Digital Transformation: Drivers, Challenges, and Opportunities

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Digital Transformation

Wikipedia:
Digital Transformation is the use of new, fast and frequently changing digital technology to solve problems. It is about transforming processes that were non digital or manual to digital processes.

CIO and Leading Digital
Digital transformation marks a radical rethinking of how an organization uses technology, people and processes to fundamentally change business performance, says George Westerman, MIT principal research scientist and author of Leading Digital: Turning Technology Into Business Transformation.

Digital
It's more than bits of information in digital formats. It's about how the bits can be combined to provide new insight, capability and value.

Transformation
It's more than modernization or continuous improvement, it's game changing, >10x improvement.

Digital Transformation
It's across all sectors driving profound change all around us. It connects, links and relates information in ways that can provide new insight, predictive capacity and value. Models underpin digital transformation.
The Next Industrial Revolution and Digital Engineering

Fourth Industrial Revolution

“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

Industry 4.0 Design Principles

Interconnection:
• The ability of machines, devices, sensors, and people to connect and communicate with each other via the Internet of Things (IoT)

Information transparency:
• The transparency afforded by Industry 4.0 - vast amounts of useful information to make full life cycle decisions concept to retirement.

Technical assistance:
• The ability of the systems to assist humans in decision making

Decentralized decisions:
• The ability of cyber physical systems to make decisions on their own

Digital engineering is defined as “an integrated digital approach that uses authoritative sources of systems’ data and models as a continuum across disciplines to support lifecycle activities from concept through disposal [1].”

Furthermore, it...combines model-based techniques, digital practices, and computing infrastructure…”

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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.
Drivers: Rapidly Evolving Enabling Technologies

3D Printing

Blockchain

Data Rich Environments

IoT / Hyper-Connectivity

Artificial Intelligence

Industry 4.0

Digital Twin

High Performance Computing

7/16/2020
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Drivers: Systems and Interconnectivity

Increased Density of System Elements & Interactions
Increased Interactions Between External Elements
Increased Density of System External Elements & Interactions
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}
Drivers: Specialized Systems of Growing Complexity
Drivers: INCOSE Corporate Advisory Board Smart Goals

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
“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.”

Challenges: Growing Complexity

Contextual Challenges

Solution Seeking

Use of term “Model Based” in Research Journals

INCOSE Membership Growth
Challenges: Understanding Exponential Growth

- Connected Devices
- Software /LOC
- Tech Adoption
- Automation
- Usage of Sensors
- Electronics Integration
- Autonomous Systems
Challenges: Magnitude and Underestimation

Traditional development methods do not adequately address the complexity of systems today

The explosive growth of cyber-physical systems has rapidly and dramatically increased complexity all around us. Seamlessly intertwining computational algorithms and physical components, these systems have significantly increased the demands on engineering rigor to ensure safety, quality, security, sustainability, adaptability, and more, all while delivering products more rapidly.

Exponential Growth

We routinely underestimate the power of exponential growth.

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

Jack Welch
Challenges: Organizational Change

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

Rating of company’s digital maturity in leadership and management

More than 80% of respondents are either followers or laggards
Challenges: Driving Digital Transformation

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

Avoid:

\[ \text{AIPI} = \text{CM(PS + BEP + FV)} \]

- \( \text{AIPI} = \text{Achieving Immediate Perceived Impact} \)
- \( \text{PS} = \text{PowerPoint Skill} \)
- \( \text{BEP} = \text{Briefer's Executive Presence} \)
- \( \text{FV} = \text{Flashy Visualization} \)
- \( \text{CM} = \text{Change Mandate} \)

Transformation is very much a people focused endeavor.

Consider:

\[ \text{ABP} = \text{CM(OE + PR + IT)} \]

- \( \text{ABP} = \text{Achieving Breakthrough Performance} \)
- \( \text{OE} = \text{Organizational Environment} \)
- \( \text{BPR} = \text{Business Process Reengineering} \)
- \( \text{IT} = \text{Information Technology} \)
- \( \text{CM} = \text{Change Management} \)

Integrate dimensions of change

Addresses dimensions in parallel

Concurrency and dimensional trades

Build grass-roots ownership

Obtain top leadership support

Transformation is very much a people focused endeavor.
Challenges: INCOSE CAB MBSE Top Needs and Obstacles

Documents to Models

Needs / Obstacles

- Translate models into decision maker language
- Ability to analyze quickly, proper level of fidelity
- Change management best practices
- Models need to answer stakeholder questions
- Connect modeling to programmatic success
- Demonstration how modeling speeds innovation
- 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

Needs / Obstacles

- Clearly demonstrate the value of system model(s)
- Models uncover errors in existing artifacts
- Aid an early adopter with a pain point
- Systems engineering and domain ontologies
- Common MBSE methods and practices
- Better ability to review model quality/accuracy
- Contracting, Intellectual Property and Policy
- Use of requirements documents versus models
- Benefits are not obvious but they should be

Model Based ROI

Needs / Obstacles

- Seeing through the “Mystique” of MBSE
- Framework to view ROI by process area
- Capitalizing models as intellectual property
- Baseline to compare MBSE application
- Weak Systems Engineering foundation for MBSE
- Lack of understanding; one size does not fit all
- Expressing “Soft” versus “Hard” ROI for MBSE
- Perceived ROI from various stakeholders
- Covering all of the ISO 15288 process areas

Findings from 2015 INCOSE International Workshop Corporate Advisory Board Breakout Sessions
Opportunity: Reinforcing Nature of Advancements

- Industry 4.0
- Digital Twin
- High Performance Computing
- 3D Printing
- Blockchain
- Data Rich Environments
- Artificial Intelligence

- NEW FEEDBACK MECHANISMS
- AGILE METHODS, APPLIED LEARNING, PATTERNS
- ARTIFICIAL INTELLIGENCE & AUGMENTED INTELLIGENCE
- ADVANCED MANUFACTURING & COMPRESSED DELIVERY TIMELINES
- DIGITAL THREAD, DIGITAL TWIN, AUGMENTED REALITY, HPC
- MODEL BASED METHODS

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Opportunity: Technological Advancements

Leverage new digital technologies within a MBSE framework to transform how organizations innovate.

While the explosive growth of digital technologies introduces many challenges, it also provides significant opportunity. Traditional methods are insufficient, and organizations must transform to use systems and model based methods to meet the challenge. Are you leveraging this exponential growth to transform how you innovate and manage your products, systems and services? The most value added part of your business—?
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?
Opportunity: The Application of Systems Engineering

model based

Systems Engineering

is the essential discipline for Digital Transformation
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.

https://www.incose.org/docs/default-source/aboutse/se-vision-2025.pdf?sfvrsn=b69eb4c6_4
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.
Opportunity: Central Role of KM in SE

### 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)


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**Note:** The diagram illustrates the interactions between different processes and stakeholders within the systems engineering framework, emphasizing the central role of knowledge management (KM) in supporting the overall system life cycle processes.
Opportunity: Capture and Formally Model Knowledge

Engineered System Information

Knowledge management

Systems Life Cycle Processes

Graph of INCOSE SE Handbook and ISO 15288 Systems Life Cycle Processes

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Opportunity: Transform Tacit to Explicit Model Based 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.


Opportunity: Develop Learning Organizations – Change the Engineering Ecosystem

Intelligent Networked Enterprise Systems
- Model Based / Digital
- Accumulate Learning
- Encode Learning
- Accelerate Execution
- Improve Outcomes

Intelligent Networked Target Systems
- Interconnected & Intelligent
- Provide Feedback
- Non-deterministic
- Agile, Flexible, Adaptable
- Require rapid updates

Accelerate Learning and Execution for Improved Outcomes
Opportunity: Framing the Digital Engineering Ecosystem

Life Cycle Management of System 2
• Advancing & Adapting
  • System Development
  • Support Processes
  • Manufacturing
  • Production
  • Distribution
  • Marketing

Life Cycle Management of System 1 (Target System)
• System Development
• Support Processes
• Manufacturing
• Production
• Distribution
• Marketing

Agile SE Life Cycle Management Model (ASELCM) Ecosystem Pattern
Opportunity: Leverage the Agile Systems Engineering Life Cycle Management Model (ASELCM) Ecosystem Pattern

ISO/IEC/IEEE 15288:2015 Systems and Software Engineering – System Life Cycle Processes (Innovation Processes) are included in all four manager roles

We have two cognitive systems

—Fast (Unconscious):
  - Works easily and automatically with low effort
  - makes quick judgements based on familiar patterns
  - It’s rapid and involuntary - instinct and intuition.

—Slow (Conscious):
  - Takes more effort and time, requires intense focus
  - Operates methodically – analytical rigor formal logic.

—These two systems interact continually, stitching between conscious and unconscious modes of thinking based on context.

Opportunity: Mimic Human System Cognition, Thinking Fast and Slow


Learning Organizations Combine Fast and Slow Thinking

— Use both intuition and analysis
— Have both a playbook and allow for adaptable play
— Manage a fixed part (fast) and a variable part (slow)

Model Based Pattern Awareness Helps Organizations:

— Identify repeatable structural and behavioral patterns
— Recognize when a situation has changed
— Know the best alternate pattern configuration
— Chunk large amounts of information into patterns or principles particular to a given problem, discipline, domain or context.
— Have more time for deeper analysis and study of new problems
“Success does not go to the country that develops a new technology first, but rather, to the one that better integrates it and more swiftly adapts its way of fighting.”

Need to operate at the “Speed of Relevance”

Opportunity: Shifting the 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.

Remember: Automating junk, makes more junk automatically
Opportunity: Trusted Model Repositories and Consistency Management

Control Model Element Change History ~ Hashed Blockchain - Time phased graph

209cga0 = 20190829: Updated mass property of XYZ
345rha4 = 20190715: Element name to conformance
678yqa6 = 20190501: Published V&V version of model
976eya9 = 20190425: Added subcomponent property N
129qka4 = 20180105: Pattern configured for Sys1

Digital Thread of a particular analysis ~ Hashed Blockchain Architecture

709xba1
2345ty0
qmj5379
ldd648z
ldnx62

709xba1
ksudh89
0987dy6
ljd648z
ljf76sn

209cga0
09812jg
09hf62a
1d873e1
09sn7dj

Tool Neutral Model, Data, Knowledge Representation

ljd648z
MagicDraw: Vehicle Parameter Model
0987dy6
Excel: Cost Model
mchjs50
Matlab: Mechanics Model
1kdnys7
Creo: CAD model attribute: Mass
Opportunity: Employ Augmented Intelligence (AUI)

- Reinforce knowledge in formal models and pattern based methods with AUI
- Maximize Human + Machine Collaboration
- Allocate work based on strengths
- The Human + Machine combined “team” is more effective than either in isolation.
- Keep the Human in the loop, automate carefully

Remember:  
AUI = Human + AI  
AUI > Human  
AUI > AI  

Kasparov’s Law: weak human + machine + better process **beats**  
strong human + machine + inferior process.
Opportunity: Use Models to Improve Outcomes

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

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

“Oh, I don’t much care where –” says Alice.

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

What is the Objective of your Model?
Know where you want to go…

The model is not the end game
Care about improved outcomes…

Poor SE dooms MBSE
MBSE multiplies good SE

Know the objective and requirements of your model, and what questions it should answer
“…All models are wrong, but some are useful"

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

George E. P. Box

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

• Increase Collaboration
• Improve Communication
• Build Shared Understanding
Evidence shows that people who think with models consistently outperform those who don’t. And, moreover people who think with lots of models outperform people who use only one.

Scott E. Page "Model Thinking" Course Description

Models are powerful; they help us understand our systems, they provide a path forward for our ideas, and they invoke action.
**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.
Opportunity: Be Aware and Be Real, Avoid the Hype

STATES OF DIGITAL TRANSFORMATION

DIGITAL DENIAL

DIGITALLY ZEALOUS

MEANINGFUL TRANSFORMATION

INSPIRED BY @DT AT #EZOS

BY @VOILONEN

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• It's a paradigm shift
• The previous state is unrecognizable
• It doesn’t happen overnight, it takes time, and effort
“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
Unprecedented change and growing systems complexity is driving 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:

- FuSE
- Transformation Initiative
- MBSE Incubator
- SysML v2
- Semantic Technologies for Systems Engineering (ST4SE)
- 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)
- Systems Engineering Foundations
- Vision 2035
- Organizational Change
- ...
Troy Peterson, SSI Vice President, and INCOSE Transformation and FUTURE Champion 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 as a Vice President at SSI, Booz Allen Fellow and Lead Engineer at 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.
Abstract

Systems continue to reach new heights of complexity and autonomy. They seamlessly intertwine computational algorithms and physical components, providing organizations tremendous opportunity while also exposing them to significant risk. The problem is that while systems become more interconnected, and intelligent development methods are lagging behind, not keeping pace with contextual and technological change. Many organizations still follow a traditional document-based approach, which is fragmented, slow, and error-prone, lacking the agility and scalability required today. Other organizations are beginning to apply model based methods; however, the approach is often ad-hoc and mirrors the document-based approach using model-based tools that usually do not scale to the broader enterprise. Many organizations are now asking how to advance development methods through model-based methods and new approaches to overcome the significant mismatch between the complexity of the systems and our ability to manage and mitigate the associated risks.

For the Department of Defense, this led to the release of the Digital Engineering Strategy and subsequent engagement with the services to transform how they deliver capability. Digital Transformation underpinned by model based methods is now the fundamental approach being pursued across industry and government domains to address system complexity and provide the order of magnitude improvements called for by today’s dynamic environment and systems. While models underpin the path forward to apply advanced methods and enable the digital enterprise to respond with the necessary speed, scale, and agility, many challenges still exist and must be addressed by the engineering community.

This presentation will outline some of the fundamental drivers for Digital Transformation, why Digital Engineering is the key to the broader Digital Transformation, as well as share some best practices, lessons learned, and activities underway to help pave the path forward for Digital Engineering.
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INCOSE Efforts & Backup
INCOSE Model Based Systems Engineering

INCOSE Definition

• Model-based systems engineering (MBSE): The formalized application of modeling to support system requirements, design, analysis, verification and validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases.

• MBSE is part of a long-term trend toward model-centric approaches adopted by other engineering disciplines, including mechanical, electrical and software.

SEBOK

• Purpose of a Model: Models are representations that can aid in defining, analyzing, and communicating a set of concepts. Some of the purposes that models can serve throughout the system life cycle are:
  • Characterizing an existing system
  • Mission and System Concept Formulation Flowdown
  • System Design Synthesis and Requirements Flowdown
  • Support System Integration and Verification
  • Support for Training
  • Knowledge Capture and System Design Evolution

The model must be scoped to address its intended purpose
INCOSE FUTURE Strategic Objective: INCOSE leads the community in shaping the future of Systems Engineering

- Engage with and Align FUTURE related INCOSE activities
  - FuSE
  - Transformation Initiative
  - MBSE Incubator
  - Organizational Change Management
  - MBSE Benchmarking Study
  - Virtual Models Community Network
  - MBSE Value Briefing

- Engage Larger External Community – Collaborate
  - Transformational Working Groups, MBSE Incubator, Challenge Teams,
Transformational Working Groups (WG)

- Agile Systems and Systems Engineering
- Digital Engineering Information Exchange (DEIX)
- 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
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...
• 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

• Model Based Enterprise Capabilities Matrix
  • Developing self-assessments and gap analysis, strategic planning, project progress aids
MBSE Workshop and Related Meetings at INCOSE IW 2017 (Jan. 28 - 31)

Chaired by INCOSE and its strategic objective to create a more well-defined approach for Systems Engineering (SE). The workshop will focus on MBSE (Model-Based Systems Engineering) and how it can be used to improve the design and development processes. The workshop will be held in conjunction with the INCOSE IW 2017 in Baltimore, MD, on January 28-31, 2017.

MBSE Workshop Objectives

Create a well-defined approach for Systems Engineering (SE)

MBSE Workshop Schedule

Saturday, January 28, 2017

1. MBSE for Systems Engineering
2. MBSE for Defense
3. MBSE for Healthcare
4. MBSE for Energy

For further information, visit the INCOSE website at www.incose.org.

SE Transformation

Objective:

To create a well-defined approach for Systems Engineering (SE) that can be used across different industries and organizations.

Production and Logistics Modeling Challenge Team

Current Projects:
• Playbook Draft: https://v2.overleaf.com/read/rsjqhqzmxtxq
• Value Proposition Draft: https://v2.overleaf.com/read/pjjpsvkskgvn

Current Goals:
• Develop a “how to do it” guide for production and logistics systems modelers;
• Articulate a value proposition for adopting MBSE for production and logistics;
• Document case studies applying MBSE methods to production and logistics systems.

How to get involved:
• Weekly meeting at 11 am (Eastern) Fridays. https://bluejeans.com/252469214
• http://www.omgwiki.org/MBSE/doku.php?id=mbse:prodlog
• Point of Contact: timothy.sprock@nist.gov

A Value Proposition for MBSE for Manufacturing Systems

George Thiers, MBSE Tools, Inc.
Alpharetta, GA, USA

Leon McGinnis, Georgia Tech ISyE
Alpharetta, GA, USA

Timothy Sprock, Bock, Conrad
Gaithersburg, MD, USA

Greg Pollari, Engenio
Cedar Rapids, IA, USA

Adam Graunke, Boeing Research & Technology
Seattle, WA, USA

Abstract

MBSE for product development has the benefits of shorter time-to-market, improved product quality, and lower program cost. [Heibel et al., 2016; Nichols and Lin, 2014; Bayer, 2018] A manufacturing system can be regarded as just another product and subject to conventional MBSE, which is “the formalized application of modeling to support system requirements, design, analysis, verification, and validation activities” throughout all life cycle phases. [INCOSE, 2007] However, to the best of the authors knowledge, this is far from contemporary practice. This paper explores contemporary practices for design, diagnosis, and improvement of manufacturing systems throughout their lifecycle, the reasons why MBSE is not contemporary practice, and the value proposition its adoption.
List of Methodologies and Methods

Methodologies Surveyed in INCOSE 2008 Report


<table>
<thead>
<tr>
<th>Name</th>
<th>Primary Point of Contact</th>
</tr>
</thead>
<tbody>
<tr>
<td>INCOSE Object-Oriented Systems Engineering Method (OOSEM)</td>
<td><a href="mailto:safrieden15thai@gmail.com">safrieden15thai@gmail.com</a></td>
</tr>
<tr>
<td>IBM Rational Telelogic Harmony-SE</td>
<td><a href="mailto:pctor.hofmann@telelogic.com">pctor.hofmann@telelogic.com</a></td>
</tr>
<tr>
<td>IBM Rational Unified Process for Systems Engineering (RUP-SE)</td>
<td><a href="mailto:mzsmoir@us.ibm.com">mzsmoir@us.ibm.com</a></td>
</tr>
<tr>
<td>Vitech Model-Based Systems Engineering (MBSE) Methodology/Vitech</td>
<td><a href="mailto:jllong@vitechcorp.com">jllong@vitechcorp.com</a></td>
</tr>
<tr>
<td>JPL State Analysis (SA) Methodology/JPL State Analysis (SA)</td>
<td><a href="mailto:Robert.D.Rasmussen@jpl.nasa.gov">Robert.D.Rasmussen@jpl.nasa.gov</a></td>
</tr>
<tr>
<td>Dorl Object-Process Methodology (OPM)</td>
<td><a href="mailto:dorl@ts.technion.ac.il">dorl@ts.technion.ac.il</a></td>
</tr>
</tbody>
</table>

Additional Methodologies Identified as Gaps Since 2008 INCOSE Survey

<table>
<thead>
<tr>
<th>Name</th>
<th>Primary Point of Contact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weikiens Systems Modeling Process (SYSMOD)</td>
<td><a href="mailto:Tim.Weikiers@oose.de">Tim.Weikiers@oose.de</a></td>
</tr>
<tr>
<td>Fernandez Process Pipelines in OO Architectures (PPOOA)</td>
<td>josel.fernandez@telefónica.net</td>
</tr>
<tr>
<td>An Ontology for State Analysis: Formalizing the Mapping to SysML</td>
<td><a href="mailto:nicolas.f.rouquette@jpl.nasa.gov">nicolas.f.rouquette@jpl.nasa.gov</a></td>
</tr>
<tr>
<td>ISO-15288, OOSE and Model-Based Submarine Design</td>
<td><a href="mailto:Paul.Pearce@deepbluetech.com.au">Paul.Pearce@deepbluetech.com.au</a></td>
</tr>
<tr>
<td>Alstom ASAP methodology</td>
<td><a href="mailto:marco.forgelen@transport.altom.com">marco.forgelen@transport.altom.com</a></td>
</tr>
<tr>
<td>Pattern-Based Systems Engineering (PBSE)</td>
<td><a href="mailto:schindel@jict.com">schindel@jict.com</a></td>
</tr>
<tr>
<td>Arcadia, a model-based engineering method</td>
<td>Polarsys/Capelia</td>
</tr>
</tbody>
</table>

http://www.omgwiki.org/MBSE/doku.php?id=mbse:methodology#incose_links
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, ...

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**Challenge Team Wiki @ INCOSE/OMG Site**


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**MBX Ecosystem Wiki**

[Image of MBX Ecosystem Wiki]

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**SysML and MBSE: A Quick-Start Course**

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Digital Engineering Information Exchange WG Overview

Problem Statement:
Despite advances in the digital era, there are significant inefficiencies when suppliers and acquirers and internal team members exchange engineering information following a traditional document-based approach.

Opportunity:
Leverage new digital technologies, forms of media and means of interaction to provide enriched system representations. Shared information, knowledge and understanding

Primary Goal:
To establish a finite set of digital artifacts which stakeholders (acquirers, suppliers, internal teams et al.) should use to exchange digital engineering information.

Efforts:
• Define a Finite Set of Digital Artifacts
• Develop Constructs for assembling of Digital Artifacts
• Leverage and Influence Standards to Improve DEIX
• Adopt a Common Lexicon

Participants:
Stakeholder Representatives/Advisors:
• Phil Zimmerman: OSD OUSD R-E
• Troy Peterson: INCOSE
• Chris Schreiber: NDIA
• David Allsop: NDIA
• Frank Salvatore, INCOSE
• John Coleman, DASD(SE) SETA

Objective:
Define a method of characterizing the current capability of one or more domains/attributes for a Model-Based Enterprise

General Approach:
Assess the current Stage of Implementation by capability maturity of the Organization for one or more relevant attributes. Highlight the attained Stage of Implementation maturity level cell and all calls to the left of the attained level Stage for all assessed relevant attributes.
Augmented Intelligence for Systems Engineering

Description & Purpose

- Augmented Intelligence describes the approaches and best practices for “team play” – where engineer and machine intelligence (such as AI, Machine Learning) can coordinate to develop transparent, traceable, and understandable system designs that are better than either human or algorithmic approaches could develop alone.

- The team seeks to develop a collaboration framework where computational approaches can effectively pair with engineers to measurably improve the systems engineering effort.

Goals

- Develop technical paper on augmented intelligence capabilities applicable to systems engineering, and conceptual applications and uses cases for how augmented intelligence could improve systems engineering.

- Technical Paper

Major Technology Areas

- Human Machine Interface, Visualization, AI, Machine Learning, MBSE

Charter and Wiki

- Chartered February 2018

Related Projects

- Agile SE

Aul = Human + AI

Aul > Human

Aul > AI

weak human + machine + better process beats

strong human + machine + inferior process.
Solutions to Validation and Verification (V&V) Questions:

- ASME INCOE Collaboration on VVUQ – focused on V&V of models. ASME V&V10-60.
- Expand standards to encompass VVUQ of broad ISO 15288 scope of models
- Model Characterization Pattern
- Model Life Cycle Management Process: Establish, Develop, Deploy, Use, Maintain, Retire
- Model Curation

Goals

1. Scale up volume of models and people.
2. Manage models over entire life cycles.
3. Increase use of what was already learned.
4. Package general principles as actionable assets.
5. Prepare for a building-block world of models.
6. Unified metadata wrapper for all models.
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.
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 modes. 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.
Continuous Learning and Transformation

Capture and Formally Model Knowledge

Apply Model Based Patterns & Build Shared Understanding

Employ Augmented Intelligence

Simplicity is complexity resolved.
Constantin Brancusi (1876-1957)

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)