INCOSE: TRANSFORMATION

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2019 INCOSE IW

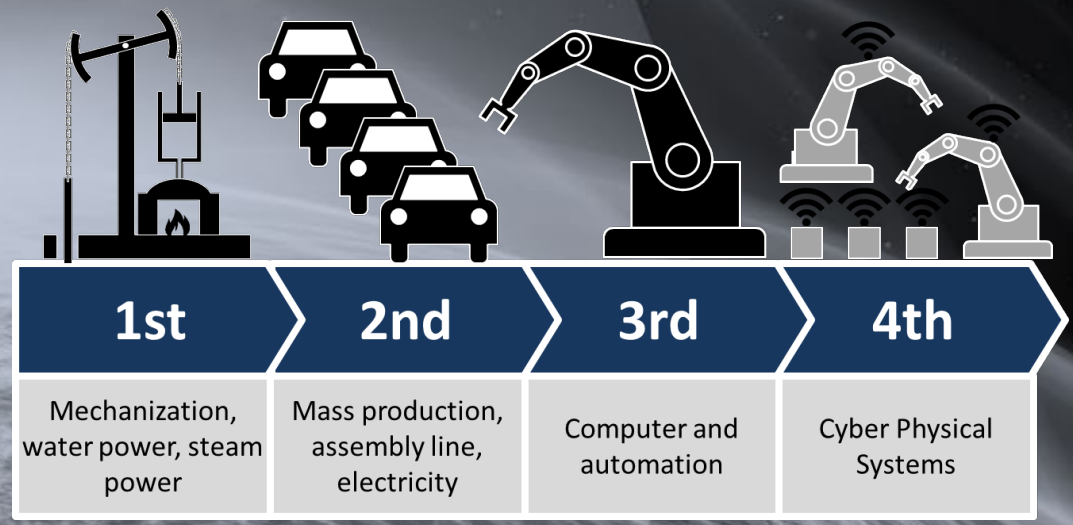
January 27, 2018

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

WORLD ECONOMIC FORUM
COMMITTED TO IMPROVING THE STATE OF THE WORLD



Systems Engineering

The Essence of the Next Industrial Revolution

Deep Shift
Technology Tipping Points and Societal Impact

WORLD ECONOMIC FORUM

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The Six Megatrends

As a foundation to its work, the council sought to identify the software and services megatrends which are shaping society, and their associated opportunities and risks.

People and the internet
How people connect with others, information and the world around them is being transformed through a combination of technologies. Wearable and implantable technologies will enhance people's "digital presence", allowing them to interact with objects and one another in new ways.

Computing, communications and storage everywhere
The continued rapid decline in the size and cost of computing and connectivity technologies is driving an exponential growth in the potential to access and leverage the internet. This will lead to ubiquitous computing power being available, where everyone has access to a supercomputer in their pocket, with nearly unlimited storage capacity.

The Internet of Things
Smaller, cheaper and smarter sensors are being introduced – in homes, clothes and accessories, cities, transport and energy networks, as well as manufacturing processes.

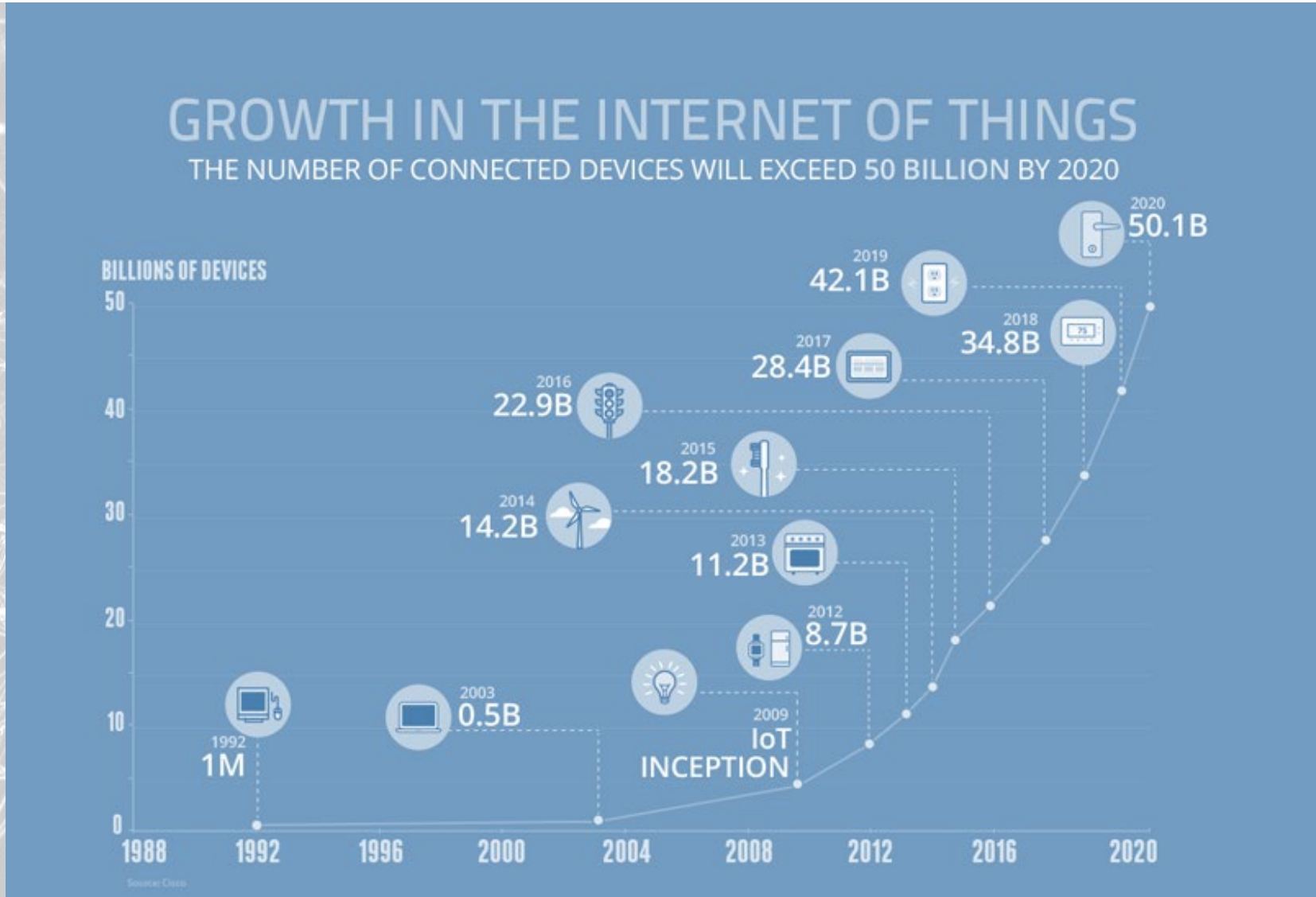
Artificial intelligence (AI) and big data
Exponential digitization creates exponentially more data – about everything and everyone. In parallel, the sophistication of the problems software can address, and the ability for software to learn and evolve itself, is advancing rapidly. This is built on the rise of big data for decision-making, and the influence that AI and robotics are starting to have on decision-making and jobs.

The sharing economy and distributed trust
The internet is driving a shift towards networks and platform-based social and economic models. Assets can be shared, creating not just new efficiencies but also whole new business models and opportunities for social self-organization. The blockchain, an emerging technology, replaces the need for third-party institutions to provide trust for financial, contract and voting activities.

The digitization of matter
Physical objects are "printed" from raw materials via additive, or 3D, printing, a process that transforms industrial manufacturing, allows for printing products at home and creates a whole set of human health opportunities.

Trends: Internet of Things

The interconnection of products is ubiquitous, occurring across domains and with systems we use every day creating a complex web of interdependent systems.



Trends: Data Science

Analytics – Data Science - Visualization/Navigation:

Improving Systems and Shared Human Understanding Across Stakeholders

Trends: Cyber-Physical Systems & Security

Cyber-Physical Systems

Intertwining cyber and physical, vast state space, new vulnerabilities

Trends: Artificial Intelligence

Augmented Intelligence

Human, Machine interactions solving complex problems

Trends: Industrial Revolution / Industry 4.0

Industry 4.0 / Industrial Internet

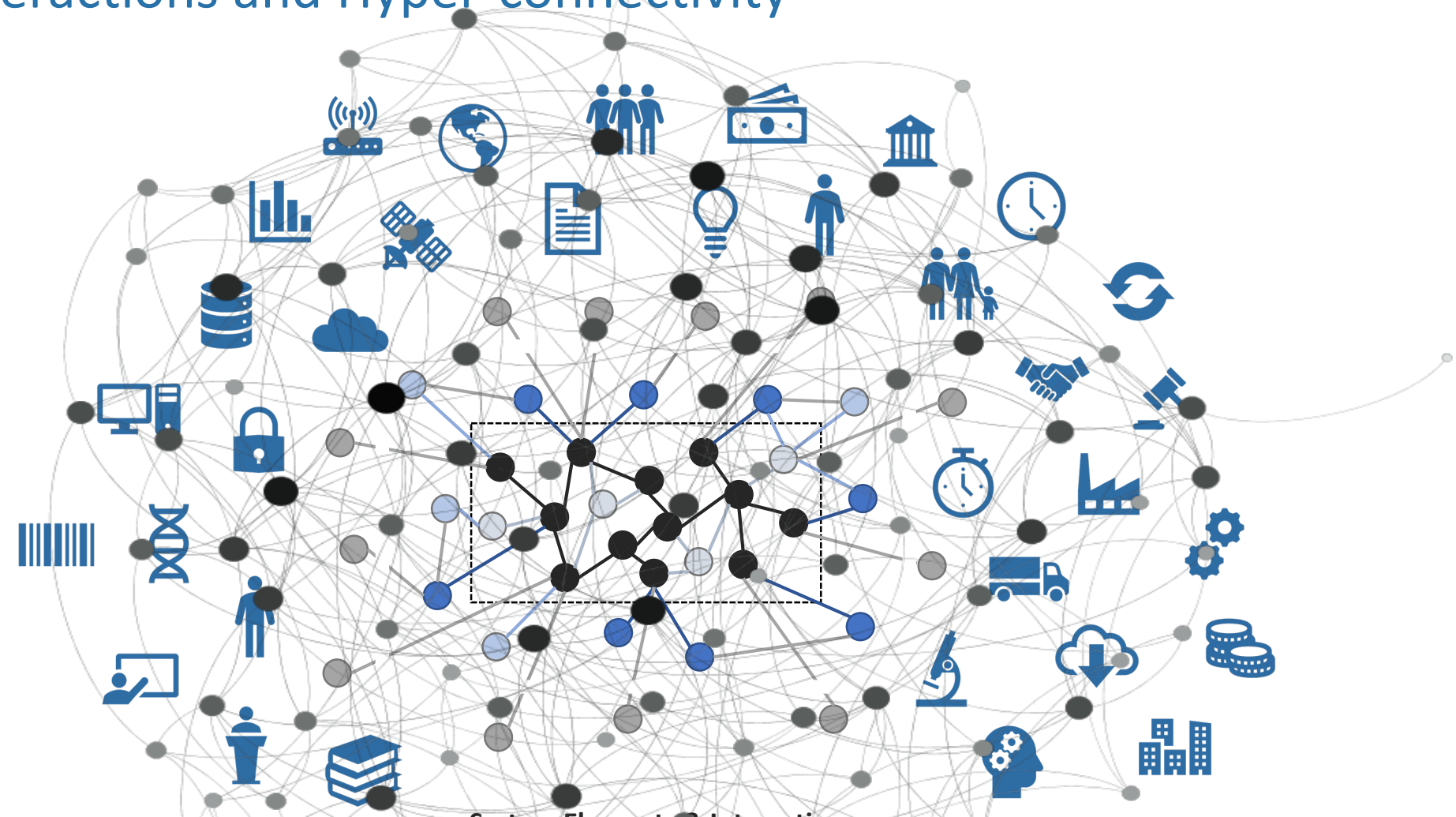
Connecting models across the lifecycle

Trends: High Performance Computing

High Performance Computing

High Fidelity System Simulations, Available/Continuous Computing Power…

Interactions and 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

Complexity and Rate of Change

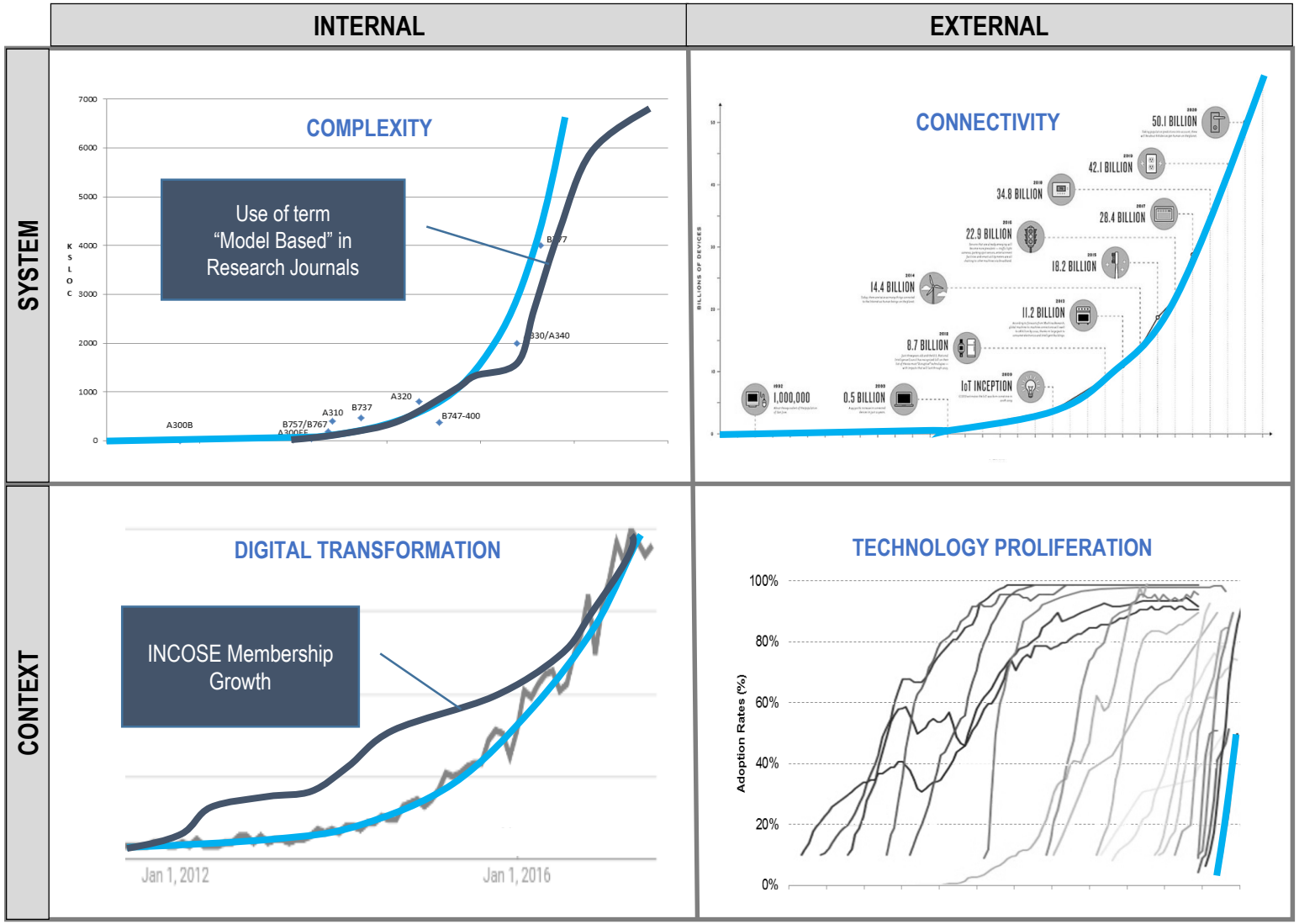
"Today more and more design problems are reaching insoluble levels of complexity."

"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.

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



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

Jack Welch

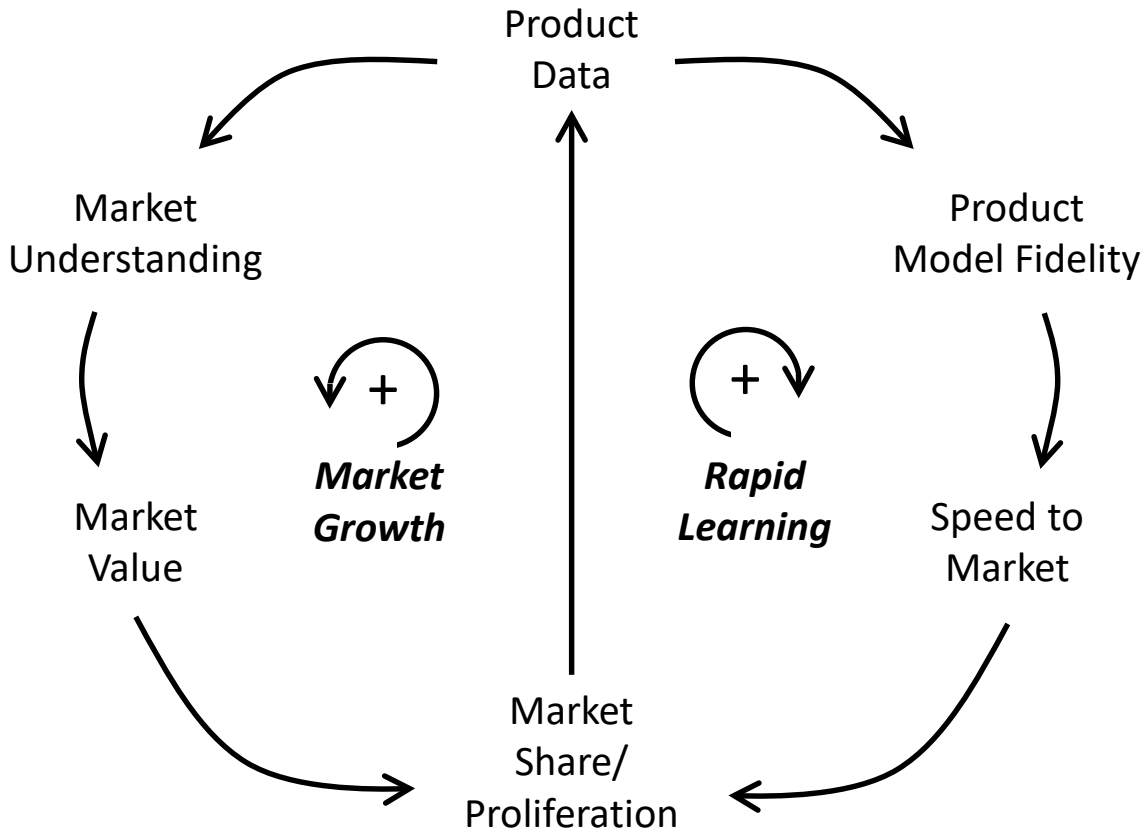
What's Required to Better Integrate Technology and More Swiftly Adapt?

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.



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.

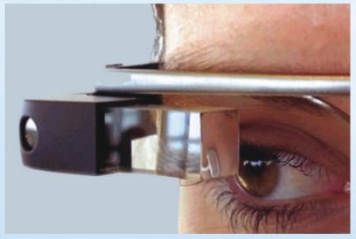
Transforming Systems Engineering

Leveraging Technology for Systems Engineering Tools

Cloud-based high performance computing supports high fidelity system simulations

Advanced search query, and analytical methods support reasoning about systems

Immersive technologies support data visualization



Net-enabled tools support collaboration

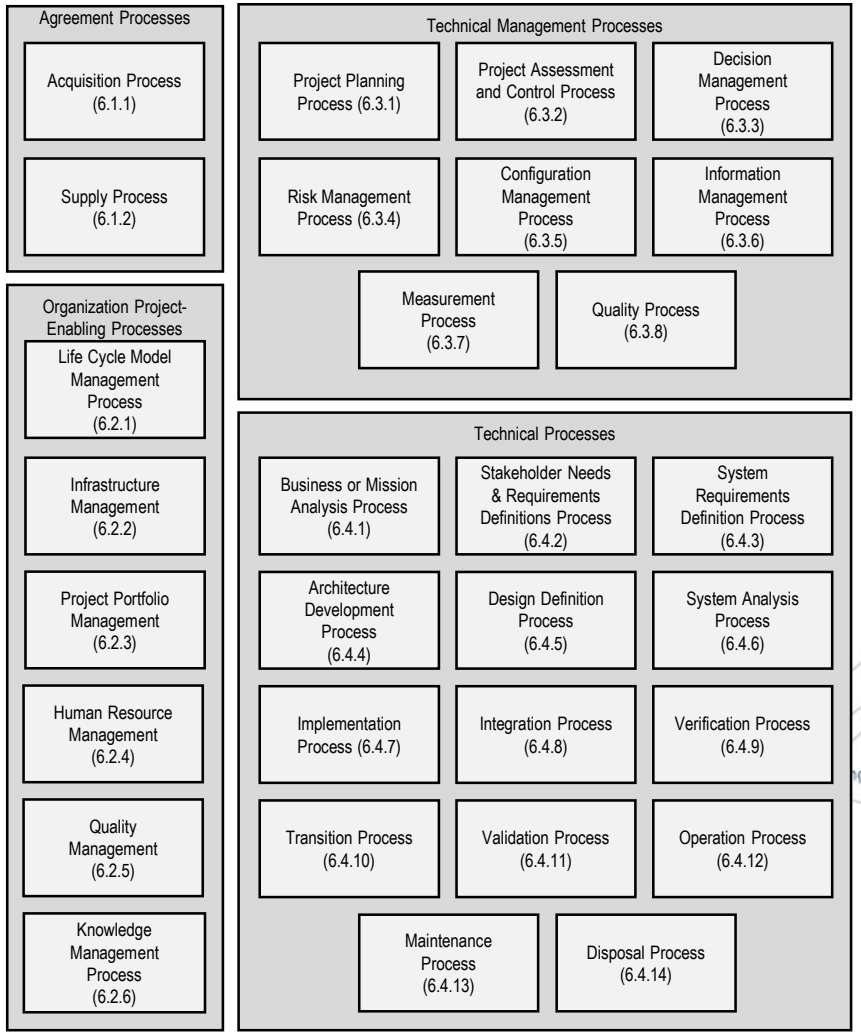
From: Current systems engineering tools leverage computing and information technologies to some degree, and make heavy use of office applications for documenting system designs. The tools have limited integration with other engineering tools.

To: The systems engineering tools of 2025 will facilitate systems engineering practices as part of a fully integrated engineering environment. Systems engineering tools will support high fidelity simulation, immersive technologies to support data visualization, semantic web technologies to support data integration, search, and reasoning, and communication technologies to support collaboration. Systems engineering tools will benefit from internet-based connectivity and knowledge representation to readily exchange information with related fields. Systems engineering tools will integrate with CAD/CAE/PLM environments, project management and workflow tools as part of a broader computer-aided engineering and enterprise management environment. The systems engineer of the future will be highly skilled in the use of IT-enabled engineering tools.

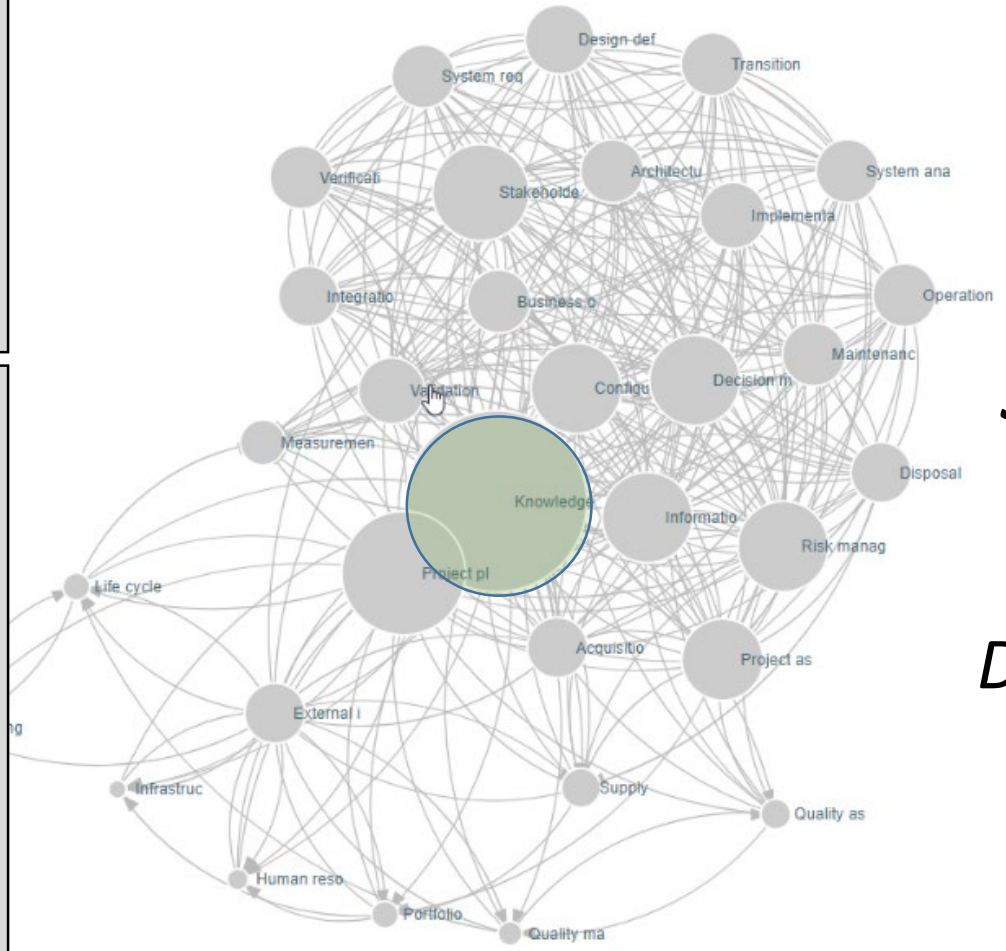
What is Model-Driven, MBSE, DE?

- 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.

Model Based Systems Engineering Scope



ISO 15288



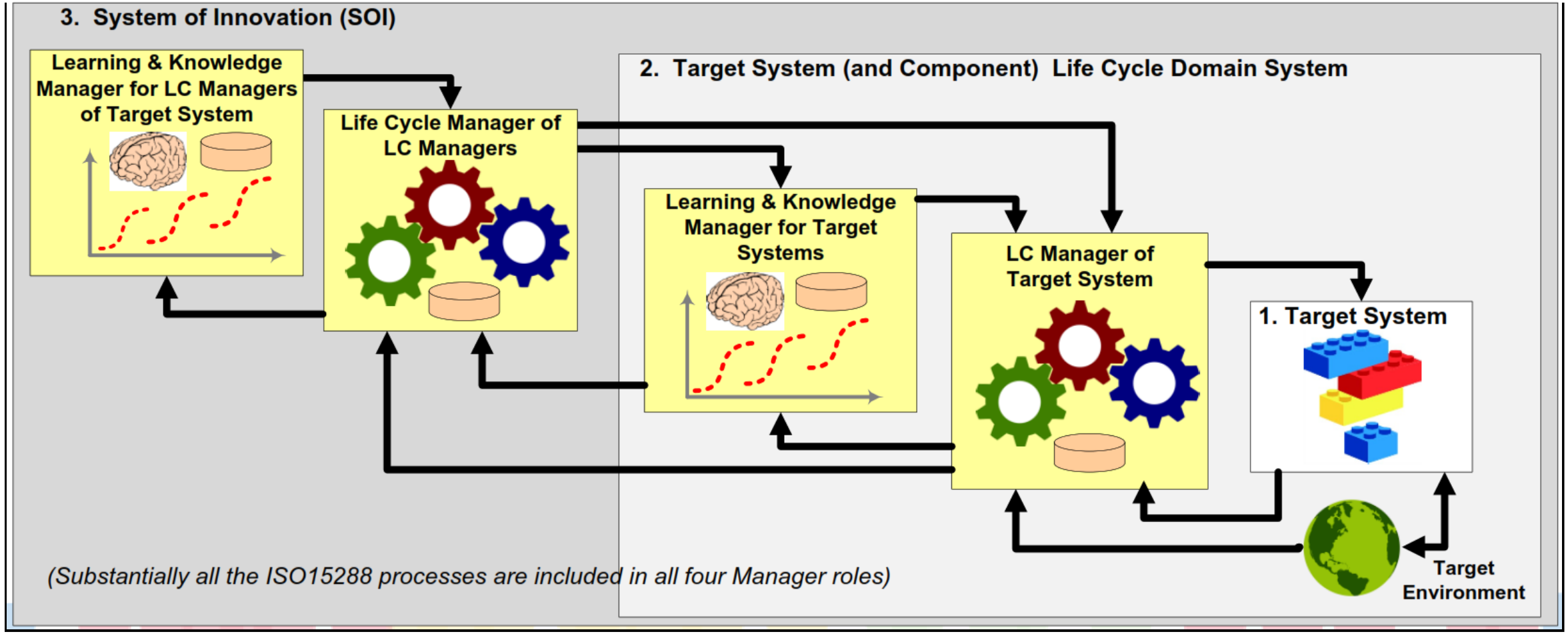
Graph of ISO 15288 Process Area interactions from INCOSE Handbook

Systems Engineering *the central cohesive discipline essential Digital Transformation*

Agile Systems Engineering Life Cycle Management Pattern

Transformation through knowledge capture and application

Agile Systems Engineering Life Cycle Management Pattern



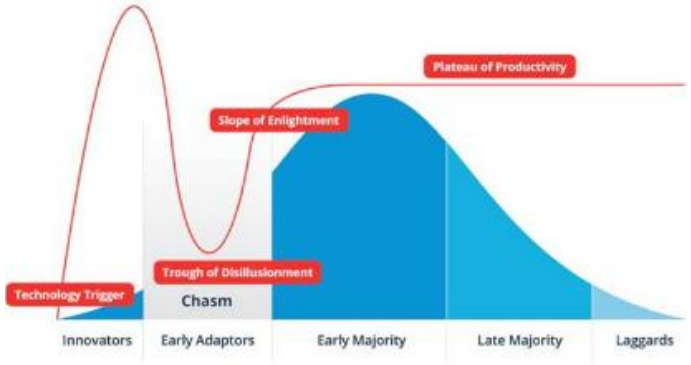
System of Innovation Environment

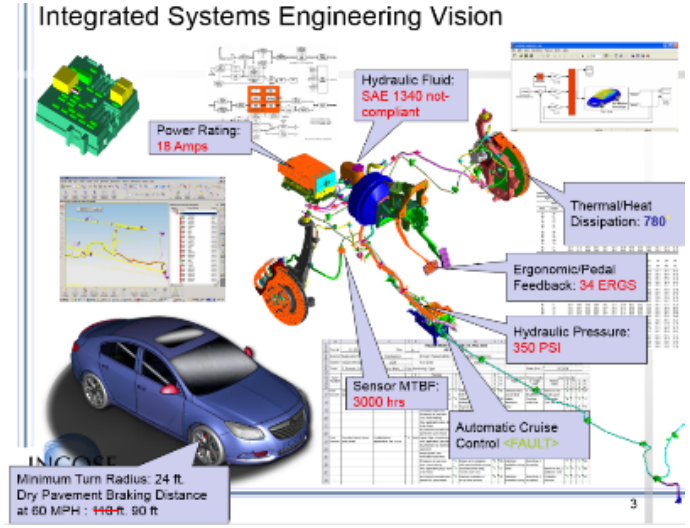
INCOSE's Transformation Strategic Objective

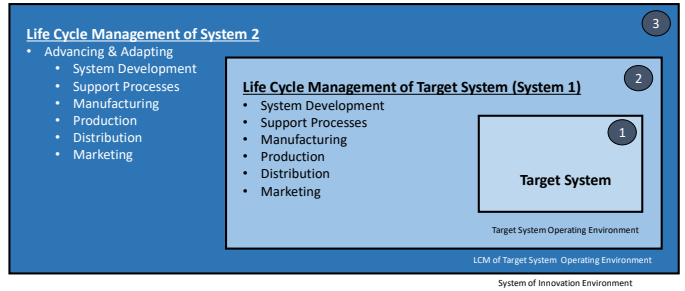
Objective:

INCOSE <u>accelerates</u> the <u>transformation</u> of systems engineering to a <u>model-based discipline</u>.

- Accelerates:
  - Understand the hype cycle[1] and bridge the chasm[2]…
  - Empower others to enlighten and influence adoption
- Transformation:
  - A marked change, as in appearance or character, usually for the better[3]. e.g. documents to models
  - Lead and support the community in crossing the chasm
- Model Based Discipline
  - System models of all types
  - Modeler Collaboration and Model Integration







1. Hype Cycle is a branded graphical presentation developed and used by IT research and advisory firm Gartner
2. Moore, Geoffrey A. "Crossing the Chasm – and Beyond" Strategic Management of Technology and Innovation Third Edition 1996
3. Excerpted from The American Heritage Dictionary of the English Language, Third Edition 1996 by Houghton Mifflin Company
4. Friedenthal, Sandy and Sampson, Mark - MBSE Initiative Overview - http://www.omgwiki.org/MBSE/doku.php

Model Based Discipline: The Next Evolutionary Step

Model Based Discipline

- Models are not new to us
- In some ways we're going "back to the future"
- Transformation is not a wholesale change
- Model based is the next evolutionary step
- A transformation whose time has come

Understand the Current State

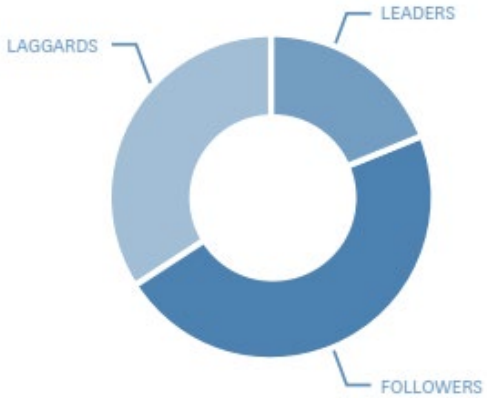
- Take inventory of current state of transition and progress toward becoming a model based discipline

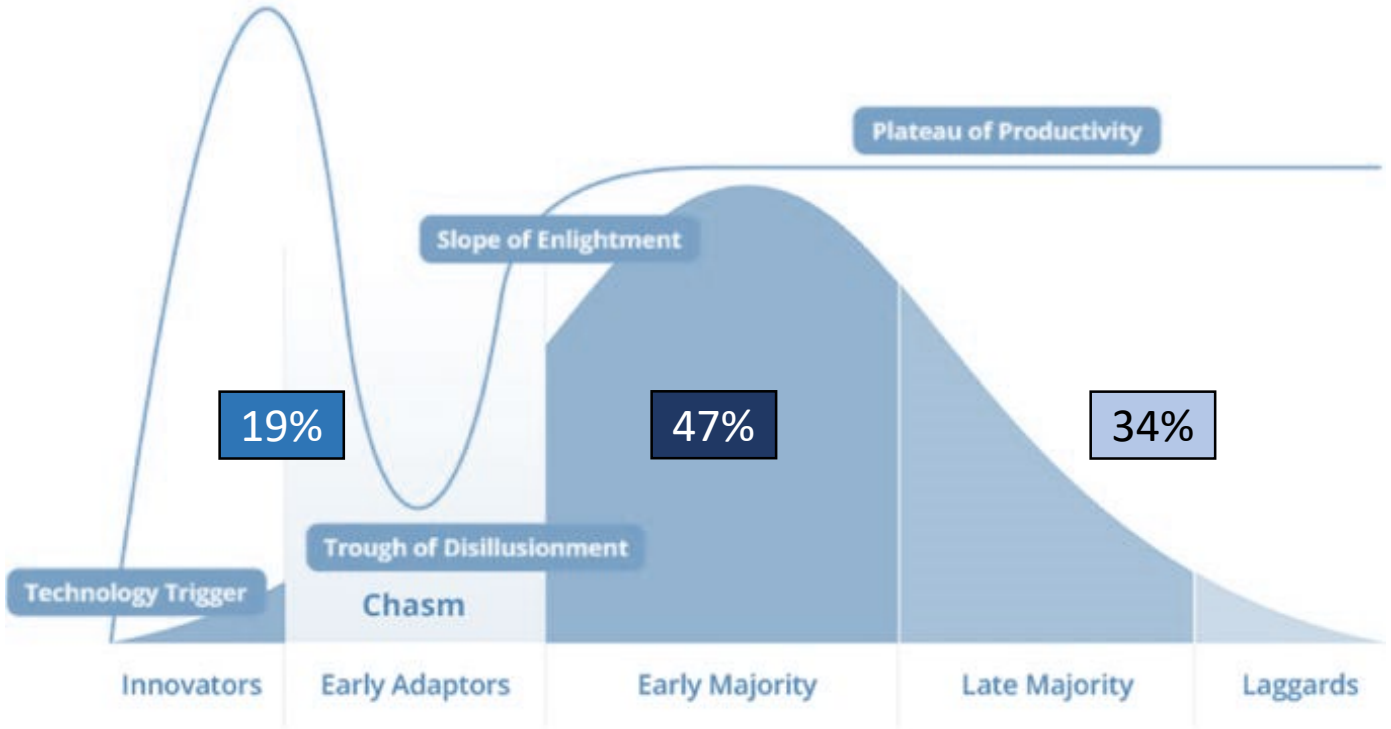
Envision and define the future state of SE:

- See Vision 2025,what are the business objectives, metrics, stakeholders, technologies, priorities etc.

"Make sure that those, *'Ideas whose time has come'*, get launched today."

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

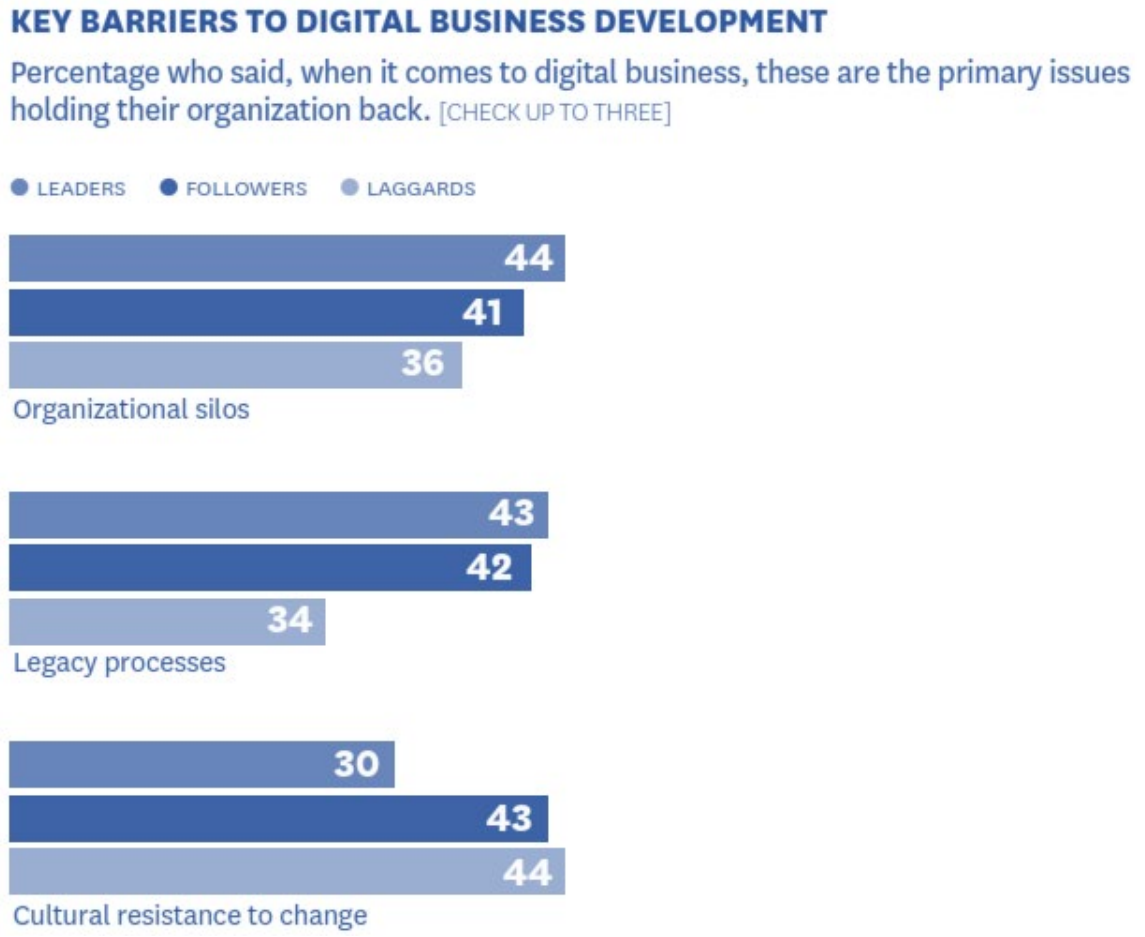
Where would you plot your organization today?

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: 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)

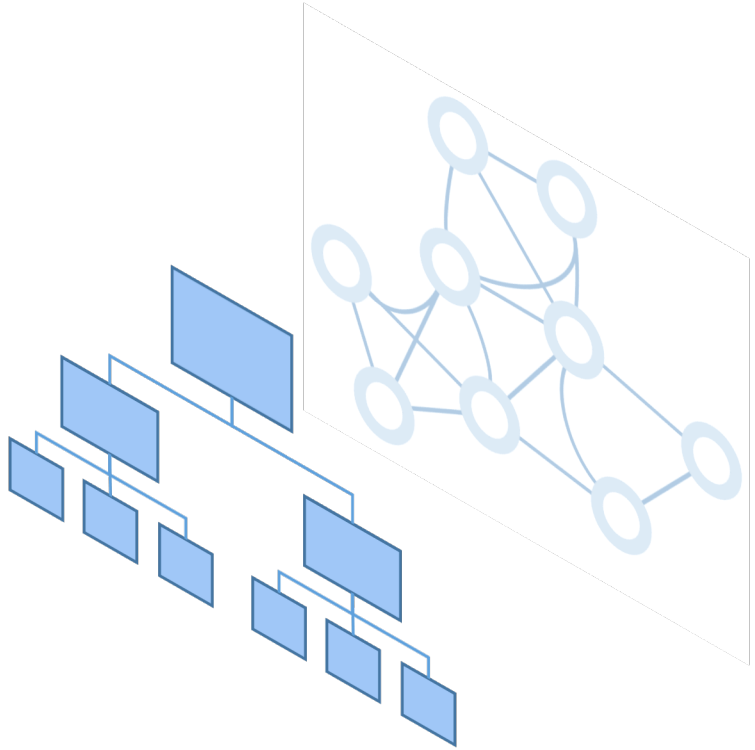
- ABP = Achieving Breakthrough Performance
- OE = Organizational Environment
- BPR = Business Process Reengineering
- IT = Information Technology
- CM = Change Management

Transformation is very much a people focused endeavor.

Organizational Transformation and Creating a Sense of Urgency

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

1. ***Creating a Sense of Urgency***
2. Building a Guiding Coalition
3. Developing a Strategic Vision and Initatives
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



John P. Kotter*: Accelerate* - In Kotter's new book *Accelerate*
he 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.

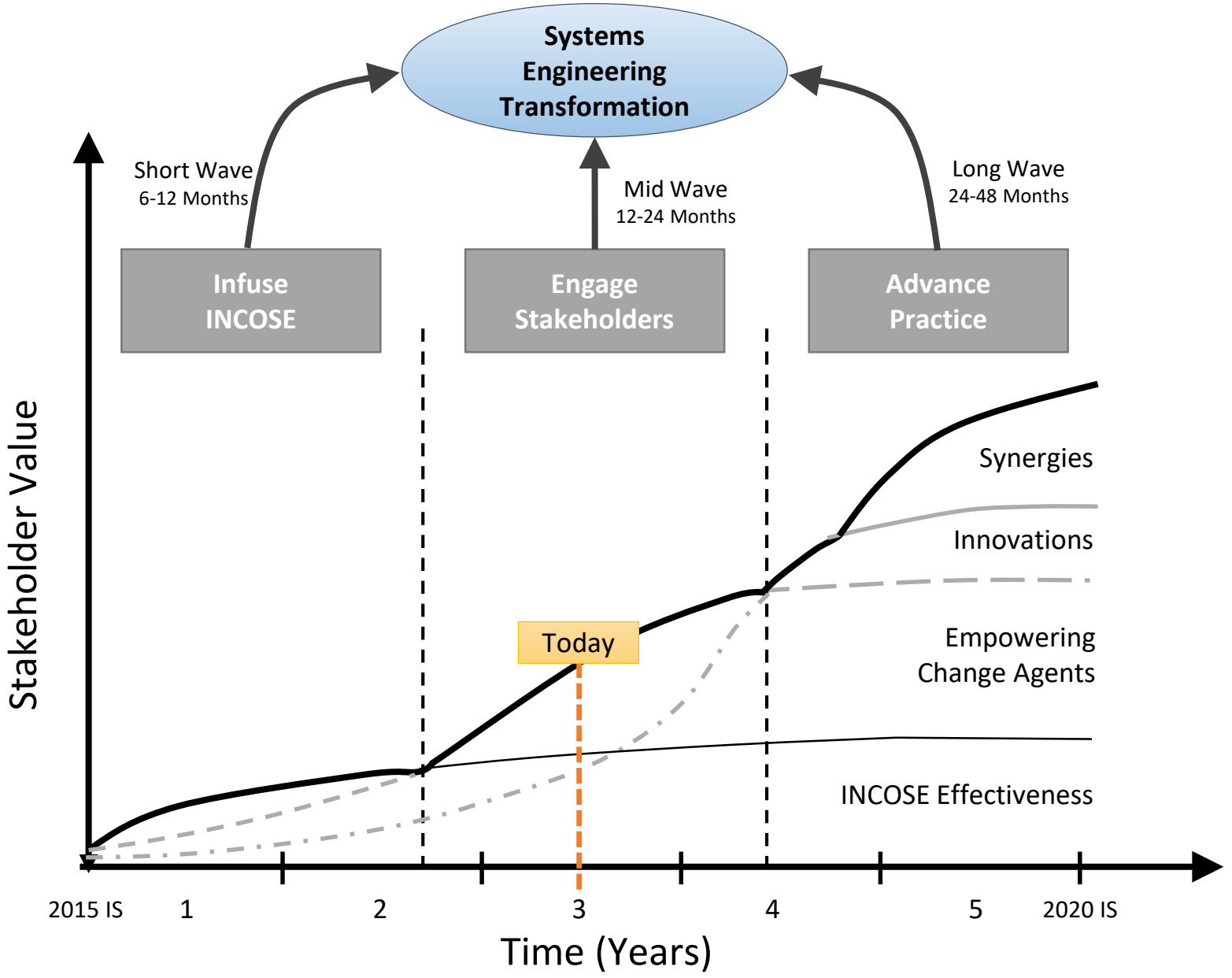
Transformation Strategy Overview

- 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 – Objectives & Initiatives

New/Related Developments

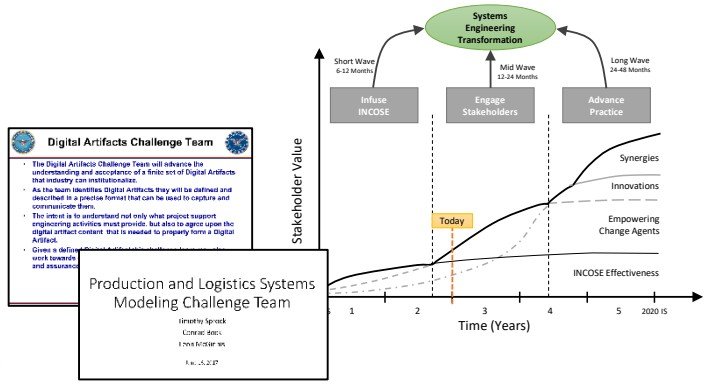
- Organizational Change Management
- MBSE FAQs Development
- Using MBSE Initiative as SE Innovation Incubator
- Collaborative V&V of models in effort with ASME
- Establishing new and expanded MOUs

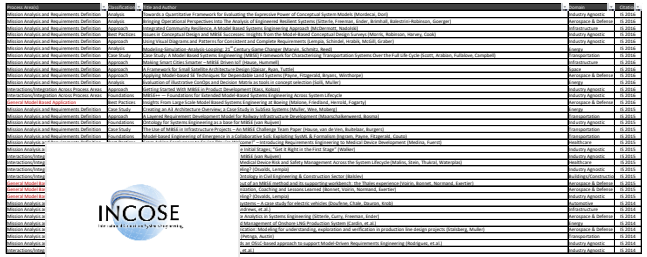
Products Under Development

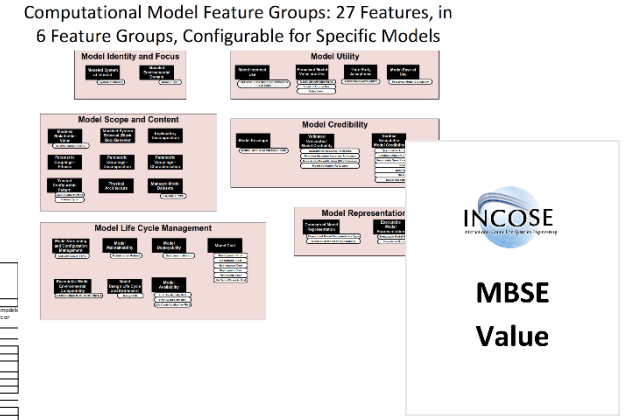
- Model Based Exemplars
- INCOSE MBSE Primer
- Value Briefing / Case Studies / ROI
- ST4SE: SE Semantic Technologies/Ontology

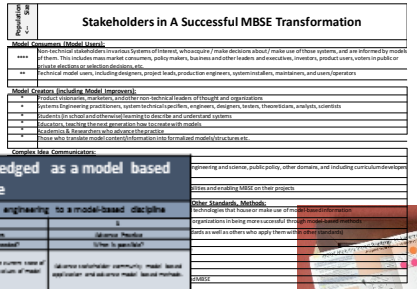
Accomplishments

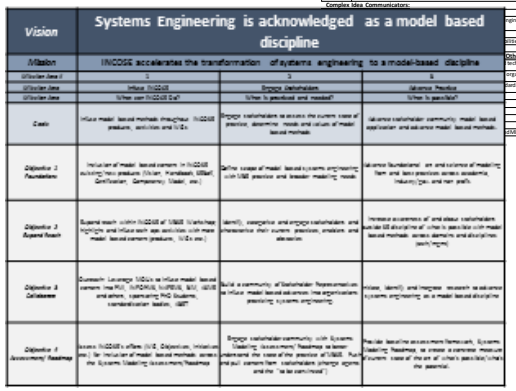
- INCOSE IS MBSE Lightening Rounds
- Transformation Paper
- Model Wrapper / Features
- INCOSE Transformation Webinar
- Assessment Roadmap
- Stakeholder List
- Enablers & Roadblocks
- Strategy & Action Plan
- Web search improvements
- Transformation website created
- Integration of MBSE throughout IW
- Many Transformation Briefings

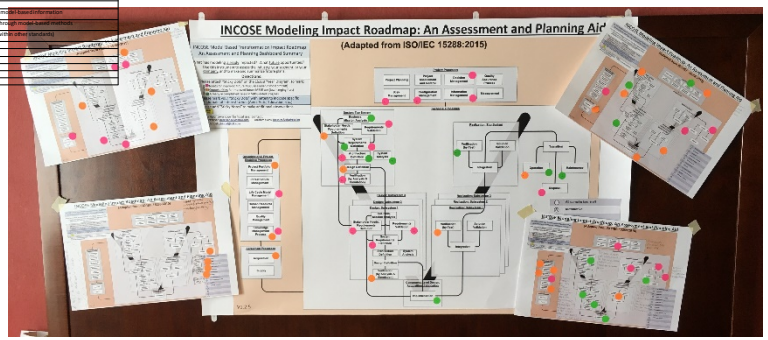












Transformation Stakeholders

The purpose of the Vision 2025 is to *inspire and guide* the direction of systems engineering across diverse stakeholder communities, which include:

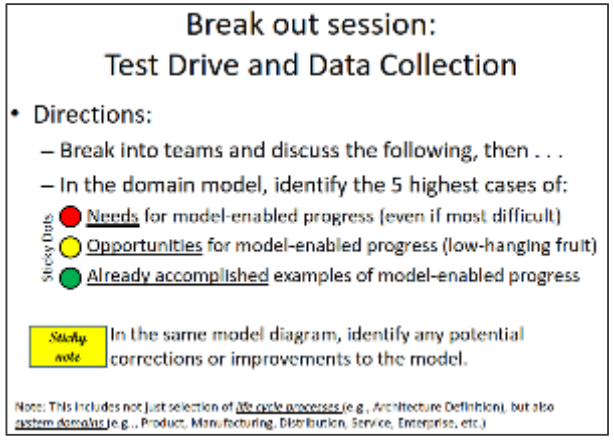
- **Engineering Executives**
- **Policy Makers**
- **Academics & Researchers**
- **Practitioners**
- **Tool Vendors**

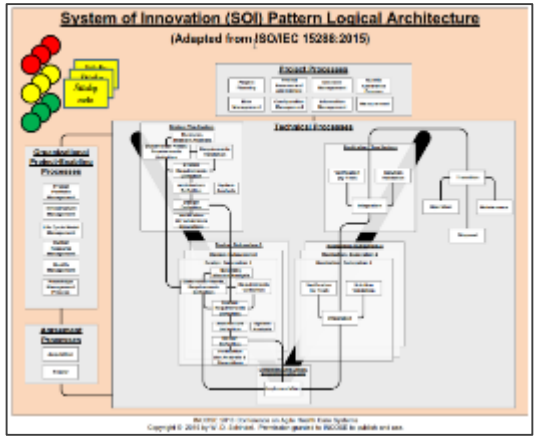
This vision will continue to evolve based on stakeholder inputs and on-going collaborations with professional societies.

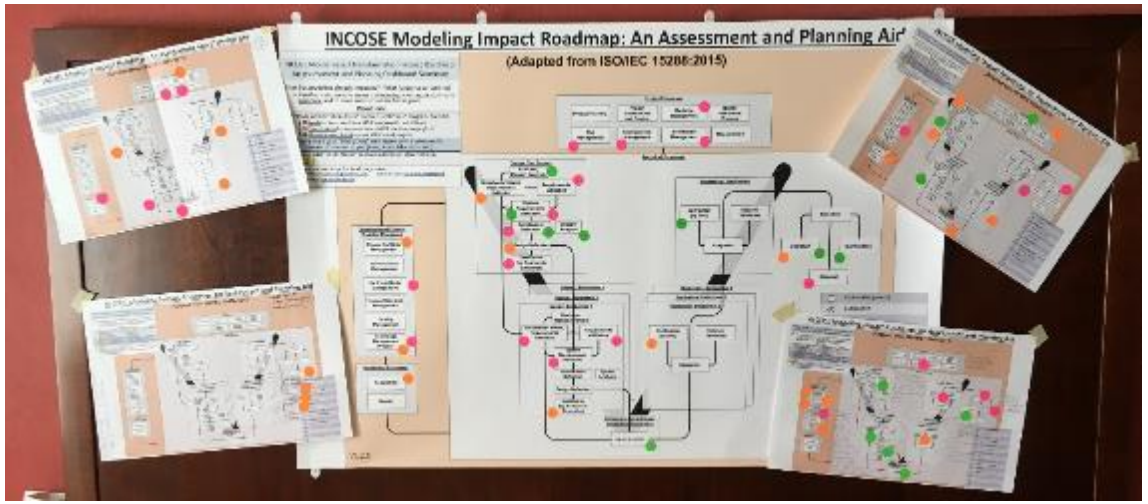
Population Size <--	Stakeholders in A Successful MBSE Transformation
Model Consumers (Model Users):	
****	Non-technical stakeholders in various Systems of Interest, who acquire / make decisions about / make use of those systems, and are informed by models of them. This includes mass market consumers, policy makers, business and other leaders and executives, investors, product users, voters in public or private elections or selection decisions, etc.
**	Technical model users, including designers, project leads, production engineers, system installers, maintainers, and users/operators
Model Creators (including Model Improvers):	
*	Product visionaries, marketers, and other non-technical leaders of thought and organizations
*	Systems Engineering practitioners, system technical specifiers, engineers, designers, testers, theoreticians, analysts, scientists
*	Students (in school and otherwise) learning to describe and understand systems
*	Educators, teaching the next generation how to create with models
*	Academics & Researchers who advance the practice
*	Those who translate model content/information into formalized models/structures etc.
Complex Idea Communicators:	
**	Marketing professionals
**	Academics/Educators, especially in complex systems areas of engineering and science, public policy, other domains, and including curriculum developers as well as teachers
**	Leaders of all kinds
**	Leaders responsible to building their organization's MBSE capabilities and enabling MBSE on their projects
Model Infrastructure Providers, Including Tooling, Language and Other Standards, Methods:	
*	Suppliers of modeling tools and other information systems and technologies that house or make use of model-based information
*	Methodologists, consultants, others who assist individuals and organizations in being more successful through model-based methods
*	Standards bodies (including those who establish modeling standards as well as others who apply them within other standards)
INCOSE and other Engineering Professional Societies	
*	As a deliverer of value to its membership
*	As seen by other technical societies and by potential members
*	As a great organization to be a part of
*	As promoter of advance and practice of systems engineering and MBSE

CAB Breakout: Assessment / Roadmap Instrument:

- Intentionally very simple:
  - Focused “one level down” from the intention to apply model-based methods to SE.
  - Level of detail = the individual ISO 15288 life cycle processes.
- Intended to address these important questions:
  - What are you trying to improve? (Which 15288 processes?)
  - Where are the biggest potential gains? The easiest potential gains?
  - What is already improved?
- But not:
  - How will your goals be accomplished?
  - What are the details of your plan?
  - Not a CMMI

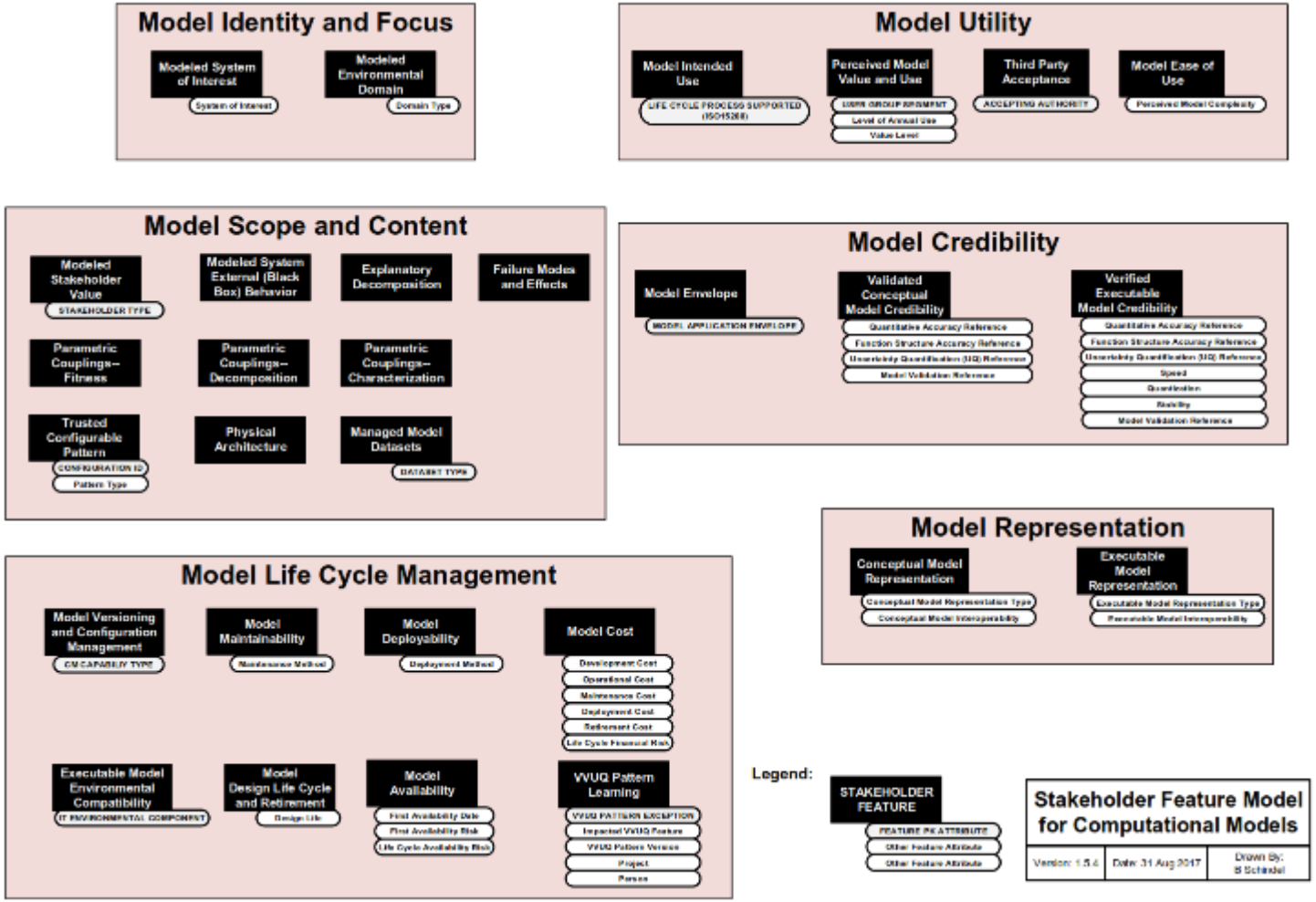




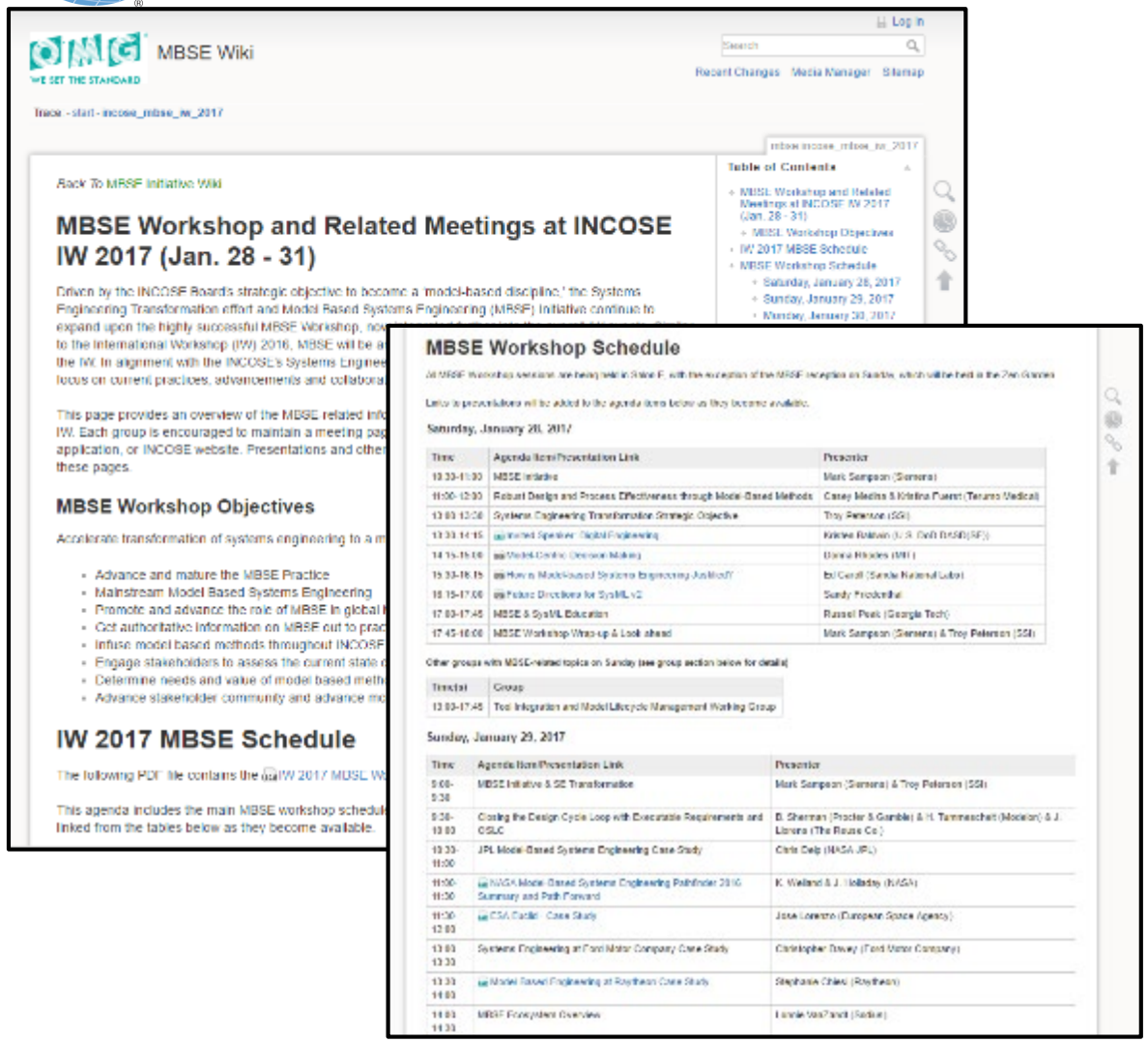


INCOSE/ASME Model Stakeholder Features Pattern

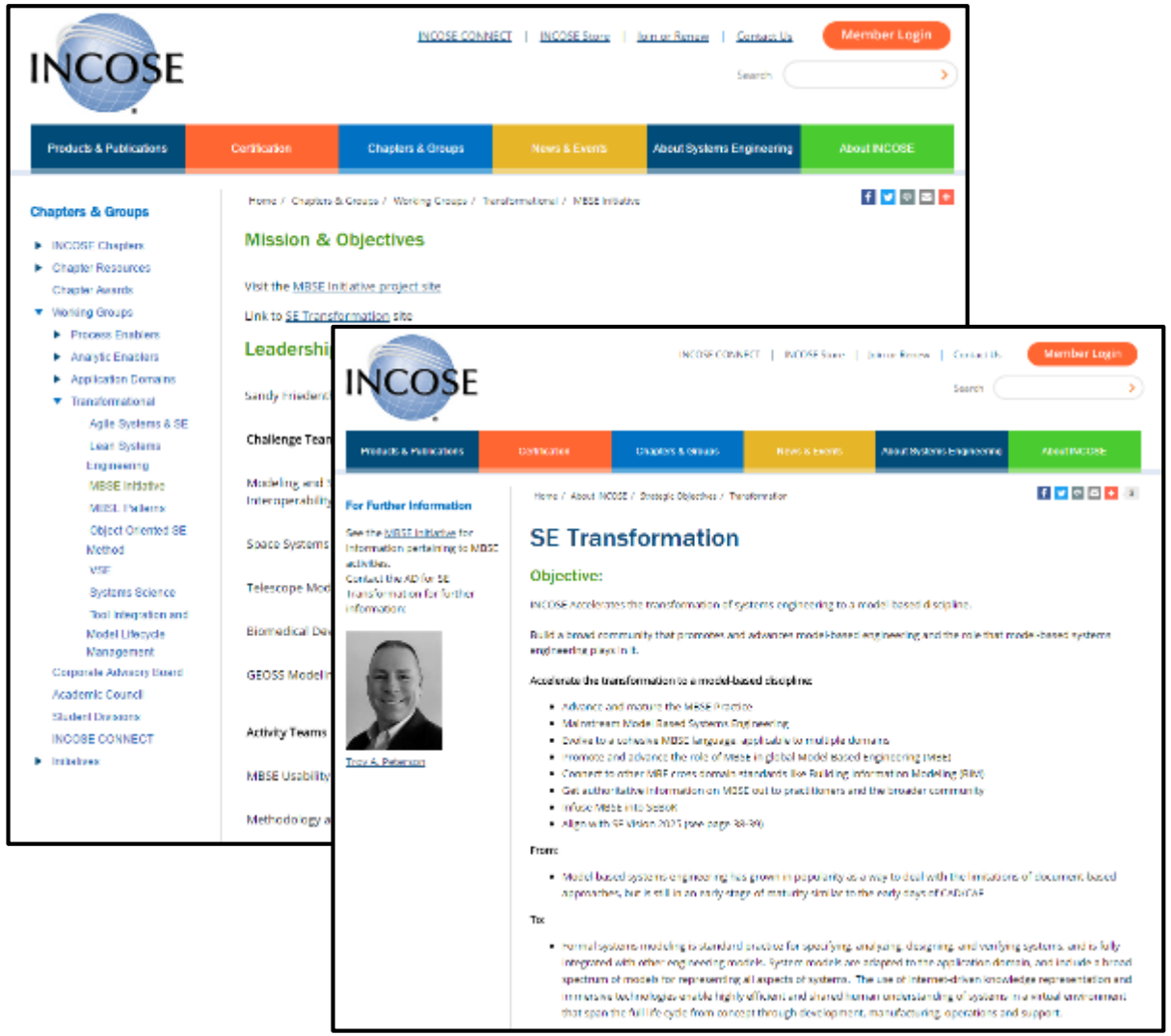
- Being created in the INCOSE supported ASME VV50 standards committee project, also in use in the INCOSE Transformation effort.
- Metadata in the form of a model itself, describing “what is in the model” – like a barcode which describes a product.
- 29 Model Features, spread across 6 feature groups



MBSE Wiki and Website



http://www.omgwiki.org/MBSE/doku.php?id=mbse:incose_mbse_iw_2017



http://www.incose.org/about/strategicobjectives/transformation

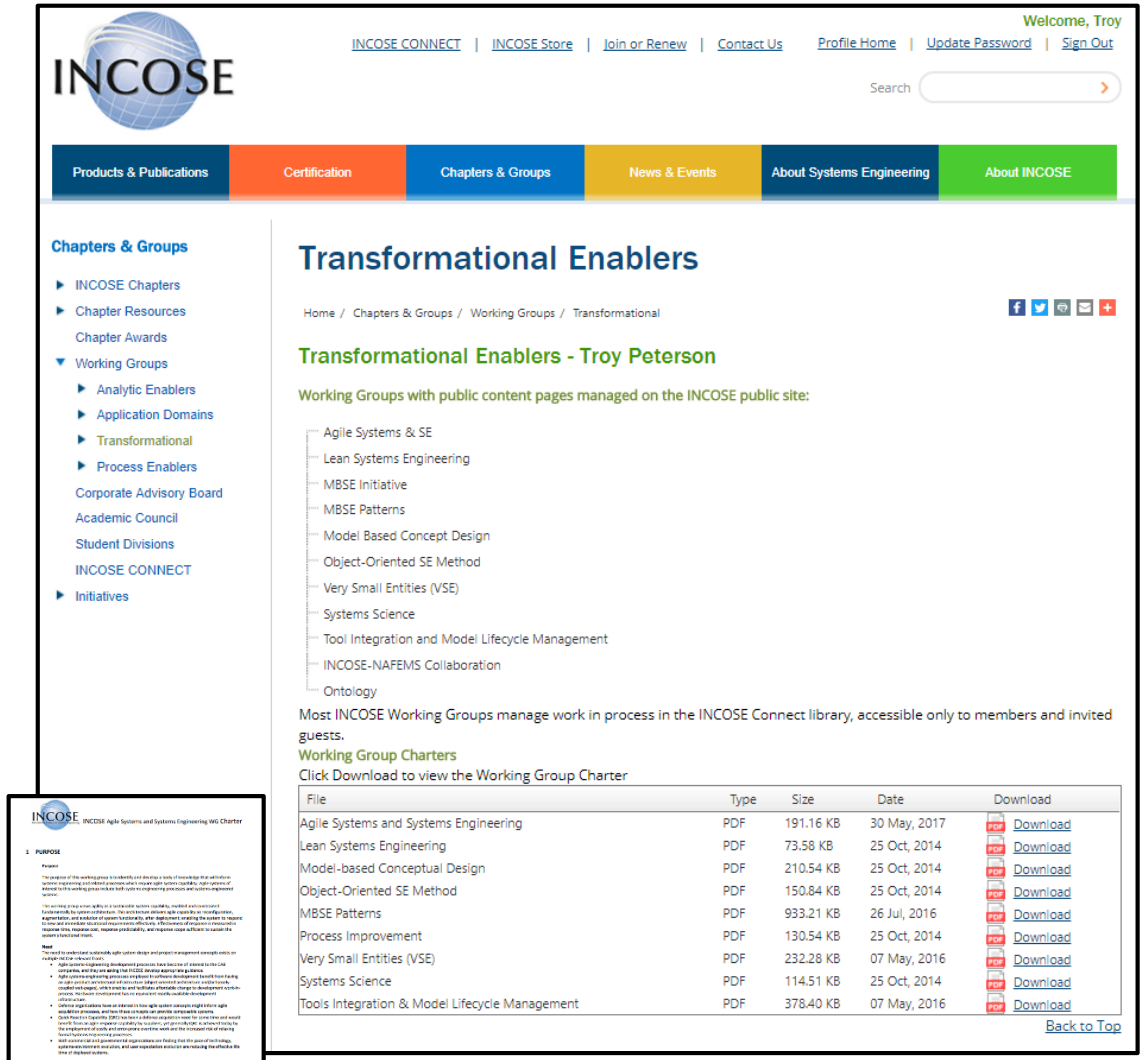
Accomplishments: Website / Discoverability Improvements

Transformational Working Groups (WG)

- Agile Systems and Systems Engineering
- Lean Systems Engineering
- Model Based Systems Engineering Initiative
- Model-based Conceptual Design
- Object-Oriented SE Method
- MBSE Patterns
- Very Small Entities (VSE)
- Systems Science
- Tools Integration & Model Lifecycle Management
- INCOSE-NAFEMS Collaboration
- Ontology

Visit site for WG charters and to learn more

http://www.incose.org/ChaptersGroups/WorkingGroups/transformational



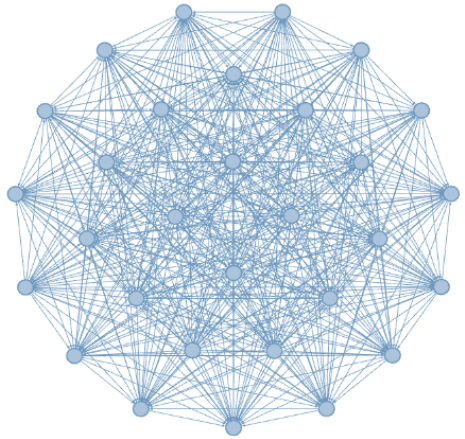
MBSE Initiative as an Incubator and Transformation Agent

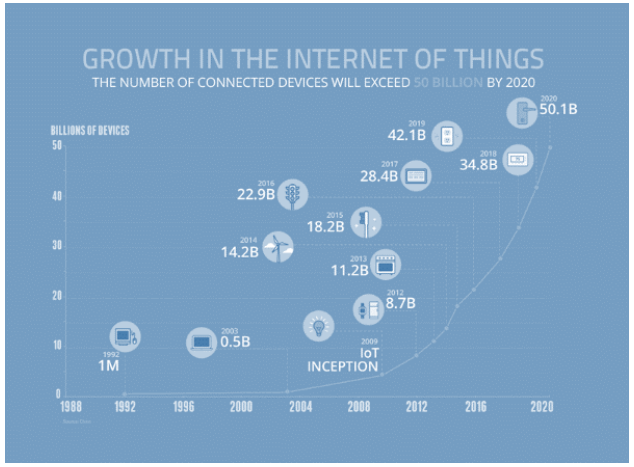
- Digital Artifacts Challenge Team -> Digital Engineering Information Exchange WG:
  - Identifying and characterizing MBSE digital artifacts across the lifecycle
- Augmented Intelligence in Systems Challenge Team
  - How can machine learning and AI aid systems engineering in the innovation process
- Production and Distribution Systems Challenge Team
  - Connecting models across the lifecycle – Industry 4.0, Supply Chain, Logistics
- V&V of models (Potential Collaboration ASME, INCOSE, NAFEMS)
  - Verification and Validation of Models – tied to ASME VV50 standards project
- Digital Engineering Capabilities Assessment
  - Developing self-assessments and gap analysis, strategic planning, project progress aids

Generic life cycle (ISO/IEC/IEEE 15288:2015)

Concept stage	Development stage	Production stage	Utilization stage	Retirement stage
			Support stage	

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…

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

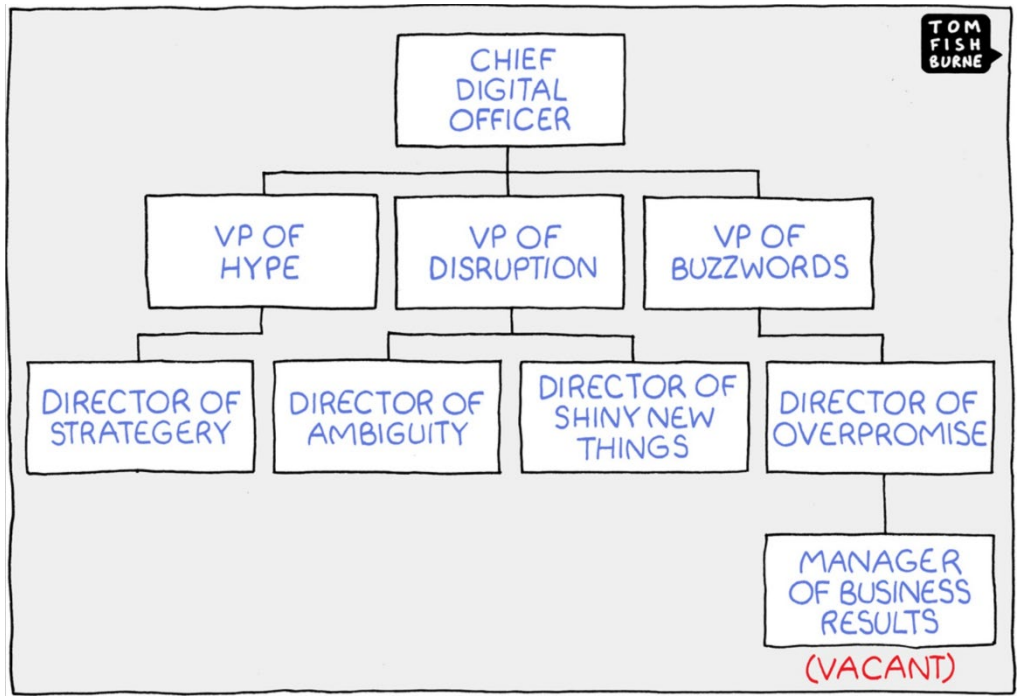
W. Edwards Deming

INCOSE’s Transformation Strategic Objective:
https://www.incose.org/about-incose/transformation

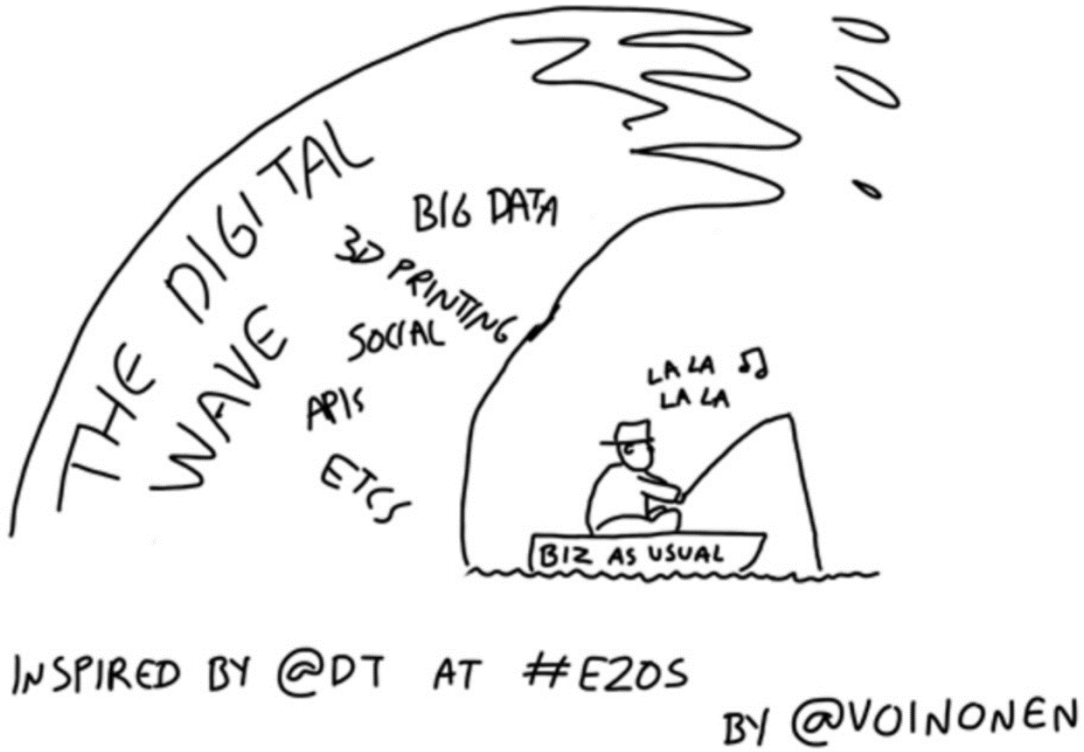
Engage as a Transformation Stakeholder Representative, visit:
https://www.incose.org/about-incose/transformation

INCOSE Q&A

Digital States



Digitally Zealous



Digital Denial

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Transformation: Change Beliefs to affect Outcomes