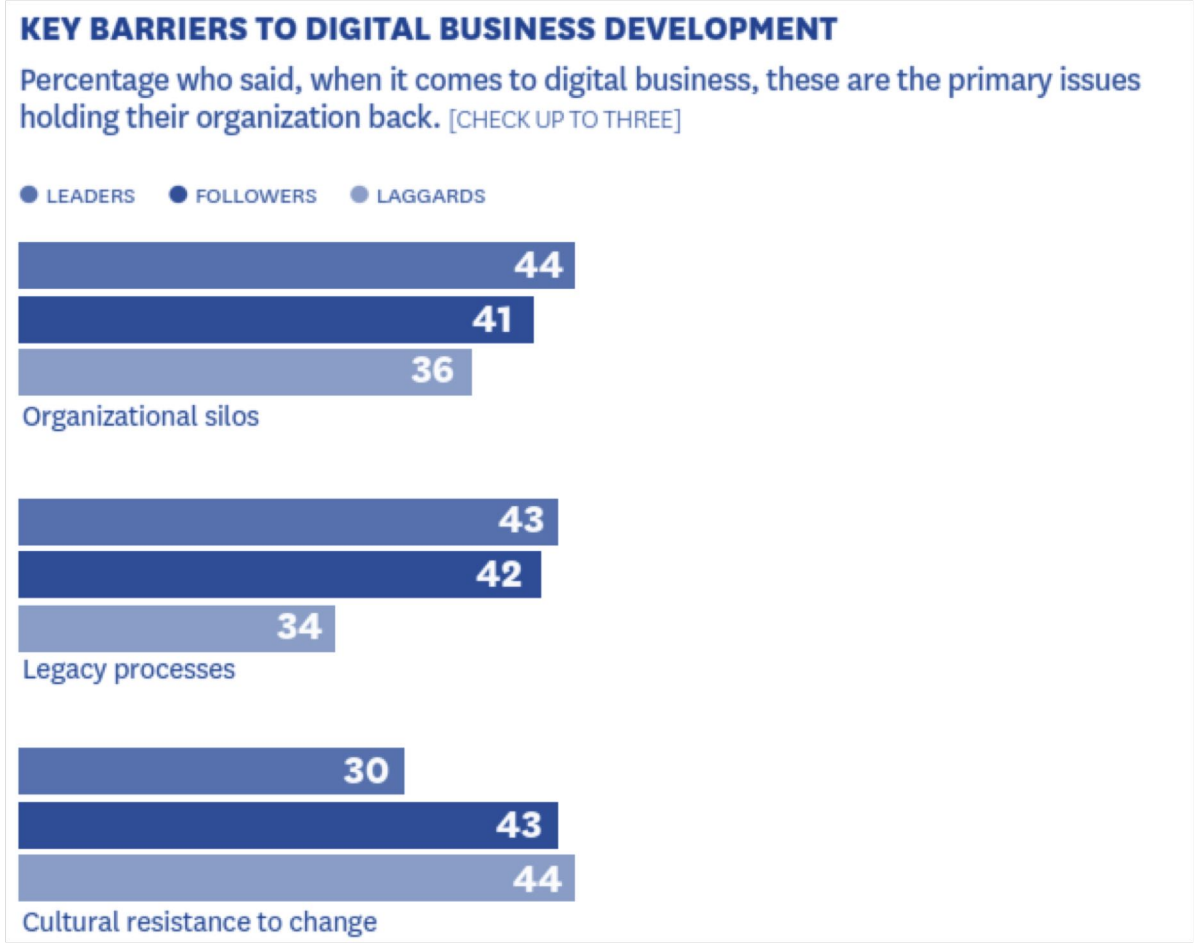
Closed Loop – to occur we must build bridges, portals, relationships

- Closed loop models must span over boundaries. Feedback loops must cross over:
  - Organizational – Cultural – Boundaries
  - Functional Boundaries
  - Contractual Boundaries / Supply Chain
  - Customer – Developer
  - Information Technology Boundaries
  - Mindset/Paradigm Belief Boundaries
  - Language Boundaries (GDT, English, CAD, Drawings,
  - Lifecycle Boundaries
  - Ethical Boundaries
  - PEST
  - Cross over, overcome,

Transformation: Driving Digital Transformation[1]

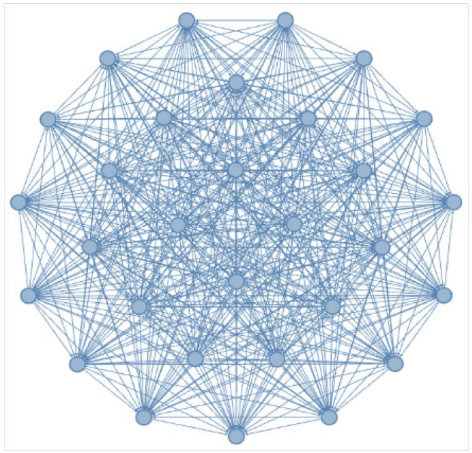
Keys to Digital Transformation (HBR Report)

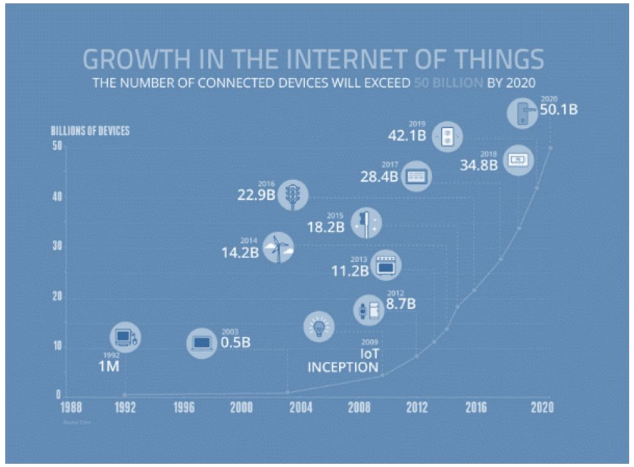
- Start from the customers perspective
- Digital leadership starts at the top
- Engage in a discussion of trends
- Think about agile
- Use examples to make it real
- Need a foundation of trust
- Use KPIs for sharing knowledge
- Break down walls wherever possible
- Need digital coaches or maters
- Create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



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

Overcoming the Challenge





Simplicity does not precede complexity but follows it.

Alan Perlis (1922 – 1990)

Simplicity is complexity resolved.

Constantin Brancusi (1876-1957)

Fools ignore complexity. Pragmatists suffer it. Some can avoid it. Geniuses remove it.

Alan Perlis (1922 – 1990)

Any intelligent fool can make things bigger and more complex… It takes a touch of genius – and a lot of courage to move in the opposite direction.

Albert Einstein (1879 – 1955)

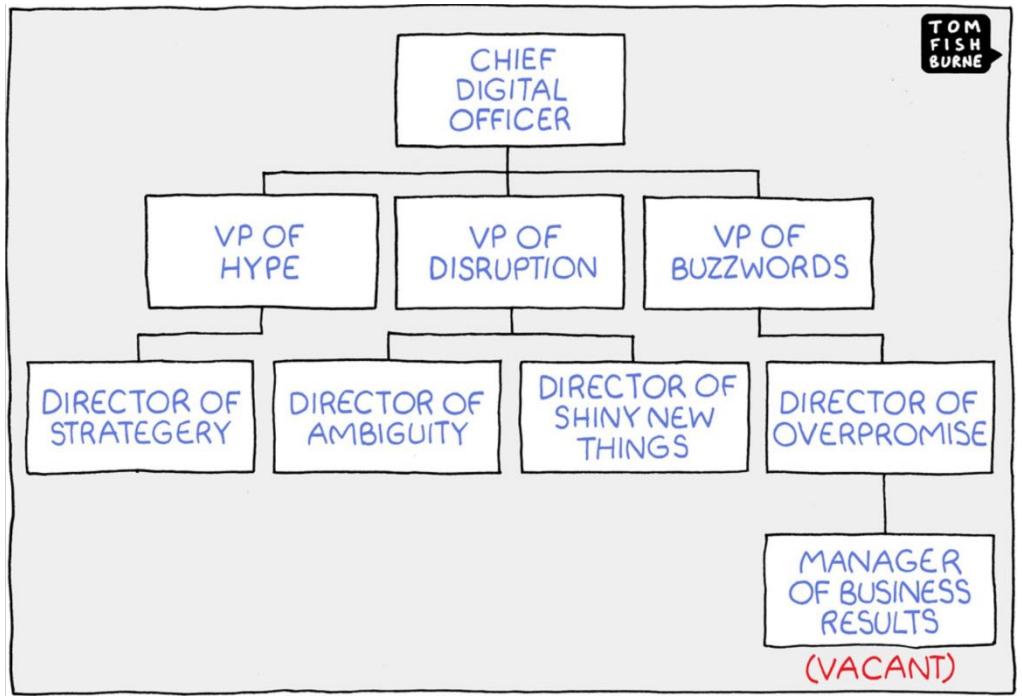
A genius! For 37 years I've practiced fourteen hours a day, and now they call me a genius!

Pablo de Sarasate (1844 – 1908)

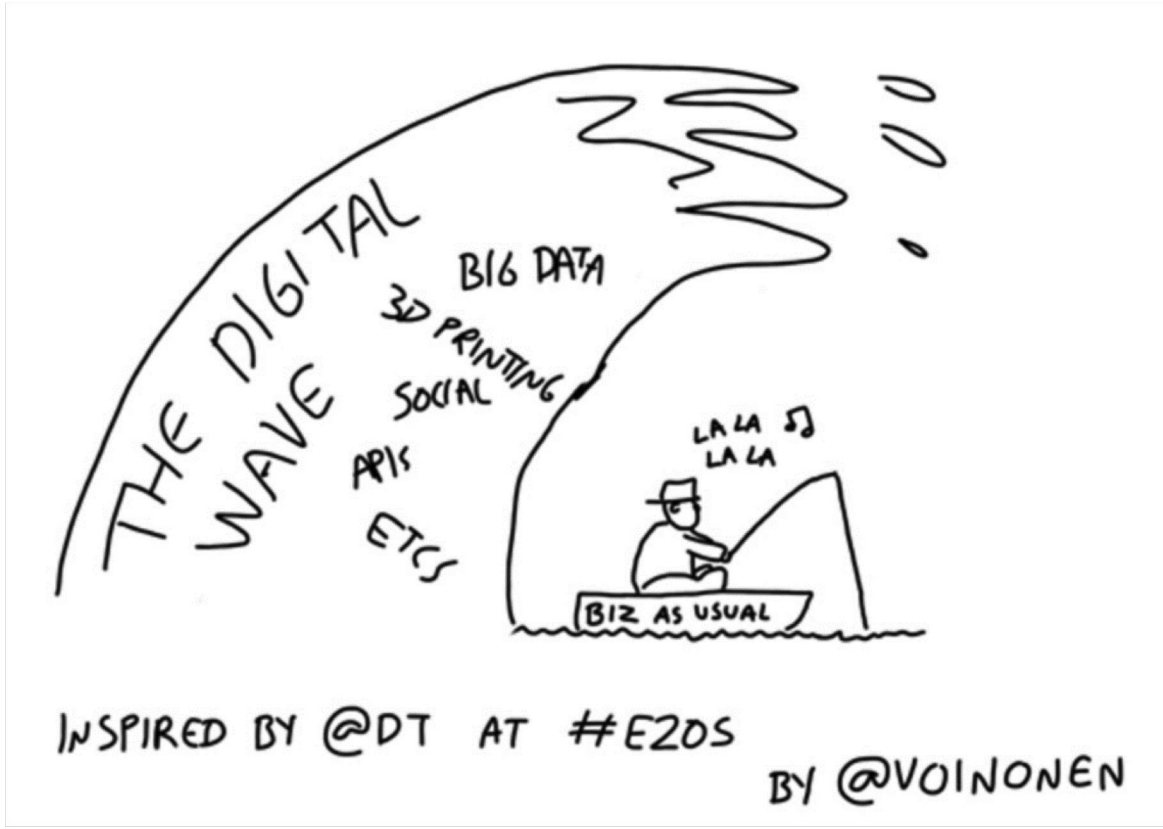
Lesson: Endure complexity, add tireless effort, and a touch of genius…

INCOSE Q&A

Digital States



Digitally Zealous



Digital Denial

Troy Peterson

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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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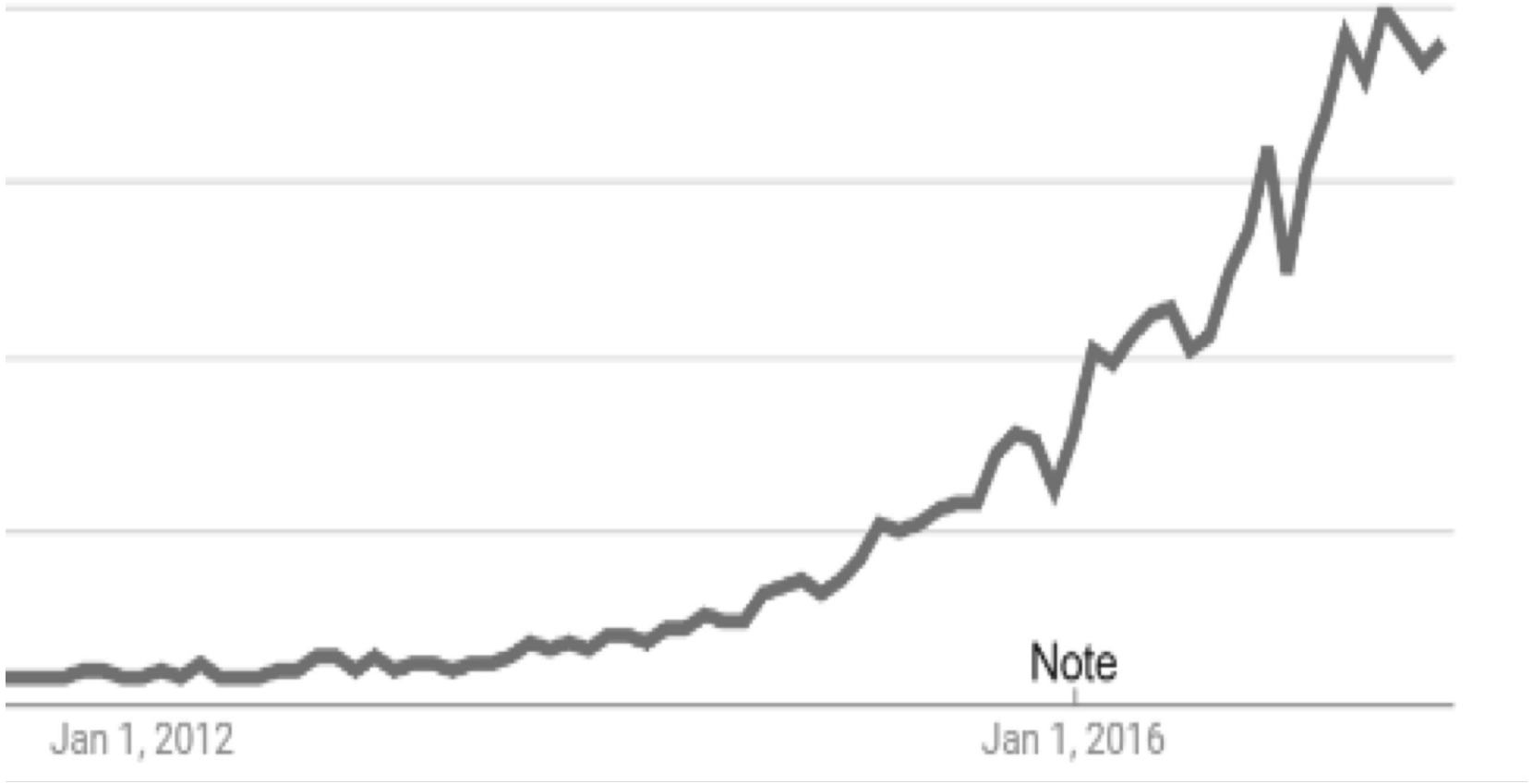
Trouble
understanding
systems?
Model them

Digital Transformation



Model Based Systems Engineering Scope

ISO 15288

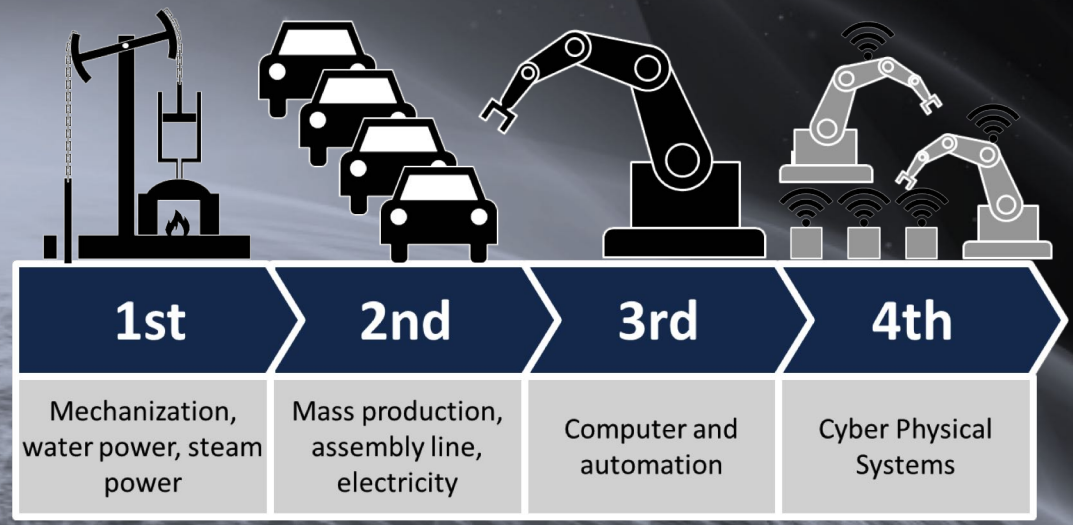
Graph of ISO 15288 Process Area interactions from INCOSE Handbook

Systems Engineering *the central cohesive discipline essential to combine domain knowledge and technologies for value creation*

Digital Transformation & the Forth Industrial Revolultion

"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
World Economic Forum



Systems Engineering

The Essence of the Next Industrial Revolution