PPI SyEN

SYSTEMS ENGINEERING NEWSJOURNAL
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Growth & Scalability in Systems Engineering

DIGITAL TRANSFORMATION
Scalable MBSE solutions

PRACTICE CHANGES IN SE
Looking beyond the familiar

PPI SyEN SPOTLIGHT: INCOSE
Interview with Kerry Lunney

PPI SyEN

EMAIL: PPISyEN@PPI-Int.com

PUBLISHER

PROJECT PERFORMANCE INTERNATIONAL

Project Performance International
2 Parkgate Drive
Ringwood, Vic 3134 Australia
Tel: +61 3 9876 7345

Tel Brazil: +55 12 9 9780 3490
Tel UK: +44 20 3608 6754
Tel USA: +1 888 772 5174
Tel China: +86 188 5117 2867

www.ppi-int.com
contact@ppi-int.com

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WELCOME

Welcome to this combined June/July-2021 edition of the PPI Systems Engineering Newsjournal!

In this edition of PPI SyEN Forum, PPI's Alwyn Smit discusses how systems thinking and systems engineering can and should be applied across a wider range of domains and disciplines – and then he challenges us to consider whether those skills are being promoted and cultivated sufficiently in the next generation.

As always, Systems Engineering News provides an overview of recent events, announcements, and happenings of general interest to the profession of systems engineering – while Conferences, Meetings & Webinars lets you know of upcoming events (or milestones of those events). These short articles keep you up to date at a glance, or you can follow their hyperlinks for further information.

The Featured Articles in this edition address questions of growth and scalability in systems engineering. First, Dr. Saulius Pavalkis and Gauthier Fanmuy outline the key challenges to expanding the success of pilot MBSE initiatives to a rollout across the larger enterprise. Then, James R. Armstrong explores whether and how systems engineering can "up its game" by looking beyond the classical "V" model of its processes to other tools and models.

In the PPI SyEN Spotlight, Managing Editor René King sits down with Kerry Lunney to look back on the first part of her term as President of the International Council on Systems Engineering (INCOSE) during a time of unique challenges worldwide.

Our Systems Engineering Sampler offers selected examples of systems engineering in theory and in practice, including articles, papers, archived webinars, and other items of note that you may have missed the first time around – while Systems Engineering Resources suggests books and similar items of potential interest.

In Final Thoughts, the mysterious Syenna offers wry observations and commentary on the nature and application of systems engineering.

It is our fervent desire that every edition of PPI SyEN provide you, the readers, with a diverse, interesting, yet relevant array of value-added information. We'd love to hear what we're doing well and where we could do better: PPISyEN@PPI-Int.com

Kevin

Kevin Nortrup
Editor, PPI SyEN

PPI Systems Engineering Newsjournal (PPI SyEN) seeks:

- To advance the practice and perceived value of systems engineering across a broad range of activities, responsibilities, and job-descriptions
- To influence the field of systems engineering from an independent perspective
- To provide information, tools, techniques, and other value to a wide spectrum of practitioners, from the experienced, to the newcomer, to the curious
- To emphasize that systems engineering exists within the context of (and should be contributory toward) larger social/enterprise systems, not just an end within itself
- To give back to the Systems Engineering community

PPI defines systems engineering as: *an approach to the engineering of systems, based on systems thinking, that aims to transform a need for a solution into an actual solution that meets imperatives and maximizes effectiveness on a whole-of-life basis, in accordance with the values of the stakeholders whom the solution is to serve. Systems engineering embraces both technical and management dimensions of problem definition and problem solving.*

PPI SyEN FORUM

Selected correspondence from readers, authors, and contributors

PPI SyEN FORUM offers the opportunity for feedback and discussion on topics around systems engineering – especially those that have been (or should be) addressed in PPI SyEN.
Please send your email to **PPISyEN@PPI-Int.com**

Alwyn Smit
PPI Principal Consultant and Course Presenter

I have always believed that systems engineering is not a job but a skill set that every engineer must have. Recently, I came across a fascinating article by Miriam Hoffman, the 2020-2021 national vice president of the FFA (formerly known as the Future Farmers of America). She wrote about systems thinking in the context of agriculture. She recalled a conversation she had with another FFA member that, in her words, "exemplified the proper balance of specialization and generalization." (The full article is available online at AGRINEWS.)

This article made me realize how stuck we can become in the application of our systems thinking, particularly within a specific application domain. I learned about systems engineering and systems thinking within the context of the defense sector, but my later involvement with INCOSE exposed me to many other domains within which the same concepts were quite effectively applied. Nonetheless, upon closer investigation of the impressive array of application domains currently represented in INCOSE Working Groups, agriculture seemed conspicuously absent.

How many other domains are out there where we may find an equally good application of systems thinking principles? The Standard Industrial Classification (SIC) system classifies industries by a four-digit code. (The North American Industry Classification System, NAICS, replaced the SIC system in North America.) In a Wikipedia article about the Standard Industrial Classification, I came across a long list of industry divisions subdivided into Major Groups. "Agricultural Production – Crop", quite ironically, was right at the top of the list. Some others that caught my eye were:

- mining;
- manufacturing;
- wholesale and retail trade;
- finance, insurance, and real estate; and
- public administration.

Is the systems-engineering community missing opportunities in these and other sectors?

Another question prompted by Miriam's article: is the systems-engineering community doing enough to promote systems engineering with our young engineers? The INCOSE Student Division web page shows that INCOSE, like the FFA, desired to reach out to the younger generation. However, the student divisions listed on the web page were all at US-based universities. From a previous visit to a Dutch INCOSE Chapter event in Amsterdam, I remember a group called "Jong INCOSE" (or "Young INCOSE"). Certainly, there must be universities in other countries that would benefit from student divisions.

How could we more actively promote systems engineering and systems thinking with the young engineers in training that will be the system engineers of tomorrow? It would be great to hear from our readers about other initiatives towards this critical goal.

Alwyn

SYSTEMS ENGINEERING NEWS

Recent events and updates in the field of systems engineering

ISO/IEC 26580:2021 Standard Released

ISO/IEC 26580 [*Software and systems engineering — Methods and tools for the feature-based approach to software and systems product line engineering*] is a specialization of the more general reference model for product-line engineering (PLE) as described in ISO/IEC 266550. It addresses feature-based PLE that has emerged as a proven, repeatable practice that is supported by commercial design tools.

Further information on this newly released (2021-04) standard can be found here.

NIST Proposes Method for Evaluating User Trust in AI Systems

The trend toward embedding Artificial Intelligence (AI) within systems of all types has increased the need to develop methods that quantify and measure human trust in such systems.

The U.S. National Institute of Standards and Technology (NIST) has published a draft document, *Artificial Intelligence and User Trust (NISTIR 8332)*, in order to stimulate discussion about how humans trust AI systems. Part of a broader NIST initiative to advance trustworthy AI systems, the report investigates how humans experience trust as they use or are affected by AI systems. The report summarizes and builds on prior psychological research on the basic nature of trust among humans, how trust has been extended to technology and how trust in simpler forms of technology may influence trust in AI.

The publication proposes a set of nine factors that contribute to an individual's trust in an AI system, which include:

- Accuracy
- Reliability
- Resiliency
- Objectivity
- Security
- Explainability
- Safety
- Accountability
- Privacy

These factors go beyond the trustworthiness of a system, the ability of a system to perform as and when required, from the designer's perspective. Being trustworthy differs from being trusted. These factors address the system's Perceived Technical Trustworthiness (PTT) from the user's perspective. The relative contribution of these factors to a person's willingness to trust AI varies by the situational context, e.g., the individual's perception of risk in a situation where an AI-powered system informs decision-making.

The report notes that a user's overall potential to trust AI is also affected by a set of intrinsic personal attributes such as personality, cultural beliefs, age, gender, experience with other AI systems, and technical competence.

NIST is seeking broad feedback on the AI trust model to guide future research, and comments are solicited via a comment-response form.

Details on the AI User Trust Program are here.

The draft document is available here.

The comment-response form is available here and should be emailed prior to **July 31, 2021** to aiusertrustcomments@nist.gov.

Call for Nominations: SE Excellence Award

The US National Defense Industrial Association (NDIA) is now accepting nominations for their annual Lt. Gen. Thomas R. Ferguson, Jr. Systems Engineering Excellence Award, given to an individual and to a group who:

- Demonstrated outstanding achievement in the practical application of systems engineering principles, the promotion of robust systems engineering principles throughout the organization, or the support of effective systems engineering process development.
- Demonstrably, through their systems engineering contributions, helped achieve significant cost savings due to new or enhanced processes procedures and/or concepts, increased mission capabilities, or substantially increased performance.

This year's award will be presented at the 24th Annual Systems and Mission Engineering Conference, scheduled for October 4 – 7 in Orlando, FL.

The deadline for nominations is **July 23, 2021**.

Find more information (including award criteria and nomination instructions) here.

Call for Authors: IEEE TEMS Body Of Knowledge (TEMSBoK)

The Technology and Engineering Management Society (TEMS) of the Institute of Electrical and Electronics Engineers (IEEE) has issued a call for authors to contribute to the TEMS Body of Knowledge (TEMSBoK).

Commissioned by the IEEE TEMS Board of Directors and scheduled to be published by end of 2021, the TEMSBoK is to provide engineers and entrepreneurs with:

- A common set of updated good practices and guides for the profession
- A reference guide for entrepreneurs
- A basis for future official formal certification programs
- The opportunity to summarize extensive literature on the Management field to publish reference documentation for supporting new initiatives and business based on technology

TEMSBoK is organized around the following knowledge areas:

- Market research and Business analysis
- Strategy and Change Management
- Leadership
- Managing Innovation
- Entrepreneurship
- Project Management
- Digital disruptions
- Digital Transformation
- Data science
- Ethics, copyrights, and legal issues
- Acronyms

Details on the call for authors are found here.

Jama Announces Beta Release of its NLP-based Requirements Advisor

Jama Software has announced the beta release of its Requirements Advisor, a tool that uses Natural Language Processing (NLP) to analyze, evaluate, and improve the quality of product-development requirements.

That analysis is based upon best practices that are recommended by the *INCOSE Guide for Writing Requirements* (written by International Council on Systems Engineering) and by the Easy Approach to Requirements Syntax (EARS, originated by Alistair Mavin). Such practices facilitate well-specified requirements that lead to improved product quality, reduced rework, and accelerated time to market.

Poor management of requirements is the most commonly cited cause of delays and failures throughout the lifecycle of the design and production of new products.

More information on Jama Software's Requirements Advisor can be found here.

Ansys Acquires Phoenix Integration

Ansys has announced its acquisition of Phoenix Integration, a provider of software that enables model-based systems engineering (MBSE). Its ModelCenter MBSE bridges the gap between engineering analysis and systems modeling, as the single source of truth for describing the evolving system design throughout its lifecycle.

Find more information on the acquisition here.

Doctoral Student Opportunity in Human Systems Engineering

The Human System Engineering Laboratory of the Engineering Management and System Engineering Department at Old Dominion University seeks a doctoral graduate student to support research exploring the intersection of System Engineering and Human System Integration.

Current research work in the Laboratory focuses on modeling and simulation of socio-technical systems using a variety of tools and system-architecting methods. Candidates should have experience with model-based design and simulation.

More information on the position and on the process for applying to it is available here.

Job opening: Architecture Analysis and Optimization for Cyber-Physical Systems

Fortiss, the research institute of the Free State of Bavaria (Germany) for the development of software-intensive systems, is looking for Scientists in Architecture Analysis and Optimization for Cyber-Physical Systems.

Responsibilities for the position include: application-based research on model-based systems engineering (MBSE), particularly in model-based analysis and optimization of architecture for cyber-physical systems; exploring more flexible and agile approaches to developing safety-critical systems; and developing, transferring, and publishing research results.

The successful candidate will have: an advanced degree in computer science or electrical engineering, with a specialization in Software and/or Systems Engineering; experience with formal methods for analysis, synthesis, and optimization of models; and strong communication skills (English/German).

More information on the position and on the process for applying to it is available here.

PPI and INCOSE to Launch Updated Systems Engineering Tools Database at IS-2021

Project Performance International (PPI) and the International Council on Systems Engineering (INCOSE) will demonstrate an improved version of their Systems Engineering Tool Database (SETDB) at INCOSE's International Symposium (IS-2021), to be held virtually July 17-22, 2021.

Reflecting three years of collaboration between the organizations, V0.9 of SETDB was released at INCOSE's IW-2021 in January. New features added in response to stakeholder feedback include capability surveys, improved search functionality, and user-experience logging.

More information on the SETDB project and a preview of its IS-2021 release is available here.

CTI Joins Forces with Bluekei Solutions for SEP-Exam Preparation Courses in APAC

Certification Training International (CTI) and BlueKei Solutions (a provider of consulting, training, project-management, and workshops on innovation, based in Pune, India) have signed an agreement to collaborate on the delivery of INCOSE SEP exam-preparation courses to the Asia-Pacific region.

Further information on CTI is available here.

Further information on BlueKei Solutions is available here.

CONFERENCES, MEETINGS & WEBINARS

Upcoming events of relevance to systems engineering

INCOSE International Symposium (IS-2021)

July 17-22, 2021 (Virtual event)

Theme: "Accelerating through Adversity"

The International Council on Systems Engineering (INCOSE) announces its 31st annual symposium, the largest worldwide annual gathering of people who perform systems engineering. The program attracts an international mix of professionals at all levels, including practitioners in government and industry as well as educators and researchers. Attendees can share ideas, network, build competency, pursue certification, contribute to the advancement of the profession (through collaboration on tools, processes, and methodologies), learn about new offerings in training and education, and forge new partnerships.

Keynote speakers for IS-2021 include:

- Victoria Coleman, USAF Chief Scientist, Senior Advisor to the Director at CITRIS & the Banatao Institute, University of California, Former Director of DARPA
- HIRAI Hirode, Director-General, Commerce and Information Policy Bureau Ministry of Economy, Trade, and Industry (METI), Government of Japan
- Lex Hoefsloot, Co Founder of Lightyear

Other highlights of IS-2021 include:

- 95+ presentations on systems engineering
- 19 countries represented by presenters
- 24 application domains
- 39 topics represented across 5 tracks
- 11 panel discussions
- 9 tutorials

The IS-2021 tutorials include:

- Artificial Intelligence for Systems Engineers: Going Deep With Machine Learning and Deep Neural Networks
- From Operational Concept Development to Systems Architecture Definition with SysML and MBSE Grid approach
- Overview of the INCOSE SE Handbook Version 4.0
- Handling Organizational Complexity
- Introduction to Model Simulation and Engineering Analysis with SysML
- Systems Security Engineering: A Loss-Driven Focus
- Modeling and Analysis of Standard Operating Procedures
- Leadership Skills for Systems Engineers
- Applied Systems Theory to Enhance Systems Engineering Practice for Complex Systems

IS-2021 Information and Registration

VIRTUAL PRESENTATION: Swarm Decision-Making (INCOSE LA & Natural Systems WG)

July 13, 2021; 5:30 PM PDT

Speaker: Gary Vincent, CSEP, Senior Principal Systems Engineer with Northrop Grumman Defense Systems

The natural world can provide examples of evolutionary systems balancing competing design requirements to arrive at an optimal solution. One such example is the domain of information processing and decision making by distributed, decentralized systems – swarms.

This presentation examines how arrive at solutions in the absence of centralized control:

- Characterizing swarm behavior (e.g., bees)
- Application to human-designed systems
- Implications for human systems

Find more information and registration here.

A Look Inside the Digital Twin Maturity Model for Infrastructure

July 14, 2021; 11AM EDT (and on-demand)

The Infrastructure Working Group of the Digital Twin Consortium is using a digital maturity model to develop a roadmap for applying a digital twin to infrastructure projects. That digital maturity model will enable organizations to measure, monitor, and improve their ability and readiness for such application.

This free, 30-minute webinar presents a look inside that maturity model and the ongoing initiatives to supplement it. It will examine five categories of importance to organizations that seek to assess their digital-twin readiness:

- Organizational structure
- Organizational performance
- Evolution of the digital thread
- Integration of business functions
- Use of catalog and repeatable design & construction elements

Find more information and registration here.

ONLINE COURSE: AIAA Digital Engineering Fundamentals

July 20-29, 2021 (Virtual course)

Instructors:

- Dr. Edward Kraft, AIAA fellow
- Gavin Jones, SmartUQ Applications Engr.

The American Institute of Aeronautics and Astronautics (AIAA) is hosting an online short course on Digital Engineering Fundamentals. This eight-hour course will be delivered as four two-hour lectures from July 20-29, 2021.

The course will introduce Digital Engineering strategies and methods to transform system-engineering paradigms deploying model-based digital surrogate truth sources, demonstrate the context and value of implementing uncertainty quantification at all levels and phases of decision making under risk, and translating high-volume, high-velocity digital data into better products, processes, and mission effectiveness.

Learning objectives for the course include:

- Gain an in-depth understanding of Digital Engineering concepts and methods
- Create, calibrate, and apply authoritative digital surrogates truth sources
- Implement quantified margins and uncertainties analyses to master risk at critical decision points
- Discover better systems and test engineering performance metrics to support Test & Evaluation (T&E) and critical decision-making under risk
- Translate the DoD Digital Engineering Strategy into practical actions to create lifecycle value

The four lectures will be on:

- Introduction to Digital Engineering Principles and Practices
- Uncertainty Quantification
- Transforming Systems Engineering and Test & Evaluation (T&E)
- Authoritative Virtualization and Decisioning

For details on cost and registration, see here.

International System Dynamics Conference

July 25-30, 2021 (Virtual event)

The System Dynamics Society (SDS) invites attendees to its 39th annual International System Dynamics Conference.

The 2021 conference, a virtual event over Zoom, will explore how structured approaches such as System Dynamics can generate insight into drivers of problems and into the design of solutions in highly complex dynamic systems. Attendees will discuss resilience to global problems, solutions to those problems, and facilitation of actualizing those solutions. The conference will include plenary sessions, a model-sharing expo, workshops, a student-organized colloquium, and a preconference "summer school" that provides a unique opportunity to learn (or to review) System Dynamics.

SDS is a nonprofit, international society that encourages the development and use of systems thinking and system-dynamics modeling. It provides a forum for researchers, educators, students, consultants, and practitioners in academic, corporate, and public sectors.

For further information on cost and registration for the conference, see here.

For further information on SDS, see here.

Upcoming scheduled training via PPI Live-Online™

For more information on content, costs, and delivery, please visit the PPI Live-Online™ website.

Course Title	Targeted Region	Local Starting Time	Dates
Systems Engineering	North America *[inquire if interested]*	8:00 EDT (UTC -4:00)	July 5-9, 2021
Systems Engineering	North America	8:00 EDT (UTC -4:00)	July 12-16, 2021
Systems Engineering	South America *[only]*	9:00 BRT (UTC -3:00)	July 12-16, 2021
Requirements Analysis and Specification Writing	Turkey	8:00 TRT (UTC +3:00)	July 12-16, 2021
Requirements Analysis and Specification Writing	Saudi Arabia	8:00 AST (UTC +3:00)	July 12-16, 2021
Systems Engineering	Asia	6:00 SGT (UTC +8:00)	July 26-30, 2021
Systems Engineering	Oceania	8:00 AEST (UTC +10:00)	July 26-30, 2021
Systems Engineering	Turkey	8:00 TRT (UTC +3:00)	July 26-30, 2021
Systems Engineering	Saudi Arabia	8:00 AST (UTC +3:00)	July 26-30, 2021

PPI offers public and in-house training, virtually and (when travel restrictions permit) in-person. Access the full list of our course offerings here: https://www.ppi-int.com/training/.

PPI also offers a range of consulting and bespoke systems-engineering services to help your projects succeed. To find out more, visit our website: https://www.ppi-int.com/consulting/.

Deploying a Scalable MBSE Solution for Digital Engineering Transformation of the Enterprise

Organizations face significant challenges in their digital transformation, but mindful pursuit of scalable solutions can mitigate such challenges.

by Dr. Saulius Pavalkis and Gauthier Fanmuy

Introduction

According to the World Economic Forum, we are at the beginning of the fourth Industrial Revolution. This revolution can be described as the advent of "cyber-physical systems" that involve entirely new capabilities for people and machines [WEF2019]. This is not only a question of technology (i.e., the complexity of technical systems), but it also includes new ways in which technology is embedded within societies and even within human bodies to provide value-added services.

Model-based systems engineering (MBSE) is a key enabler of digital transformation of the modern enterprise [SERC2018]. Recent MBSE-maturity surveys from the International Council on Systems Engineering (INCOSE) and the Systems Engineering Research Council (SERC) indicate that most organizations are already in the early-adoption process of MBSE [SERC2020]. However, successful expansion beyond those pilot projects depends upon the scalability of the solutions chosen.

Organizations can best succeed in the adoption of MBSE on a company-wide scale, first by understanding the key challenges to scalability, then by choosing state-of-the-art tools and methods for mitigating those challenges. This article will focus on understanding those key challenges.

Key Enterprise Challenges to Scalability

Large projects

MBSE typically utilizes a systems-modeling language such as OMG SysML [SysML2019], as well as other integrated models and model-based activities when needed. SysML models and metamodels can be quite large, as SysML supports more than 200 tightly connected concepts. Model dependencies are much more complex than those used by Product Lifecycle Management (PLM) for bill-of-material configurations. Figure 1 [INCOSEIW2014] shows a small set of the relationships among SysML elements.

A large MBSE project can have hundreds of thousands or even millions of elements. Due to relationships between meta-elements and model elements, SysML project data is highly integrated. Capabilities such as validation, search, change-impact analysis, and data visualization require substantial memory. Significant resources can be required to load, update, and communicate that amount of data.

Also, a large MBSE project may have 100 or more people working on it. These can include a core team as well as seasonal contributors from various engineering disciplines, all of whom may need to access and to modify the model at the same time.

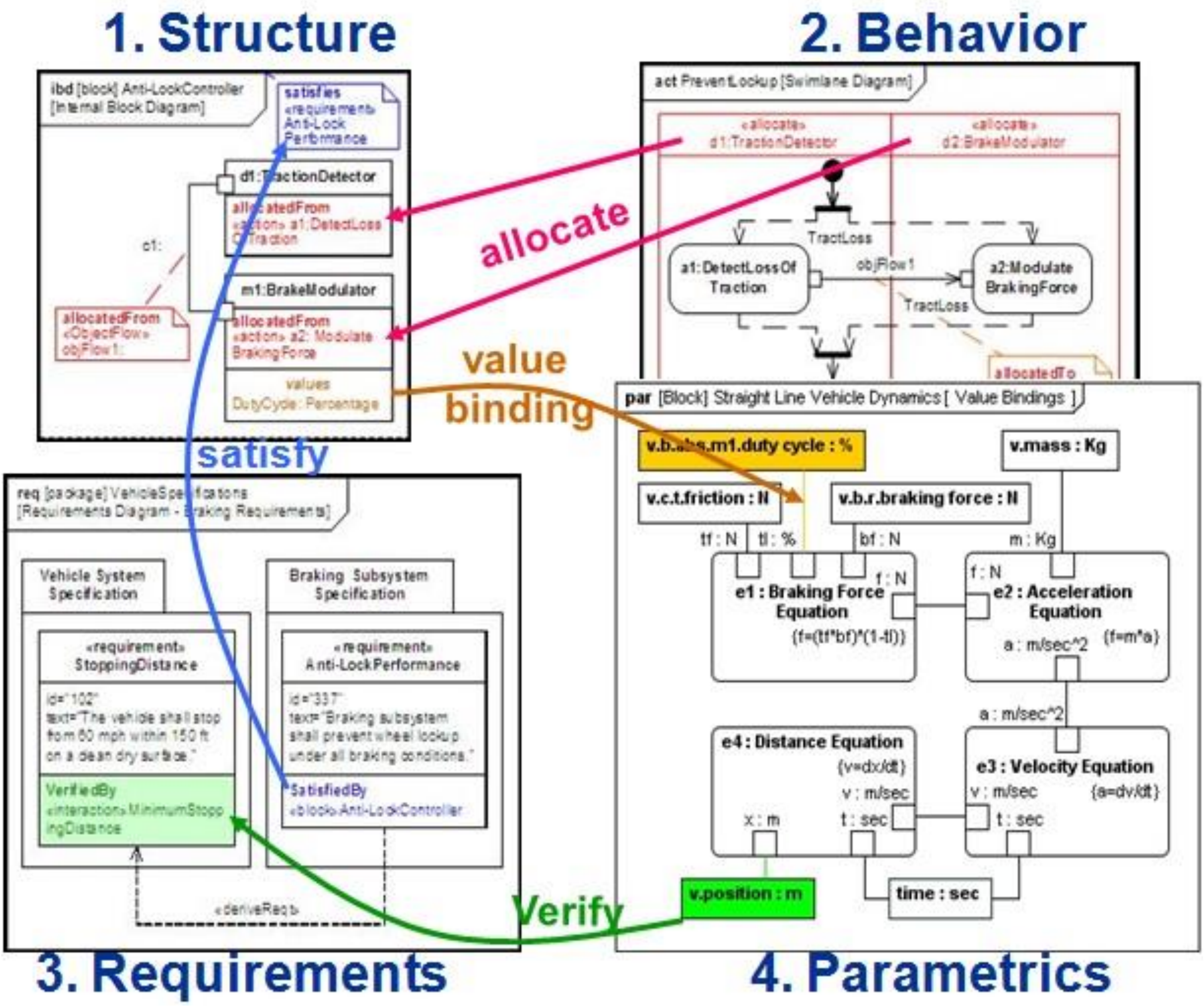

Figure 1: Sample of relationships between system elements in SysML (best available image)

Collaboration across remote or distributed teams

Typically, a governmental agency (such as the US DoD, Department of Defense) shares requirements for a model, then requires that contracting organizations respond with a proposed solution that traces back to the provided model, as defined in the DoD Digital Engineering Strategy [DODDES2018]. This requires collaboration across remote or distributed teams, as shown in Figure 2.

Similar situations occur between commercial organizations such as automotive OEMs and suppliers, and these also require remote or distributed collaboration. Even different departments within the same organization can have independent repositories with classified models, each of which have different access rights that dictate which parts can be interchanged or accesses and changed by whom.

Proper support for such remote or distributed collaboration requires further capabilities that must be scalable to be effective. The MBSE platform must be able to function across disconnected model repositories and to operate with subsets of the model data while maintaining the integrity of the model – all while observing and preserving the needed confidentiality of data and internal networks.

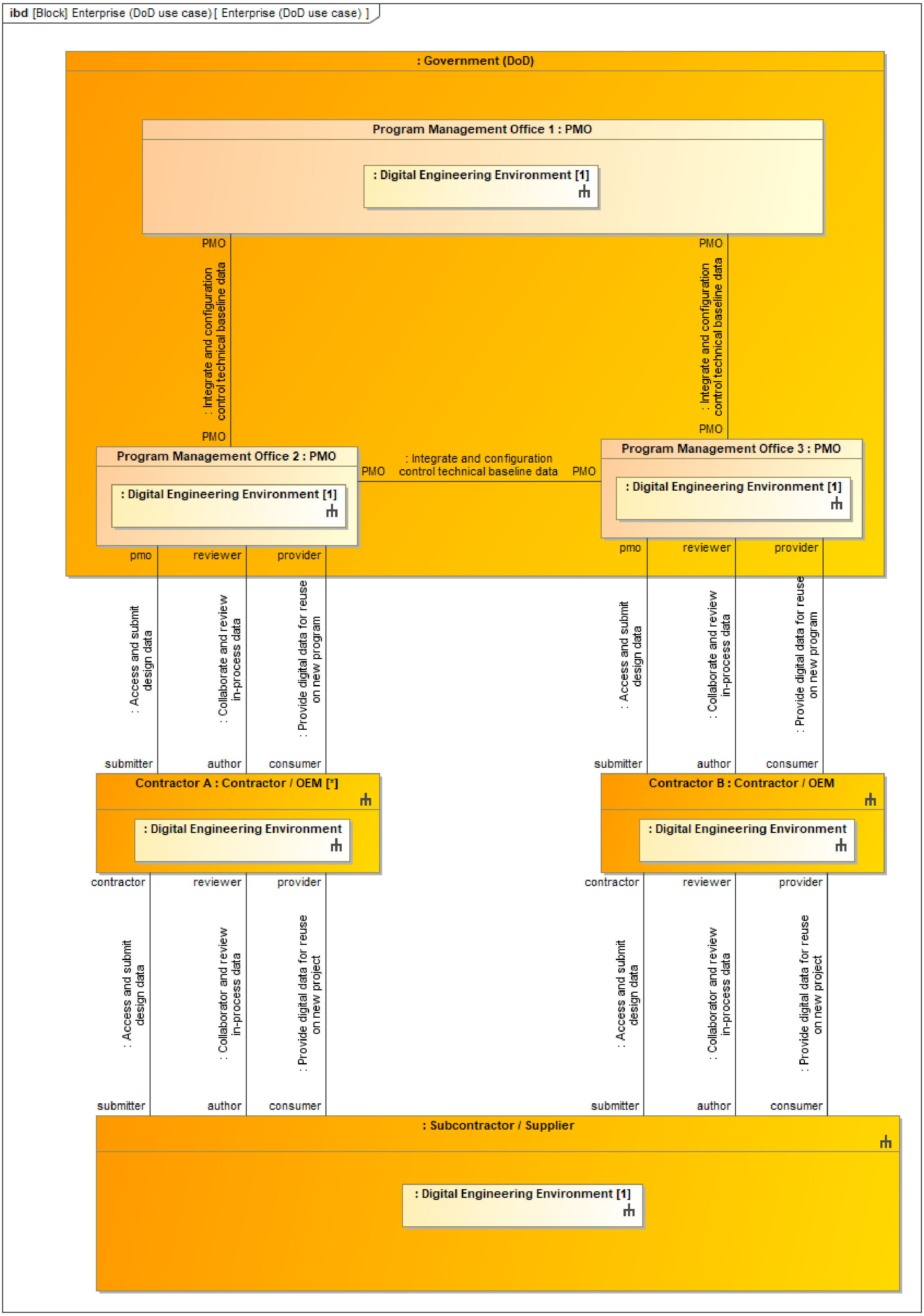

Figure 2: Distributed engineering environment interactions

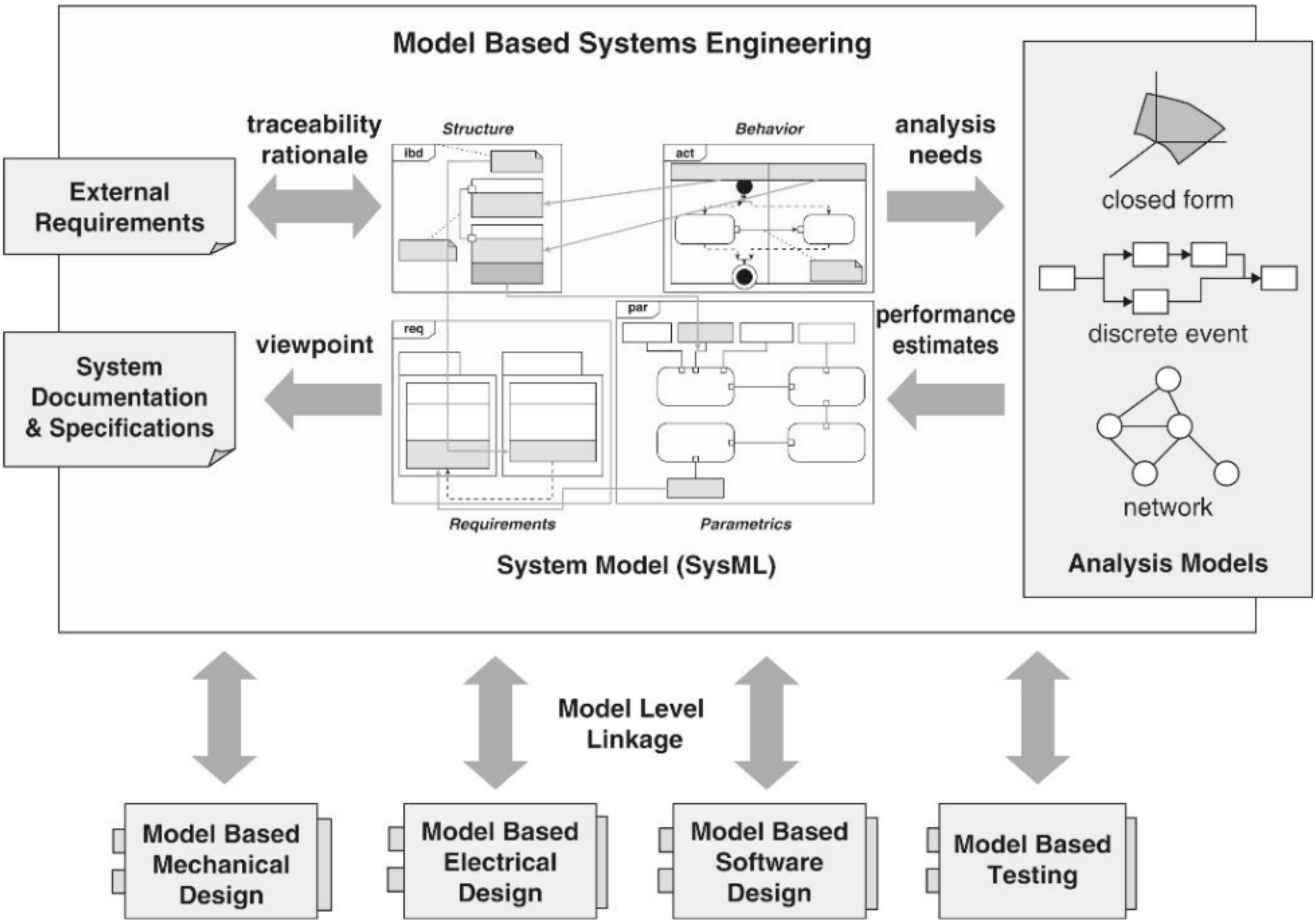

Figure 3: The system model and its typical relationships to other artifacts

Integrating the model with its larger ecosystem

A systems-engineering project is never in isolation. Figure 3 shows typical system-model relationships to other artifacts [FRIEDENTHAL], and figure 4 illustrates the necessity for models and data to be interoperable [DODDES2018].

Figure 4: US DoD Digital Engineering Strategy

Traditional, document-based engineering can have problems with data consistency when system-engineering artifacts are produced independently of the model and disconnected from the authoritative source of truth. Having the same information stored in different places duplicates work required, not only to generate that information but also in synchronizing it – and in remediating the problems that result from developed discrepancy. Textual and verbal communication can introduce errors and inaccuracies. work in the

- Traditional systems engineering textual and verbal communication of information leads to errors.
- Storing the same information in different places duplicates work and introduces inconsistencies on update.
- As work products evolve independently over time, traceability and reconciliation can be cumbersome processes.

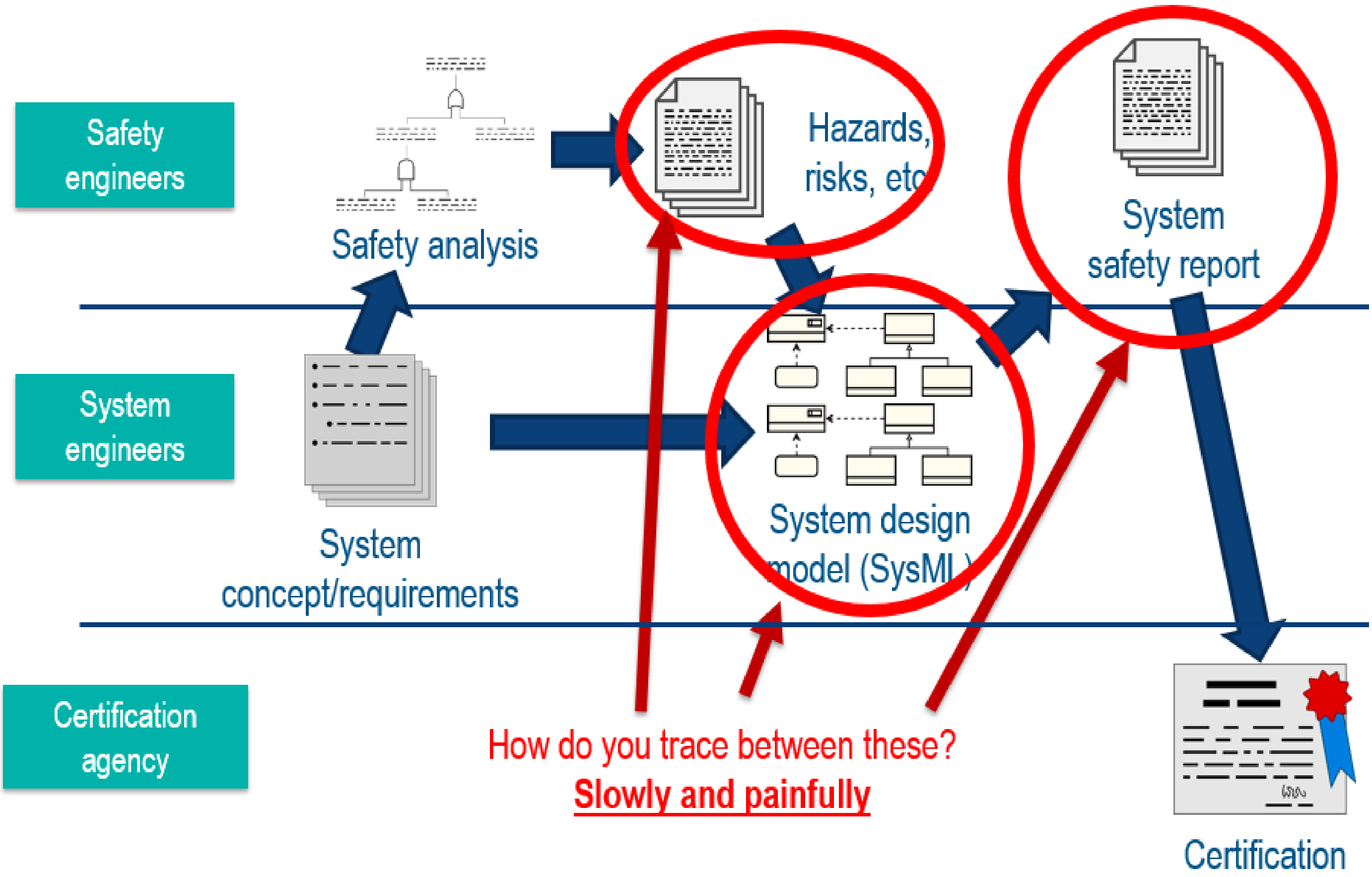

Figure 5: Problematic tracebility with non-integrated systems and speciality engineering (e.g., safety)

Early in the MBSE-adoption process, INCOSE identified the need for an MBSE language [OMGSYSML] that would interact with many different engineering disciplines and solutions. Figure 5 illustrates the problems that can arise in the absence of complete integration of such interactions, in which case it often becomes a human task to exchange data (e.g., through an Excel document) or to communicate results (e.g., through Power Point).

Larger organizations may have hundreds of different tools and databases, such as:

- Scoping tools for requirements verification, trade studies, and similar early activities
- Requirements-engineering tools to import, derive, reconcile, refine, trace, and manage requirements for the system and project
- Design tools to specify requirements and to model in software, mechanical, electrical, fluid, and other engineering disciplines
- Analysis tools for system optimization and for safety, reliability, and other "secondary" yet critical characteristics of the system
- Verification and validation tools, typically tightly integrated with requirements management and with system/product architecture, often exercised throughout the lifecycle from finding problems in the early stages to final system testing
- Industry tools that essentially are universal across suppliers and customers in a market, such as the Open Group Future Airborne Capability Environment (FACE Consortium) used in aerospace

For many markets and applications, secondary requirements (such as safety, reliability, fitness for use, etc.) are as important as the functional requirements themselves. When (for example) an analysis of a design in progress identifies issues of safety that must be addressed and mitigated, that information and its implications demand immediate and confirmed attention throughout the design team. However, in a non-integrated form, this information is often scattered and unreliable – a problem that only worsens at larger scales.

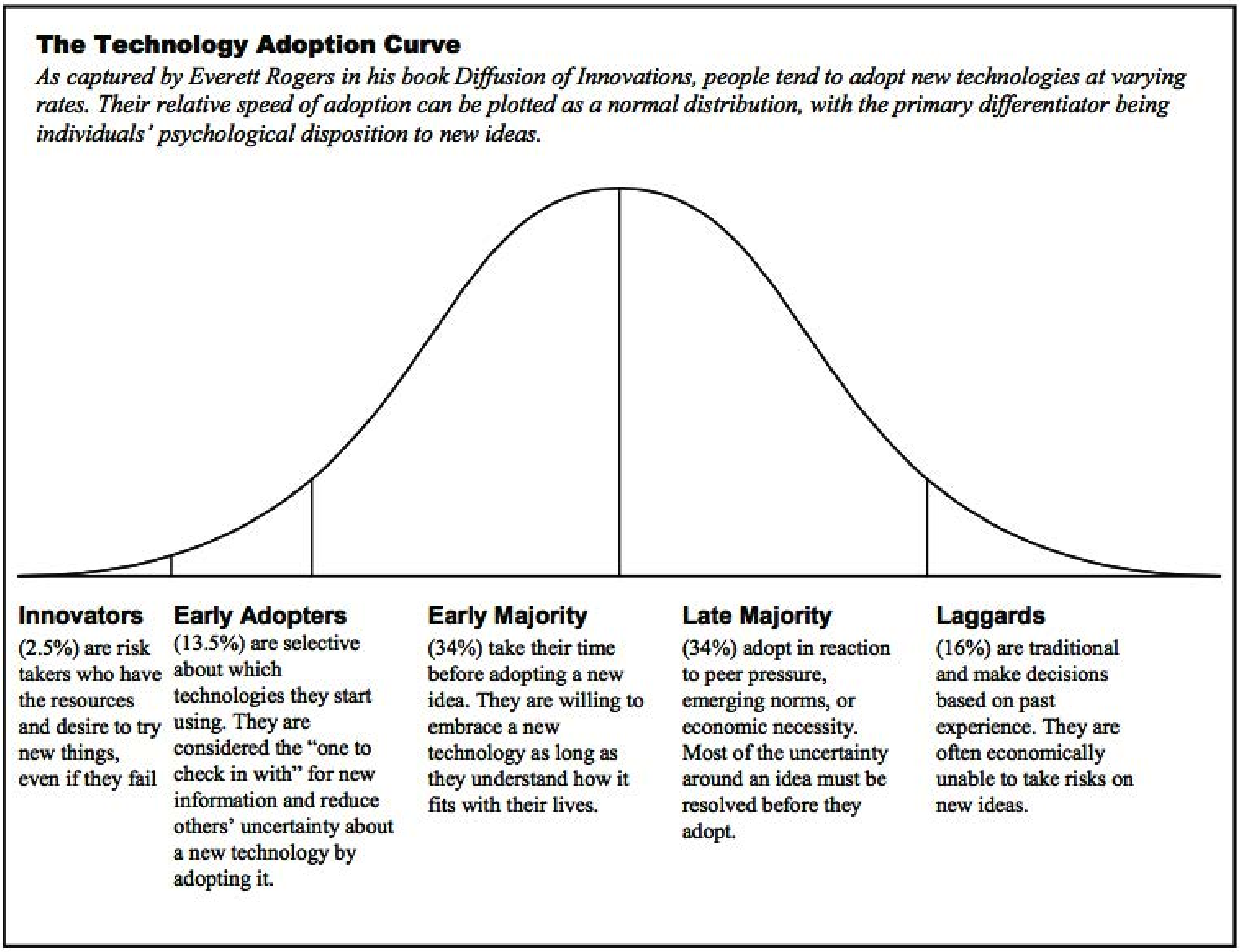

Figure 6: The technology-adoption curve

Cultivating organizational readiness for wider-scale adoption of MBSE

Typically, new ideas, products, services, and technologies can be seen as going through a stepwise process of adoption, from innovators and early adopters to a majority. Figure 6 shows a technology-adoption curve that was first defined by Ryan and Gross in 1941, following a normal distribution of percentage-adoption over time.

Such adoption curves are applicable within an organization as well as across a market. Initial pilot programs of MBSE adoption by carefully chosen groups within companies may be quite successful, but requirements and sensibilities of other groups and stakeholders often are rather different than those of the pilot group, and different factors may drive their success.

Challenges to the readiness of larger portions of the organization to adopt MBSE can include:

- Getting "buy-in" from stakeholders and political support from leadership
- Finding and allocating the right resources for immediate operational needs
- Identifying a lead MBSE engineer, a team of MBSE experts, a support team for tools and methods team, and necessary management for digital engineering management
- Preparing and aligning MBSE tools and methods across the organization, including those for standard and reusable libraries
- Integrating and interfacing MBSE models, data, and processes with non-modelers
- Prioritizing and sequencing MBSE projects according to available resources, relevant applicability, and similar factors to cultivate a stepwise series of success-stories

Maturity of organizational culture & of individuals

The best tools, methods, and resources can take a company only so far in their journey of MBSE adoption. The ultimate success of such upward scaling depends upon the maturity of the organization's culture and leadership, as well as that of the systems engineers involved. It is important to maintain a big-picture, long-term perspective throughout the process, with the experience and wisdom of senior systems engineers complementing the energy, insight, and technological expertise of younger ones. Everyone must understand the benefits and the costs of adopting MBSE, then be committed to its successful implementation as facilitator of better products and services, not simply as the latest, trendy "badge of honor".

Conclusions

Organizations can face significant challenges when scaling the adoption of MBSE from pilot projects to full-scale implementation. Those challenges include:

- The sheer size of most MBSE projects
- The need for collaboration across remote and/or distributed teams
- The need to integrate the model with its larger ecosystem
- The need to cultivate organizational readiness
- The need for maturity of organizational culture and of individual contributors

Once those key challenges are understood, then organizations can mitigate those challenges by choosing the right tools and methods for their MBSE expansion.

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About the authors

Gauthier Fanmuy is a System Engineering Expert at Dassault Systèmes, in charge of definition of end-to-end value, model-based systems engineering solutions. He has previously worked at ADN Europe as Technical Director and systems engineering consultant; at PSA Peugeot Citroën, deploying and applying Systems Engineering in vehicle projects; and at Dassault Aviation, managing technical-integration projects. An author and speaker, Gauthier teaches Systems Engineering at ENSTA School and Paris Sorbonne University. He is co-founder of the SPECIEF association for the promotion of Requirements Engineering and IREB certification in France.

Dr. Saulius (Saul) Pavalkis is a MBSE Transformation Leader and Senior Consultant at Dassault Systèmes, where he previously worked for 18 years in model-based solutions and the core R&D team. He is an expert in systems modeling, simulation, MBSE ecosystem, interfaces and integrations, traceability, and queries. He is an INCOSE CSEP and an OMG OCSMP. Dr. Pavalkis has authored multiple papers on MBSE for INCOSE and NDIA, and he is a CAB (Corporate Advisory Board) representative for INCOSE. He received his BS and MS in Telecommunication and Electronics, and his PhD in Computer Science, from Kaunas University of Technology.

Moving Up Through Levels of Practice in Systems Engineering

With systems engineering and the projects that it undertakes becoming ever more complex, should we be looking beyond the familiar "V" diagram?

By James R. Armstrong

Abstract: Systems engineering is often viewed as a particular set of processes applied with some tailoring in a variety of situations and relying on the concepts defined in the general models of the practice. Once the relationship to a particular model is established, it typically is maintained across all applications. Using analogies from sports, science, and other fields, this article suggests that we need to actively progress our thinking and practice past the limits of the most popular models, pointing to several activities that currently are attempting to do so.

Introduction

The "V" model (Figure 1) is widely utilized to visualize the overall concept of an end-to-end systems-engineering process. It is quite useful in explaining the approach of decomposing needs into the component level, then building components into a solution at the system level. However, when the model is used as the primary driver for systems-engineering processes and application, misunderstanding and misapplication of it can be problematic for the systems involved. Fortunately, there are adjuncts and approaches that can help systems engineers to progress past this basic view to a more complete practice of the discipline.

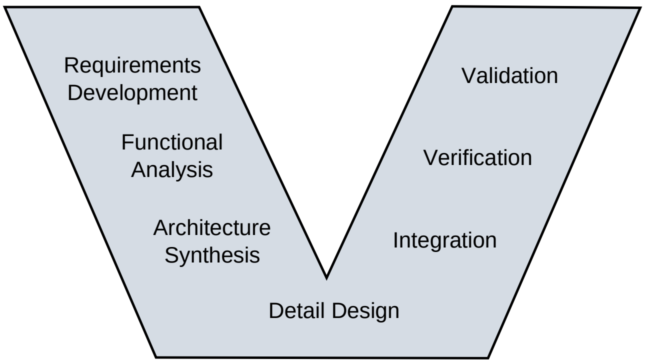

Figure 1: "V" Model of systems engineering

Examples of Practice Changes in Sports

A prior paper (Armstrong, 2006) used a sports analogy to characterize the role of the system integrator. A similar analogy can be made to the general practice of systems engineering, with particular attention paid to the need for continued advancement – not just in the skills of individual practitioners, but also in the way in which systems engineering is understood and described as a discipline.

In several years of coaching, playing, and watching various sports, I've noticed that as the players progress from beginners to advanced levels, not only do the skills improve and change, but the game itself changes. This is particularly true in soccer ("football" to the world outside of the USA). As the game progresses from five-year-old children to top professional ranks, there are definite and significant changes in the game at various points. The player or coach must understand and master the change to rise to the next level.

At the beginning level, a cloud of preschool children can be seen mobbed around the ball, with everybody chasing it up and down the field like a cloud of gnats. Out of this, a few more skillful players begin to emerge, but the game remains essentially the same. The first real change is also the most visually obvious, as shown in Figure 2. Players learn basic positions and play spread-out over the field. The basic skills of running and kicking are still applicable, but to these, the mental understanding of positions and how to play them are added.

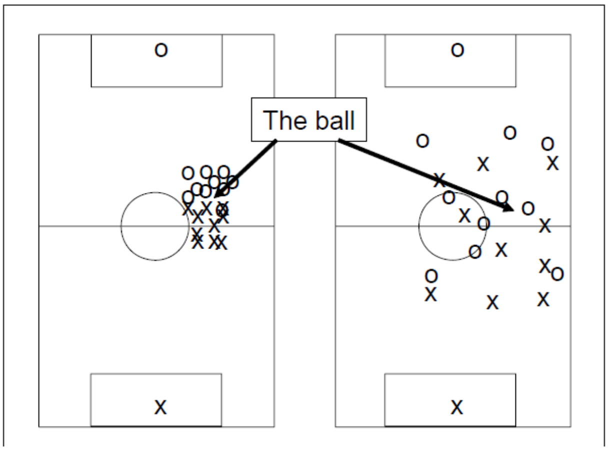

Figure 2: First game-change in soccer

From this point, the next change is the addition of basic passing and longer kicks to send the ball down the field. This style of play can be described as kickball because most of the play consists of individual players kicking the ball forward with little apparent further thought.

After this stage, teams learn to pass more effectively to their teammates and to get in position to receive passes. Control of the ball becomes more important, and emphasis shifts to maneuvering as a unit offensively and defensively. Emerging subtleties can become important: in one high-school championship game, the difference was the abilities of the winner to complete short passes in traffic, as opposed to longer passes in open space.

As the practice progresses to higher levels, teams also learn scripted offensive and defensive plays. At first, those plays are attempted as planned and practiced with the assumption that they will work. When they don't, the individual players improvise. As the skill levels progress, teams learn how to respond to different situations together and adjust as a unit.

Further change has come from introduction of analytics into sports. The first significant application was in baseball, and this affected everything: choice of whom to play, what skills to teach, and even gameplay itself, as offenses and defenses adjusted (often in real time) as suggested by analysis of historical data, instead of staying with generally accepted approaches. Exaggerated shifts in field positions for certain batters are the most obvious evidence; pitchers worrying less about avoiding the center of the plate on a first pitch fastball and giving up fewer walks is a less obvious result. Overall, the reliance on data has again produced a different game.

The basic takeaway from these examples in sports is that the game itself changes as each new level is achieved. Not all differences may be as obvious as the change from "cloud" to "position", or as that from "kickball" to "possession", but they are critical to the teams and players advancing to that next level.

Example of Practice Changes in Science

The field of theoretical physics is another example where "the game" itself has changed as the tools and techniques have improved. Sir Isaac Newton generated his laws of motion and of gravity, which sufficed to explain physics for many years. Albert Einstein then introduced his Theory of Relativity, which allowed a far more complete view of time, space, and the universe. Then came Quantum Theory and String Theory, which addressed several observations that prior theories could not explain. Recently, physicists have started measuring the once theoretical gravity waves, and the field of astrophysics keeps changing with each new concept that graduates from informed speculation to demonstrated proof.

These were not linear, incremental changes to the practice of the discipline: these were game changers that transformed not only how physicists did what they did, but also what they did, and even why they did it. As powerful as they once were, Newtonian physics are now of limited value in answering current questions.

Relevance to Systems Engineering

As suggested earlier, misunderstanding and misapplication of the classical "V" model for systems engineering can be problematic for both the engineers and the systems involved.

The most common problem is overemphasis of a distinct separation and serialization of the left and right sides of the "V". Such perspective implies that integration, verification, and validation are performed only after the system has been completely designed and its top-level build has commenced. This assumption can miss early opportunities to verify requirements against architectures, designs, models, and prototypes – or even to verify and validate the requirements themselves. Similarly, there can be the mistaken assumption that requirements are captured completely early in the program and do not change thereafter – but real-life experience demonstrates that acquisition and refinement of requirements often continue throughout the development of the functional and physical architecture.

Another potential issue with the "V" is that its initial emphasis on decomposition, from the system level down to constituent components, can allow engineers to underappreciate some of the holistic characteristics and requirements that are set aside during that decomposition. Such underappreciation tends to allow a reductionist perspective to creep into the subsequent bottom-up assembly and integration of components. When this is combined with a lack of integration activities in earlier phases, many cross-component issues are not discovered until late in the program.

Is it possible for systems engineering to take a lesson from sports and science, by improving its tools and skills such as the "V" model to bring a whole new level of elevated play and thereby changing the "game" itself?

Figure 3 shows the classical "V" model in gray, unfolded in a way that suggests a waterfall (another common depiction of the systems-engineering process). This downplays the hierarchical decomposition and re-assembly, but the retained activities and sequence still suggest hard demarcation between activities that precede detail-design and activities that follow it – and they still suggest that formulaic following of this sequence is sufficient to complete the development program.

This adaptation of the "V" model can be modified further to recognize and illustrate the continuous overlap of all activities throughout the program, as shown by the addition of the green bars in Figure 3. For example, despite best efforts to capture requirements at the start of development, few real-life programs are completely able to avoid modified or

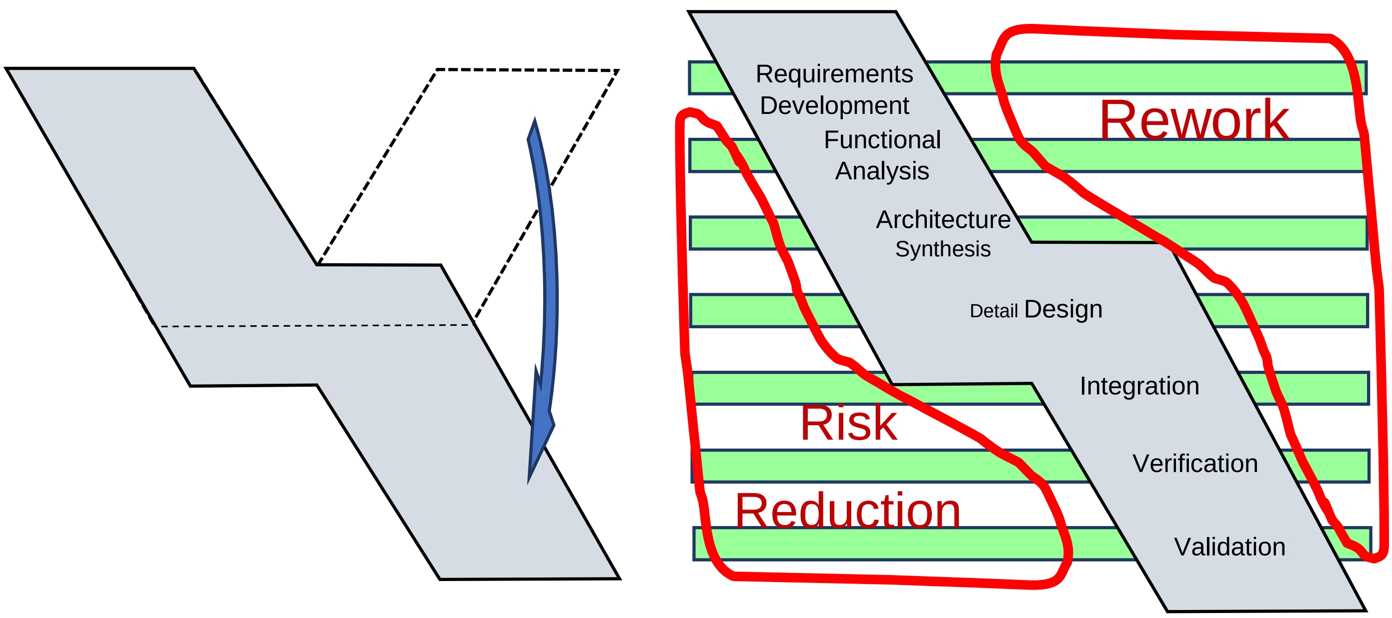

Figure 3: The "V" model, unfolded as a waterfall

incremental requirements and the resulting rework. Similarly, it is possible to perform at least initial subsets of integration, verification, and validation early in the program, when any issues uncovered are much less expensive to correct – thereby reducing risk to the program. As a result, this model-variant supports the continuous involvement of all activities as defined in Integrated Product Development. Cascades or further variants can show the repeated cycles of the flow for incremental or agile developments.

However, the development process for real systems of any size seldom precisely follows an exact, prescriptive sequence. At any point in the developmental timeline, some components or technologies may still be in research stages, with others may already in production. Some early or inherited decisions may constrain subsequent choices beyond the ability of the system architecture, interfaces, and allocations to adjust and to accommodate, mandating revisitation. Few models sufficiently address any preceding or facilitating activities (such as research) or the production, operations, and maintenance phases which also often involve and require systems engineering.

A more complete concept of the actual interaction of systems engineering activities might be better modeled as a neural network. As with the neurons in the brain, each part is continuously performing the appropriate tasks for the overall job, having multiple continuous connections with other participants but not necessarily continuous interaction.

One such approach to model the interaction among team members has been defined by Tyson Browning, using Design Structure Matrices (DSMs, an application of N^2 matrices). The approach was initially applied to grouping software functionality to reduce the complexity of external interfaces among modules. Figure 4 shows the same approach used to look at the interactions among various development-team members to determine which of them need to communicate in which groupings. In some instances, the identified optimal groupings are not those planned in traditional integrated team meetings.

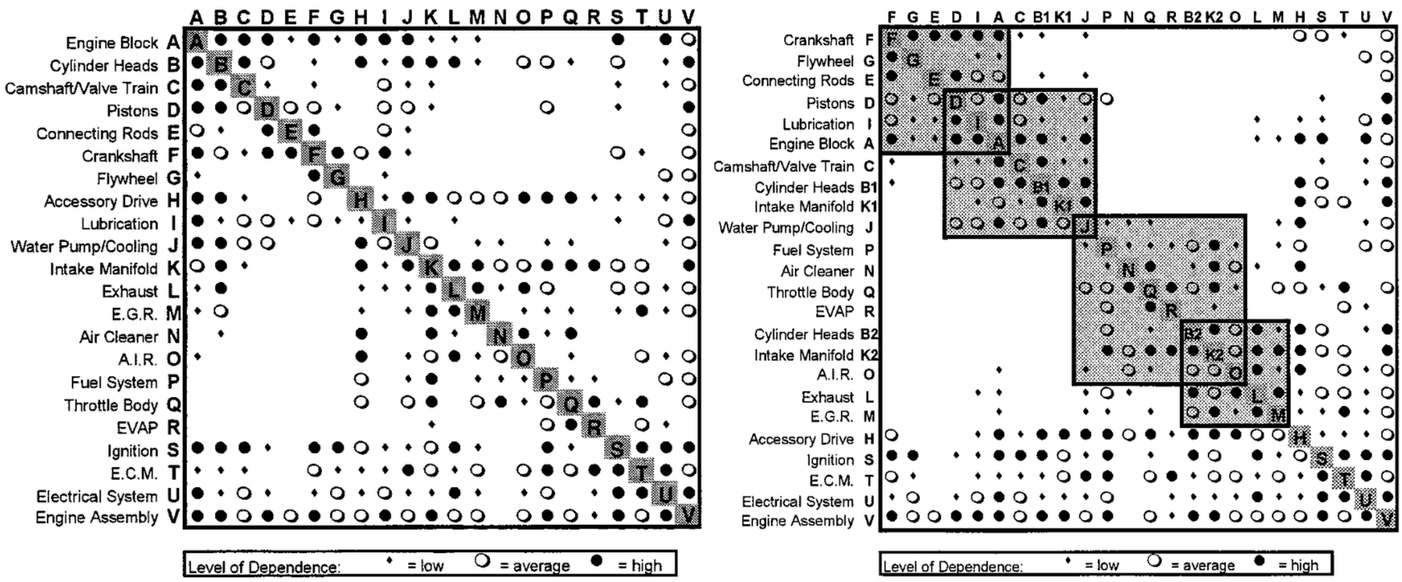

Figure 4: Example of a design-structure matrix (DSM) for software functionality

(T. R. Browning, Applying the Design Structure Matrix to System Decomposition and Integration Problems: A Review and New Directions, IEEE Transactions on Engineering Management, VOL. 48, NO. 3, August 2001)

Another potential "next level" in systems engineering is to view its processes more like designed plays in sports: laying out a basic plan for execution, but with a contingency plan that prepares for possible deviations from expected outcome. Such deviations include detected failures in the system design, whether through early peer reviews, digital models, prototypes, or verification or validation testing. While every company has some form of review process to determine how to respond when a failure is detected, not enough of them have standard mechanisms to analyze all such failures and to implement risk-based remediation based upon that analysis as feedback into the development process. For example, fully implemented Orthogonal Defect Classification (ODC) not only identifies the fix for an individual failure, but it also finds and addresses the root causes of the failure's occurrence and evasion of earlier detection – even looking across projects to find patterns across the organization.

The Capability Maturity Model Integration (CMMI®) defines a set of levels of capability for an organization's processes to meet its goals, and these levels can be applied to the practice of systems engineering. These levels range from the first level (characterized by processes that are poorly planned and controlled) to the fifth level (focusing on continual improvement). This roughly parallels evolution in sports, from individual play, to team play, then to reliance upon analytics. While the CMMI® has been criticized when too much emphasis is been placed on achieving a specific score, it also has provided significant benefit when used to assess what is working, what is not, and through which next steps to improve.

Application to Individuals & Organizations

Most systems engineers start out in another engineering discipline, then transition into system engineering with progressively greater scope. A recent study on the development of systems engineering expertise (Armstrong, 2017) identified a typical progression: from limited responsibility at the component level, to subsystems, to systems, and finally to systems of systems. Systems engineers also need to learn about other engineering disciplines that contribute to the projects on which they work. As the scope and complexity of systems grow, so also does the need for greater leadership, coordination, and cooperation. However, if one's understanding of the process of systems engineering is limited by the simple description of the classical "V" model, the progress may not be as successful as needed.

Companies also have growth patterns. Many are founded on the technical accomplishment of one or more individuals, and several have grown quite large with maintaining the "hero culture" that relies on an individual to save the day. Others started out building components, and while some stay in that focus, others either chose or are forced to move up to subsystems or systems. Delphi Automotive, for example, was primarily a component provider, before undertaking the On-Star system.

As such shifts occur, there will be changes in the way systems engineering is practiced. A company's architecture-level drives the focus of its requirements processes, as shown in Figure 5. A company at the systems level is focused on the need level down (process A), while a company at the component level is focused on the incoming specifications and their internal design efforts (process B). If an organization wishes to change their work, or if an individual wishes to move to another company that is working at a different architectural level, the game will change, and they will have to make the adjustments to be successful.

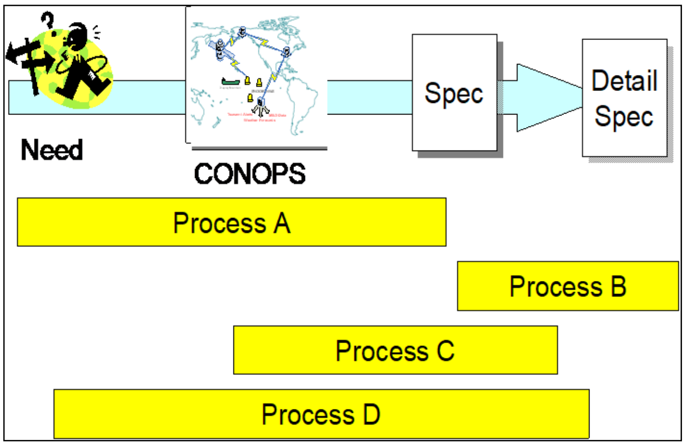

Figure 5: Variations in scope of requirements-design processes

Reluctance and Learning

Once any level of success has been achieved, there is commonly a reluctance to changing the approach that has brought the current success. This is true in sports as well as the workplace.

One team of new soccer players at the "cloud" level in development wasn't progressing very quickly from just listening to the coaches' instructions. However, one day they were warming up where they could observe two other games in their youth league: on one field were two of the bottom teams in the league playing "cloud" soccer, and on the other field were two top teams spread out in positions. Even 6–8-year-olds could not miss the point of which teams they wanted to emulate.

At a higher level, a team of early teens had been successful in the prior years playing the "kickball" style of soccer. When they aged into the high school league, they were hesitant to change what had been successful. It took a few loses to incentivize learning.

In the field of theoretical physics, one adage is that the practice only changes when the old physicists die out.

In systems engineering, companies are most incentivized to change their practice when they lose a bid to a competitor, when a customer complains, or when they forfeit a significant award fee or progress payment. Of course, many organizations and individuals recognize value in upping their game without waiting for these types of pressures: the current level, its strengths and weaknesses, and the next steps to improve can be identified and action taken to make the move to the new game.

What Next?

George Box is often quoted as saying, "All models are wrong, but some are useful." (Box, 1979) Even the best models only approximate reality, so the real question is, "Is a given model good enough for a particular application?"

The current updates to ISO/IEC 15288 and the INCOSE SE Handbook are moving away from the left/right view of limited application of processes, to full life-cycle applications. This should help drive the practices to a more integrated view of the individual processes.

However, it will take a willingness of companies, management, and practitioners to think more complexly about systems engineering and not require a simple explanation that can be used in all situations.

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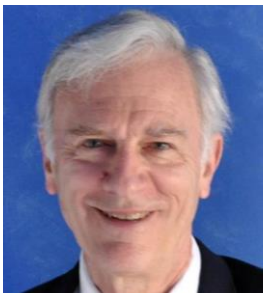
About the author



James R. Armstrong has practiced systems engineering for 54 years, performing various roles including configuration management, test, deployment, chief engineer, program manager, and program element monitor. For the last 30 years, he taught, consulted, and appraised systems engineering in industry and government, and he has been on the author teams for several systems-engineering standards and models. He has a BS in Mechanical Engineering from Rensselaer Polytechnic Institute, an MS in Systems Management from the University of Southern California, and a PhD in Systems Engineering from Stevens Institute of Technology. He has an INCOSE Expert Systems Engineering Professional (ESEP) certification.

PPI SyEN SPOTLIGHT: INCOSE

Interview with Kerry Lunney, ESEP, 2020-2021 President of the International Council on Systems Engineering (INCOSE)

René King, Managing Editor of PPI SyEN, sat down with Kerry Lunney to discuss INCOSE and the systems engineering profession in general. The following excerpts from that interview are edited for clarity and for conciseness. [Part 1 of 2]

What has been your experience, leading INCOSE through the unprecedented period of the COVID-19 pandemic?

It has been challenging, interesting, and surprising. Obviously, everybody and everything was impacted by the pandemic and by the other humanitarian crises that were and are still happening around the world. INCOSE members, volunteers, operations, membership benefits, certification activity, and outreach initiatives were all impacted. Everybody had to balance the demands of family, work, and volunteering – and INCOSE is a volunteer-driven organization. Maintaining such balance was even more difficult due to the unplanned need to revisit the planning and logistics of events and other commitments that were impacted by the pandemic. Some of our outreach initiatives had to be postponed, as the other technical societies and organizations were focusing just on surviving the disruption and adjusting to a new future from COVID-19.

However, the pandemic and other world events also forced INCOSE to move forward with more urgency in some initiatives that may have taken a little longer under more "normal" conditions. We really stopped to think, "what can we do to make a difference?" This had a positive influence on our trajectory, and I was ready to embrace it.

What was and still is a nice surprise is the resilience and dedication of the volunteers that rose to the challenges presented! I was also pleased to receive thank you and word of encouragement from our members on what we were doing, which is good sign. Other than not being able to meet face-to-face, I think INCOSE did okay!

In a 30-second "elevator pitch" to a key leader within an organization, how would you describe systems engineering and the benefits of applying it?

I didn't have one before this interview, but your question stimulated the construction of one, so here it is: "'Have you ever wondered how your home information systems are now becoming more integrated or how your local transport system is highly integrated with other services? These are just simple examples of how interconnected and interdependent different systems in the world are becoming. And to make this happen with elegant designs, you need our skills to engineer such systems."

At the start of your presidency, what were the key areas that you wanted to focus on developing within INCOSE? How are things going so far, and have your priorities shifted due to the impacts of COVID-19?

During my presidential campaign, I spoke of four key areas on which I wanted to work from the start of my presidency:

- subject-knowledge enrichment;
- integrated INCOSE communities;
- communication and accessibility; and
- refined tactical operations.

As the overall INCOSE vision evolves across presidencies, these areas build upon prior foundations while seeking improvement over time. I believe there has been progress in each of these four areas, although not all have evolved at the same rate.

For subject-knowledge enrichment, digital engineering and transformation topics are underway, as is artificial intelligence (AI). There is work to be done with big-data analytics, IoT or IoE (Internet of Things/Everything) and Serious Games, but there are elements of all these in Digital Transformation, System of Systems Engineering, and similar initiatives. However, in all we undertake, we need to harmonize the theory with the practice. We also want to expand the awareness of systems-engineering subject matter to people who wouldn't typically classify themselves as "systems people", which we've done through creating awareness through marketing and communication channels like social media.

The integration of INCOSE communities can be linked to the improvement of communication and accessibility. There is more integration across communities as a positive by-product of our greater virtual operation in response to the pandemic. The need and the opportunities to support each other – particularly through the sharing of lessons learned – have increased. All of this is facilitated by additional means to meet and to collaborate, such as the Systems Engineering Cafés and the monthly webinars. We're currently developing community pages on Microsoft Teams and Yammer – this project has also been accelerated due to the onset of the pandemic.

To improve our tactical operation, we have engaged more professional support services. We've already seen improvement in our IT offerings such as our websites, collaboration tools, and membership-engagement support. We are currently investigating professional support and services at the executive level for our Board of Directors activities and to free up time for the leadership team to tackle strategic aspects of INCOSE. There have been a lot of changes that may not all be visible to members but are happening behind the scenes; even the way we manage our financials has improved, as we've moved away from Excel spreadsheets to professional accounting software.

We're less than four years away from 2025. What is your take on the progress that INCOSE has made towards achieving the INCOSE SE Vision 2025?

The Board of Directors has asked ourselves this question a lot; it's a good question, yet also one that's hard to answer. INCOSE itself has made progress, but has systems engineering? Of course, the answer is both yes and perhaps no.

The 2025 Vision itself was and is a great launching pad for visualizing the future. It provides insight and guidance regarding where we should be expending energy, consolidating, or expanding – whether this is a process, an application, a principle, or a tool. It also helps us to identify opportunities for growth, or where new approaches are needed, or where more innovative solutions may be better. We use the INCOSE 2025 Vision to visualize the path forward, where we continue to build from our strong foundations and add new and creative approaches and practices as needed.

INCOSE has seen substantial progress in one of the key areas that I highlighted earlier, "subject-knowledge enrichment". Digital-engineering activities, our promotion and application of MBSE, our Future of Systems Engineering (FuSE) collaboration, and even our Grand Challenges initiative are making progress. Many of these initiatives were started by my predecessors, while a few have been started during my term.

However, there's still much that we need to do. We still need to find a grand challenge or two where we can make a significant difference. There are several roadmaps that we could develop if we want to be regarded as experts in systems engineering, such as roadmaps for research or for education and training. We also could take a more active role in the vast world of systems-engineering standards, identifying those with the greatest relevance to our members and therefore on which we should focus in the future.

With 2025 fast approaching, what can you say about the next INCOSE SE Vision?

The 2025 Vision arrived faster than we predicted – it has essentially arrived, and we are already working on the SE Vision 2035 with other contributors worldwide. It's currently in a major review cycle, and we're planning to release it in early 2022.

What we've seen in the past – and what we want to maintain for the future – is longevity of the INCOSE Vision. Therefore, the Vision needs to be kept relevant. To accomplish that, we plan regular reviews of the systems horizon and subsequent updates to the Vision, whether as a major release or just as a supplement.

For the INCOSE Vision 2035, the emphasis will be on the major trends that will continue to have significant impact on systems over the coming years. Increasing interconnectedness and interdependencies are emerging across various systems and solutions. The rate of change is increasing; the digital world is expanding; and sustainability and resilience are critical. Education and training are becoming more ongoing and more the responsibility of the individual. These and others need to be addressed to deliver high-quality systems, whether as a practitioner, an educator, a researcher, or a policy maker – and INCOSE should address each of these pillars.

What support do engineers need from their senior leaders, executives, directors, and managers to promote the practice of sound systems engineering? How can INCOSE be an active part of cultivating that support?

My first reaction upon hearing this question is to flip it around and to ask, "How can an organization afford **not** to have sound systems engineering practices?" Without such practices, sooner or later an organization will have to make unplanned remedial changes, whether retrofitting, redesigning, or whatever it may be.

Of course, this assumes that the organization understands what constitutes the practice of sound systems engineering – and this can be an important point at which INCOSE begins to be a significant source of support: we need to be recognized as the experts and champions of systems engineering. INCOSE should be the first place to which organizations think to go for expertise and guidance in the application of systems engineering. We also need to be seen as influencers in our field, actively working on challenges and issues of the present while always looking toward the future. There's nothing wrong with talking about interesting topics, but if they have little bearing on issues of today or tomorrow, our energies are better spent elsewhere. We don't want to sit on the laurels of the past.

INCOSE can further support the sound practice of systems engineering by cultivating the up-and-coming individuals working in systems and systems engineering: those who just joined the workforce, those who are advancing through the workforce, those who are switching from researcher to practitioner, etc. INCOSE also can reach out to people traditionally outside of the "world of systems", educating them on the importance of a systems approach, of systems research, or of systems-related education and training. This starts with an awareness and an appreciation of the important role that systems engineering plays in building the world in which we all want to live.

Lastly, we don't need to go it alone! We can collaborate with other technical organizations, and we can support industries and domains that are new to systems engineering. We're all better, together! If there is an area into which INCOSE would like to expand – such as the oil and gas domain – we would prefer to partner with an organization or technical society that's already in that space and to find a problem on which we can collaborate.

Of course, that's all easier said than done. If working for INCOSE were a full-time job for us all, it would be much easier. Nonetheless, we have those as objectives, and we are making progress towards achieving them.

Part 2 of this dialog between René King and Kerry Lunney will appear in the next edition of PPI SyEN.

SYSTEMS ENGINEERING SAMPLER

Selected examples of systems engineering in theory and in practice

ARTICLE: The Relationship Between "Systems Thinking" and "Systems Engineering"

Systems thinking is gaining greater awareness, recognition, and support as an important element and approach to successful solution of complex challenges across multiple industries. Unfortunately, such increasing awareness has also generated uncertainty as to what "systems thinking" actually entails in the practical world.

This article introduces many key concepts of systems, systems thinking, and systems engineering from the perspective of utilities and smart-infrastructure companies in the UK. This quick yet comprehensive overview may be a good resource to which to point interested newcomers to systemic concepts.

Access the article here.

ARTICLE: Human System Integration Ontology: Enhancing Model Based Systems Engineering to Evaluate Human-system Performance

Too often, current practices in systems-engineering address human-system integration concerns after system architectures have already been created. Further discrepancies result from differences in terminology between people who are, and are not, trained in human-factor engineering.

This article identifies central building blocks to create an ontology for human interaction, interfaces, and integration. This can extend current system-modeling capabilities to enable the human element to be analyzed as part of the overall system-development process.

Access the article here.

ARTICLE: Leveraging MBSE to Propel Electric Aircraft

With intense pressure to be first to market with safe and reliable electric aircraft, original equipment manufacturers (OEMs) in aerospace are rethinking their product-development processes. As they explore tradeoffs between hundreds of design configurations and prepare for the challenges of certification, systems engineering is critical to their success, including a digitalized approach that connects all aspects of requirements, conceptualization, design, manufacturing, and maintenance.

Model-based systems engineering (MBSE) is growing in popularity in aerospace, serving as a digital backbone that improves integration and efficiency of complex systems and processes, allowing greater collaboration across domains and throughout the supply-chain. This fosters a flexible, open ecosystem to facilitate digital transformation within and across companies.

Access the article here.

ARTICLE: Reducing Construction Time and Costs of Small Modular Reactors through Model-Based Systems Engineering

A consortium in the UK nuclear industry is utilizing systems engineering to facilitate the design of modular technology for factory fabrication, easier transportation, and on-site assembly of Small Modular Reactors (SMR).

The program is part of an initiative to construct a fleet of up to 16 factory-built, 440MWe nuclear-power stations, to be operational within a decade. A modular approach to the serial production of entire plants aims to reduce costs by reducing on-site build-time.

Model-based systems engineering (MBSE) manages the complexity of the product and of the overall project, thereby reducing risk and development time. A "digital twin" will integrate, document, and communicate all design data throughout the lifecycle of the nuclear power plant.

Access the article here.

ARTICLE: An Appraisal of the Systems Engineering Journal's Treatment of Software Over the Last Two Decades

Systems engineering and software engineering are largely interdependent, especially as software plays an ever-increasing role in the design and operation of human-made systems. However, many chief systems engineers and program managers are not well experienced in software or in software engineering.

How have conversations about software within systems-engineering circles changed in the past twenty years? Selected issues of INCOSE's *Systems Engineering Journal* were examined to assess the evolution of acceptance of the vital role (and special needs) of software within the systems that are being engineered. While articles specifically about software engineering were largely absent across the sampling, some encouraging trends include greater recognition of software as a fundamental means by which desired capability is achieved, not as a separate part of the system.

Access the article here.

INTERVIEW: A PLE approach allows companies to build a product line portfolio as a single production system

Product-Line Engineering (PLE) is of growing importance in systems engineering, digital engineering, and manufacturing production processes. It offers substantial improvements over traditional product-engineering strategy by framing a product-line portfolio as a single production system, not as a series of multiple stand-alone products.

Design News interviewed Dr. Paul Clements, VP of Customer Success for BigLever Software and one of the "founding fathers" of PLE, to learn more about this paradigm shift in product-engineering and how it can benefit companies.

Read the interview with Dr. Clements here.

ARTICLE: On the Requirements Engineer Role

Requirements Engineering (RE) is a critical step in the development of software and of systems, and inadequacy of RE is widely regarded as a primary factor in the failure of development efforts. This article presents the results of an interview-based descriptive study of the many ways in which companies assign the role of requirements engineer and the variety of tasks that they are asked to perform in that role.

The study and its conclusions come from the perspective of software and IT, but the issues have relevance to systems engineering as well.

Read the complete article in *Communications of the ACM* here.

WHITE PAPER: Infrastructure 4.0: Achieving Better Outcomes with Technology and Systems Thinking

The Infrastructure 4.0 project community of the World Economic Forum was created to encourage a more holistic, outcome-focused framing for infrastructure. This white paper contains 13 recommendations for improving the adoption of emerging technologies into the development of infrastructure. These include both high-level strategies based upon systems thinking and practical, concrete steps that use technology as an enabler. Through a focus on improving outcomes for people and nature, infrastructure can serve as a platform to connect the built environment, the natural world, and human lives in a way that allows all three to thrive.

Find more details and download here.

WEBINAR: There is No (Real) Systems Engineering Without Systems Thinking

The best foundation for systems engineering is the pairing of good, sound engineering with solid, intentional systems thinking. While tools, checklists, and models are all important, the absence of an understanding and application of such a foundation can prevent systems engineering from delivering its full value.

Download the slides and watch the recording from INCOSE Chesapeake Chapter here.

WEBINAR: Systems Thinking as it Applies to Systems Engineering

The application of systems thinking to systems engineering can strip away artificial complexity, dispel popular misconceptions, and enable the delivery of better results by engineers.

Download the slides and watch the recording from INCOSE Chesapeake Chapter here.

NASA Systems Engineering Handbook

The January-2020 update (Rev 2) of the NASA Systems Engineering Handbook includes using Model-Based Systems Engineering (MBSE) to improve development and delivery of products, as well as lessons learned from the Genesis, Columbia, and Mars Reconnaissance Orbiter programs to improve the overall systems-engineering infrastructure and capability.

Access the SE Handbook here and here.

WEBSITE: The Moral Machine

From self-driving cars on public roads, to self-piloting reusable rockets landing on self-sailing ships, machine intelligence is supporting or even supplanting human activities at an ever-increasing pace. Inevitably, machines will have to make decisions that involve human welfare. This calls for clearer understanding, not just of how humans make such choices, but also of how humans perceive machine intelligence making such choices.

Made by Scalable Cooperation at the MIT Media Lab, the Moral Machine is a platform for crowdsourcing a human perspective on moral decisions made by machine intelligence. Visitors are shown moral dilemmas, such as an autonomous car that must choose between killing two passengers or five pedestrians. Visitors then can judge which outcome is more acceptable, can see how their responses compare to others', and even can design their own scenarios for other visitors to browse, share, and discuss.

Access the Moral Machine here.

ORGANIZATION: Swiss Society of Systems Engineering

The Swiss Society of Systems Engineering (SSSE) is a non-profit organization formed in 2011 by engineers across a broad range of industries, who share the passion of practicing, advancing, and promoting Systems Engineering (SE) principles – the most fundamental of which is, "doing engineering better".

The SSSE has been recognized officially as the Chartered Swiss Chapter of International Council on Systems Engineering (INCOSE).

Despite having many multilingual members, the SSSE operates primarily in English. They produce a quarterly newsletter that includes information on recent activities, upcoming events, and systems-engineering in general.

Learn more about SSSE on their website.

SYSTEMS ENGINEERING RESOURCES

ARTICLE: System of Systems Engineering

This article develops the concept, foundations, research directions, and practice implications for System of Systems Engineering (SoSE). It explores the perspectives of complex systems of systems, then synthesizes these into a set of common themes found in the literature and identifying shortcomings in the current state of SoSE. It suggests the implications for design, deployment, operation, and transformation of complex systems of systems, and it proposes the structure for a research agenda to advance the knowledge and practice of SoSE.

Access the article at [Taylor & Francis Online](#).

ARTICLE: Perspectives for process systems engineering — Personal views from academia and industry

This article reflects on the past, present, and future of process systems engineering (PSE), from an academic and industrial point of view. It suggests that PSE historically has emphasized methodologies and tools to support process modeling, simulation, and optimization (MSO). It asserts that MSO technologies have matured into commoditization, thereby requiring PSE to shift its emphasis to model-based applications in product and process design, control, and operations. It further asserts that PSE should prioritize systems thinking and systems problem-solving over the mere application of computational problem-solving methods. With such redefinition, PSE can continue to play an active role in providing enabling technologies for product and process innovations, in chemical-engineering industries and beyond.

Access the article at [ScienceDirect](#).

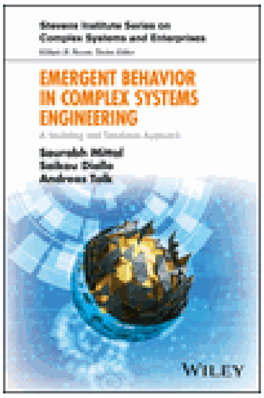
ARTICLE: Innovative virtual prototyping environment for reconfigurable manufacturing system engineering

This article presents a new approach to the design and implementation of virtual prototyping environments (VPEs) that provide support for the engineering of reconfigurable manufacturing systems (RMSs). The primary aspects of VPE tool-development include:

- Ensuring the consistency between real- and virtual-system architectures, design tools, and design processes; and
- maximizing the potential of three-dimensional computer-based virtual models as a basis for distributed engineering collaboration.

The article proposes a component-based (CB) approach to the design and implementation of VPEs, to enable more effective management of the complex engineering life cycles of RMSs by globally distributed engineering partners.

Access the article at [Sage Journals](#).



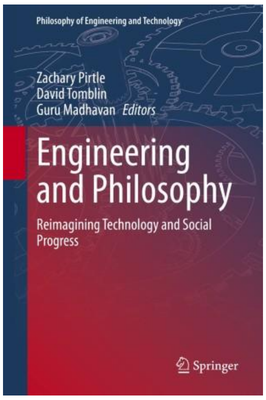
Emergent Behavior in Complex Systems Engineering: A Modelling and Simulation Approach

Modeling and simulation, along with Big-Data technologies, allow the exploration and investigation of scientific theories through computational infrastructure. This book presents theoretical considerations and tools that can facilitate such study of emergent behaviors in manmade systems.

Simulation technologies can further our detection, analysis, understanding, and management of emergent behavior in complex systems, thereby enabling engineers to reap the benefits of innovations while avoiding the dangers of unforeseen consequences.

An overview of current discussions on complexity and emergence show how systems-engineering and simulation together can facilitate insights in the engineering of complex systems, offering contributions from authors at the forefront of various related disciplines such as philosophy, science, engineering, sociology, and economics – and forecasts the next generation of complex-systems engineering.

See this book at Wiley Online Library.

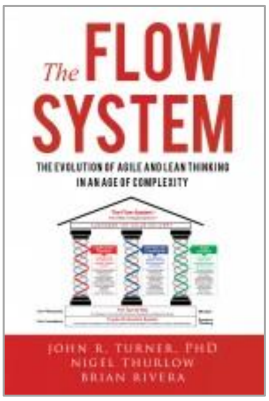


Engineering and Philosophy: Reimagining Technology and Social Progress

Engineers tend to love to build "things", and most have an innate desire to improve society. However, such desires are often not connected or developed through reflections on the complexities of philosophy, biology, economics, politics, environment, and culture.

This book brings together practitioners and scholars to inspire deeper conversations on the nature and varieties of engineering. Through both perspectives, it seeks to reimagine how engineering can and should serve society.

See this book at Springer.



The Flow System: The Evolution of Agile and Lean Thinking in an Age of Complexity

Organizations operating in complex environments must increase their agility. The Flow System is rooted in the Toyota Production System and elevates Lean Thinking with a combination of complexity thinking, distributed leadership, and team science. This Triple Helix of Flow can help organizations to become more innovative, adaptive, and resilient.

See this book at UNT Press and a discussion on it (in two parts) at InfoQ here and here.

PPI SYSTEMS ENGINEERING GOLDMINE

The PPI Systems Engineering Goldmine is a free resource that contains a wealth of reference information relevant to the engineering of systems.

SE Goldmine features include:

- Thousands of engineering and project-related downloadable documents (4GB+)
- Searchable database by description, title, keywords, date, source, etc.
- Extensive library of standards, and links to standards
- Searchable systems engineering-relevant definitions, 7800+ defined terms

Registration is required for access to these resources. Get more information here.

FINAL THOUGHTS

Syenna's Corner

Once upon a time, it was regarded as impolite to ask a lady's age, but my reflections this month on various acronyms may allow you to make an informed estimate of mine…

I got into a nostalgic frame of mind when I was recently reminded of the acronym, WYSIWYG (for "What You See Is What You Get", typically pronounced as "wiz-ee-wig"). If one believes a first page of Internet-search results (and who doesn't!?), this term was invented by Charles Simonyi in the 1970s.

Later in my career, I did some business studies and came across the neatly contrasting ideas of "Make What You Can Sell" (MWYCS) and "Sell What You Can Make" (SWYCM). A cynic might observe that SWYCM for the manufacturer often becomes WYSIWYG for the customer. That same cynic might suggest that the fashionable name for SWYCM is "Agile".

Occasionally, I like to share three rules of choosing metrics: make them informative, make them automatic to collect, and beware of WYMIWYG ("What You Measure Is What You Get", or "why-my-wig"). The last rule cautions that what's easily monitored and improved isn't always what's important. For example, when hospitals focus on reducing how long patients stay in the waiting room before being seen, typically those metrics are improved – but too often, the number of patients "buffered" in corridors then goes up, resulting in the same or even worse patient experience.

When I started out in Engineering, I was using analog computers, and our editing tools were scissors and sticky tape. Civil aircraft were just making the transition from analog to digital systems, which made for some very interesting learning curves. The first digitally controlled aircraft could only fly to 32,767 feet; one could almost feel altitude changing in 1-foot steps; and I found out about aliasing the hard way.

Now, "aliasing" does not refer to creating a dodgy personality on unsocial media, but rather to an important principle of sampled systems: improper sampling of a signal can lose information and get misleading results. I invented my own Simonyian acronym for this: WYSINWGO ("What You See Is Not What's Going On", or "wizzin-we-go"). And believe me: WYSINWGO, when whizzing we go, is not fun.

I hope, dear reader, that you found this insight into a pre-digital world of some interest.

Yours faithfully, and ever grateful that my parents named me after your splendid newsjournal,

Syenna

An SE Riddle for you

What is Syenna thinking in this diagram?

If you are the first person to send in a correct answer, Syenna will personally pay for a tree to be planted in your name. (Employees and associates of PPI and CTI are welcome to submit answers but are ineligible for the prize.)

Why not submit a riddle of your own, to be published in a future edition of PPI SyEN?

Send your answer or riddle to: PPISyEN@PPI-Int.com.

Syenna Margaret Puck is a free-lance journalist, social-media influencer, and figment of some overactive imagination. She lives and works in Europe.