PPI SyEN

SYSTEMS ENGINEERING NEWSJOURNAL
EDITION 101 | MAY 2021

Sociotechnical Systems

ENTERPRISE ARCHITECTURE
Friend, foe, or subset of SE?

PURPOSEFUL HUMAN ACTIVITY SYSTEMS
A theoretical foundation

CULTURE, STRUCTURE, DISAPPOINTMENT
Organizational essentials

TECHNICAL LEADERSHIP
Not just for managers

A PROJECT PERFORMANCE INTERNATIONAL PUBLICATION | PPI-INT.COM

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WELCOME

Welcome to our May 2021 edition!

As noted in PPI SyEN's objectives (lower-left corner of page 3), systems engineering can't overlook the human element. The entirety of conceptualizing, designing, building, and testing a product or service system is itself a sociotechnical meta-system. (As the INCOSE Patterns Working Group points out, that developmental meta-system is the work product of a still greater meta-system of innovation, process-improvement, education, training, etc.) Furthermore, a product or service system will be operating and delivering its value within a target sociotechnical system: its specifiers, customers, users, operators, beneficiaries – all of whom are just a sociotechnical subsystem of the larger market/industry and society in general.

Systems engineering is all about understanding, managing, even optimizing emergent properties that result from interoperation of elements in a system. This month's featured articles explore how systems engineering can apply to sociotechnical systems.

- Thomas Manley investigates (and seeks to arbitrate) the "family feud" between enterprise architecture (EA) and systems engineering (SE): from their early days as best friends, to their falling-out over who got top billing, to rumors of a reunion tour that organizations await eagerly.
- Javier Calvo-Amodio draws from his extensive background in systems science, to build a solid theoretical foundation and to propose practical use-cases for the concept of purposeful human activity systems (PHAS), in the quest to improve the design and management of organizations.
- I revisit and revise my article from 2019 on a conceptual model for organizations as sociotechnical systems, then I propose a simple, qualitative methodology that can equip everyone throughout an organization with the mindset and the mandate to improve its operation and quality.
- Don Gelosh explains six interrelated capabilities of technical leadership, then examines why these – in addition to technical knowledge and skills – are essential to the fundamental practice of systems engineering. (Spoiler alert: SE is a collective activity – a sociotechnical system.)

Wishing satisfying, even delightful emergent properties for all your sociotechnical systems,

Kevin

Kevin Nortrup
Editor, PPI SyEN

Views expressed in externally authored articles are not necessarily the views of PPI nor of its professional staff.

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 SyEN readers, authors, and editors

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

René King
Managing Editor, PPI SyEN

For some people, "enterprise engineering" is a vocation; for others, it's just another buzzword among the growing list of engineering fields that are ever more difficult to distinguish from one another. In this month's exciting May 2021 journal, you'll read different perspectives on the engineering of enterprises and of other sociotechnical systems. Those articles may challenge your thinking on the topic – we hope so, anyway!

As you're reading this edition of PPI Systems Engineering Newsjournal, please know that we'd love to hear from you. This forum is intended to be a space where PPI SyEN editors and authors can engage with the readers about topics relevant in systems engineering today.

If you're interested in participating in this conversation, sharing your perspectives and enriching the body of knowledge of systems engineering, please click here to access the survey. At the end of that survey, you'll be asked to indicate whether we may publish your response – so you may see your feedback to us in an upcoming edition, unless of course you choose otherwise.

We at PPI SyEN value the time, perspective, and engagement of every single reader. Literally, we do this all for you, our readers, as we noted in our special 100th edition last month. If you haven't read yet through that edition, please take the opportunity to do so here - it's packed with high-value content, on which we'll be building for the next 100 editions to come.

René

FEEDBACK

Don't make PPI SyEN run "open-loop"! Help us help you, by letting us know what's on your mind.

Do you have questions, comments, affirmation, or push-back for authors and articles in SyEN?

Are there trends in systems engineering that give you cause for celebration – or for concern?

What subjects, themes, or other content would be of greatest interest to you in future editions?

Would you be interested in suggesting a contributor – perhaps yourself – for a future article?

Tell us about it, at PPISyEN@PPI-Int.com

Keep it civil, sensible, and succinct – and your feedback just might appear in PPI SyEN FORUM.

We reserve the right to edit for clarity and content.

SYSTEMS ENGINEERING NEWS

Recent events and updates in the field of systems engineering

Updates to PDMA's Knowledge Hub (kHUB)

The Product Development Management Association (PDMA) has announced a re-launch of its Knowledge Hub (kHUB) website with a new look and feel, in response to member feedback. The kHUB platform extends PDMA's Body of Knowledge by focusing on seven knowledge areas that support innovators and product-development professionals across diverse industries:

- Strategy
- Portfolio Management
- Product Innovation Process
- Product Design and Development Tools
- Market Research in Product Innovation
- Culture, Teams and Leadership
- Product Innovation Management

kHUB is a searchable repository of articles, webcasts, podcast, blogs, and whitepapers that facilitates the creation and exchange of product-management and development knowledge and best practices. It provides the basis for individual professional development and for organizational innovation, leading to a competitive edge.

Recently published content includes:

- Article – Journal of Product Innovation Management: The Digital Transformation of Search and Recombination in the Innovation Function: Tensions and an Integrative Framework
- Podcast – Portfolio Management and the PDMA Body of Knowledge for Innovators and Product Managers
- Webcast – Product Innovation: When You Built It, But They Didn't Come: Improving Your Product Messaging
- Blog – Product Innovation Process: Appreciation for Cooper and Edgett's Stage-Gate® Process

kHUB provides a built-in, language-translation feature to support global access to its content.

Access the PDMA kHUB here.

INCOSE Announces New Fellows for 2021

The International Council on Systems Engineering (INCOSE) has announced its 2021 slate of INCOSE Fellows. INCOSE Fellows have made significant, verifiable contributions to the art and practice of systems engineering in industry, government, or academia. The award recognizes practitioners from government and industry applying knowledge and contributing to the systems engineering practice in designing and acquiring systems; researchers developing new knowledge, pushing the theory forward; and teachers disseminating knowledge and developing the next generation of successful systems engineers.

The 2021 INCOSE Fellows are:

- Guy-André Boy – For globally advancing Human-Systems Integration as a core part of systems engineering in industry and academia.
- Daniel A. DeLaurentis – For outstanding contributions to modeling and simulation methodology as well as design theory for systems of systems and complex aerospace vehicles.
- Eberhard Gill – For contributions to space systems engineering research and education.

- Neil G. Siegel – For significant contributions to the methodology and practice of developing and validating large-scale, complex military systems performance.
- Ram D. Sriram – For advancing theory, practice, and computational tools for designing complex engineered systems.

Kerry Lunney, INCOSE President, stated, "Becoming a Fellow of INCOSE is such a rewarding accomplishment and acknowledgement of your experience, influence and contribution to Systems Engineering. As an individual, you are being internationally recognized for your talent. Congratulations to our new Fellows! And rest assured, INCOSE will be reaching out to you to help fulfil our vision."

Learn more about INCOSE Fellows here.

INCOSE President Interviewed for *Create* Magazine, Ahead of Inaugural IPEC

The president of the International Council on Systems Engineering (INCOSE), Kerry Lunney, was interviewed for an article in the May edition of *create* magazine. The article, "How systems engineering is helping us navigate a complex world", previews her plenary address at the inaugural Integrated Project Engineering Congress (IPEC) in May.

Ms. Lunney's presentation at IPEC will discuss the "exciting and scary" problems engineers may face over the next 20 years, as well as some of the ideas and techniques needed to help tackle them. In the interview, she also expressed her hope that the engineering profession and the wider community will come to embrace systems thinking to navigate the changes in our world.

create magazine is produced by Engineers Australia, which was founded in 1919 as the Institution of Engineers Australia, to be the voice of the Australian engineering profession and to advance the science and practice of engineering for the benefit of the community.

Read the interview with Kerry Lunney here. Read more about the IPEC here in PPI SyEN.

INCOSE releases membership numbers

The latest membership statistics from the International Council on Systems Engineering:

- 18000+ members
- 3489 certified SE professionals
- 120 corporate members
- 74+ chapters worldwide
- 68 countries with active members
- 55 working groups

INCOSE is a not-for-profit membership organization, founded to develop and to disseminate the transdisciplinary principles and practices that enable the realization of successful systems. INCOSE connects systems-engineering professionals with educational, networking, and career-advancement opportunities in the interest of developing the global community of systems engineers.

VISION: A better world through a systems approach.

MISSION: To address complex societal and technical challenges by enabling, promoting, and advancing systems engineering and systems approaches.

See more information on INCOSE here.

New Capella MBSE Tool Add-on Aids ALM and RM

Publication for Capella is an add-on that provides integration between the model-based systems engineering (MBSE) workbench Capella and repositories (such as Polarion, Doors, Next, etc.) that are compliant with Open Services for Lifecycle Collaboration (OSLC). This enables connection of the user's system architecture in Capella to work items managed by Application Lifecycle Management (ALM) and Requirements Management (RM) tools.

Resulting benefits can include:

- Digital continuity, from requirements to architecture
- Better communication and collaboration
- Single & integrated sources of truth

Discover more about this add-on here.

Vitech Announces Release of GENESYS 2021 MBSE Development Tool

Vitech has announced the release of GENESYS 2021, its integrated, model-based systems-engineering (MBSE) software platform that covers all four domains of systems engineering — requirements, behavior, architecture, and verification & validation. Newly added features include entity-level inheritance, binding and extended fields for parameters, and enhanced visualizations and modern user experience.

Designed to facilitate collaborative teamwork, it provides modeling and simulation for products, system architectures, and systems of systems across their lifecycles. Parent company Zuken recently integrated Vitech's GENESYS into its global sales portfolio and consulting network.

Read the news release here.
Learn more about Zuken Vitech GENESYS here.

Update to Free SAIC Digital Engineering Validation Tool

The free SAIC Digital Engineering Validation Tool uses unique validation techniques to promote modeling consistency, thereby reducing errors, aiding analyses, and improving the quality and functionality of system models. SAIC hopes that community use of this tool will stimulate discussion and adoption of industry best-practices.

The recently released version 1.7 includes:

- 184 validation rules for MagicDraw and Cameo Enterprise Architecture
- 123 rules for IBM Rational Rhapsody
- Customizations for managing data-rights, conducting failure-analysis, etc.
- Model-based style guide
- Example system model (*Ranger* lunar probe)
- Explanatory videos

More information and free download here

Call for Papers: Special Issue of *IEEE Software* on Digital Twins

IEEE Software, a bimonthly, peer-reviewed magazine and scientific journal that is published by the Computer Society of the Institute of Electrical and Electronics Engineers (IEEE), is issuing a Call for Papers for a special issue for articles relating to any area of software-engineering approaches for digital twins. This includes, but is not limited to:

- Methodologies for the construction of digital twins:
  - Representing requirements and use-cases for digital twins
  - Articulating the business case and stakeholder-benefits for digital twins
- Quality-assurance techniques for digital twins:
  - Ensuring that simulations produce valid predictions or control systems in the correct way
  - Evaluating digital twins
  - Verification techniques for digital twins and the associated data
  - Security and privacy
- System architectures for digital twins:
  - Model Reference Adaptive Control used as the basis of digital twin engineering
  - Integrating digital twins with existing industrial approaches such as Industry 4.0
- Technologies for digital twins:
  - Programming language extensions to support digital twins
  - Libraries and platforms for digital twin construction

IEEE Software would welcome case studies and experience reports from industry that relate to the aspects listed above. Articles describing collaborations between academia and industry are particularly welcome.

Submission deadline: June 14, 2021

Access details and submission guidelines here.

GAPS PROGRESS REPORT RELEASED FOR ADDITIVE MANUFACTURING

America Makes and the American National Standards Institute (ANSI) announced today the availability of a Gaps Progress Report, tracking the efforts to address gaps that were identified in the Standardization Roadmap for Additive Manufacturing (version 2.0, June 2018), published by America Makes and the ANSI Additive Manufacturing Standardization Collaborative (AMSC).

The AMSC is a cross-sector coordinating body established in 2016, whose objective is to accelerate the development of industry-wide additive-manufacturing standards and specifications consistent with stakeholder needs. Its Standardization Roadmap for Additive Manufacturing, developed with contributions from more than 300 individuals from 175 public- and private-sector organizations, lists published standards, those being developed, and others that are needed to help grow the additive manufacturing industry. It identifies 93 gaps where no published standard or specification currently exists to respond to a particular industry need. The roadmap also flags 65 of these gaps as requiring pre-standardization research and development (R&D).

The gaps progress report was compiled by ANSI staff based on inputs from standards-development organizations (SDOs), subject-matter experts, alert mechanisms, and independent research. It lists newly published standards and new standards projects, alongside suggestions for future roadmap modifications. The report is not a consensus document but rather is intended to serve as an interim "living document" that will be maintained and periodically re-published until such time as the AMSC develops a next version of the standardization roadmap.

Read the original news-release here.

Download the Gaps Progress Report here.

Cooperative Agreement on Systems Engineering Signed in Eindhoven

Representatives from Holland Innovative, VDL Enabling Technologies Group, the Netherlands Organization (TNO-ESI, for applied scientific research), the High-Tech Systems Center of the Eindhoven University of Technology (HTSC), and Brainport Development have signed a cooperation agreement around the importance of systems engineering to the high-technology manufacturing industry in Brainport Eindhoven technology region.

During the ceremony at HTSC in April 2021, Wouter Leibbrandt of TNO-ESI explained the motivation behind the initiative: "If there is one thing that has become clear to us, it is the crucial role of system thinking and mastering system complexity as a fundament to be successful. We need to foster this competency." Naomie Verstraeten of Brainport Development further noted that systems engineering is the basis of the entire high-tech manufacturing industry, pulling together the various other technical knowledge and skills.

The initiative seeks involvement, cooperation, and coordination of all stakeholders in the ecosystem, from educational institutions to industry to governmental agencies. Its objective is to facilitate the continuation of growth of the regional high-tech industry.

Read the full announcement here.

> *"If you don't develop a strategy of your own, you become a part of someone else's strategy."*
>
> *Alvin Toffler*

Amentum Launches MBSE Collaboration Center near NSWC Crane

Amentum, a contractor to U.S. Federal and allied governments, announced the opening of its Model-Based Systems-Engineering (MBSE) Collaboration Center near the Naval Surface Warfare Center (NSWC) in Crane, Indiana.

The center creates new engineering capabilities to benefit the greater Department of Defense (DoD) customer base in the application and practice of MBSE and related digital tools. Training, certification, educational resources, and development and sharing of MBSE best practices are cornerstones of its offerings.

Located at Amentum' s Westgate II facility in Crane, the center was originally slated to open in 2020 but was delayed to accommodate post-COVID safety practices for the health of its employees and customers. It provides services onsite presently but will offer remote delivery in the future.

See more information on the center here.

"Long-term commitment to new learning and new philosophy is required of any management that seeks transformation. The timid and the fainthearted, and people that expect quick results, are doomed for disappointment."

Dr. W. Edwards Deming

PPI Announces Its Consultancy to Support Astronomy Project in the United States

PPI has won a contract to provide systems engineering and SE-PM-integration advice to a major client in the USA astronomy sector. This is PPI's second consultancy supporting an astronomy project, with its first being with a European client in relation to processes for system architecting.

PPI Sets Single-Day Registration Record

On May 8th, PPI set a new single-day record for registrations for PPI and CTI open courses. The registrations were from a wide variety of companies, sectors, and countries, reflecting the recognition of systems engineering as a path to excellence. As demand for corporate training is strong, so too is interest from individuals looking to advance their careers through the power of systems engineering.

For information on PPI's flagship Systems Engineering Five Day course, look here.

For information on CTI's INCOSE Systems Engineering Professional (SEP) Exam Preparation, look here.

CTI Expands Business in Asia

CTI is expanding the reach of its INCOSE SEP Exam Preparation training in Asia, with several new courses (in-house and public) taking place in China and India this year. CTI will share an updated public schedule, dedicated to the Asia region, before the end of May 2021.

This expansion is pursuant to CTI's goal of seeing a 10% increase in the number of certified Systems Engineering Professionals (SEPs) around the world in the next 12 months as a direct result of CTI training.

For more information on training to achieve SEP certification, in Asia or elsewhere in the world, please contact us.

CONFERENCES, MEETINGS & WEBINARS

Upcoming events of relevance to systems engineering

WEBINAR: Systemic Leadership and the Systems Thinking RoundTable

Wednesday, May 19, 2021 (11:00a–12:00p EDT)

Speaker: Dr. Sue Gabriele

Systemic leadership enhances current best leadership theory and practice with systems thinking. Systems thinkers better identify and use all the relevant information around them in their decision-making and action plans.

This webinar draws evidence and examples from general systems theory, engineering, education, management, and psychology. It differentiates material cause from human cause, and a Systems Thinking RoundTable demonstrates facilitation of free exchange of views among participants. It suggests how everyone can be more effective, satisfied, and appreciated, at work and in their daily lives.

Information and registration

WEB PRESENTATION: There Is No (Real) Systems Engineering Without Systems Thinking

Wednesday, May 19, 2021 (6:00 – 8:30 PM EDT)

Speaker: Zane Scott

Systems engineering is more than a process, a checklist, and some models – it needs a solid foundation of intentional systems thinking, without whose first principles one can walk through the steps yet miss the real rewards.

This webinar explores how systems thinking is a paradigm-shift, from the commonly held reductionist version of the scientific method, to a holistic perspective whose application can facilitate the full power of systems engineering.

Information and Registration

WEB PRESENTATION: INCOSE "Systems of Systems" Working Group Overview

Thursday, May 20, 2021 (6:30 – 8:45 PM CDT)

Speaker: Dr. Judith Dahmann

Increasingly, many capabilities are the product of systems of systems working together to create user value. Systems engineering is ever challenged to expand its perspective to broad, global, societal opportunities.

This webinar examines the origin, history, and resources of the INCOSE Systems of Systems Working Group (SoSWG), which was created to facilitate application of systems engineering to systems of systems.

Information and Registration

Institute of Industrial and Systems Engineers (IISE) Annual Conference & Expo

May 22-25, 2021 (Virtual event)

Keynote speakers: Nadine Sarter, Andres Medaglia, Walt Ehmer

Join leaders in the field, up-and-comers, and students to network, gather new ideas and learn about innovative tools and techniques.

Highlights for 2021 include:

- Special Q&A with Apple CEO, Tim Cook, who will receive the "Captains of Industry" Award
- Packed program with 700+ presentations, including COVID-era solutions
- Content available to attendees post-conference
- Live chat networking, including events that virtually replicate ballroom receptions
- Town halls, awards, competitions, and more

Information and Registration

Integrated Project Engineering Congress

May 26-28, 2021 (Virtual event)

The inaugural Integrated Project Engineering Congress (IPEC) co-locates RISK Conference 2021 and Project Controls Conference 2021 with the **Systems Engineering Test and Evaluation (SETE) Conference 2021**, which is sponsored by the Systems Engineering Society of Australia (SESA, affiliated with INCOSE) and of the International Test and Evaluation Association (ITEA). For 2021, this also includes INCOSE Sector 3's **Asia Oceania Systems Engineering Conference (AOSEC) 2021**.

All presentations will be delivered virtually. Attendees can participate live or on-demand.

Program and registration

IEEE Technology & Engineering Management Society Conference: Asia-Pacific

November 16-19, 2021 (Bangkok, Thailand)

June 1, 2021 – Call for Papers deadline

TEMSCON–ASPAC 2021 will focus on the challenges and practices of technology and innovation management in today's business environments, particularly in emerging markets. Topics include:

- Entrepreneurship and its ecosystem
- Business-model innovation in emerging markets
- New markets for entrepreneurs
- Technology and innovation management
- Engineering & Operations management
- New technology directions and challenges

View the Call for Papers

WEB PRESENTATION: Systems Thinking as it Applies to Systems Engineering

Wednesday, June 16, 2021 (6:00-8:30 PM EDT)

Speaker: Dr. Joseph Kasser

When systems thinking is applied to systems engineering, the artificial complexity is stripped away, the myths are identified for what they are, and systems thinking is shown to be a powerful tool that is used by many outstanding systems engineers.

This talk provides a perspective of systems engineering that is not often discussed, and it encourages thinking about systems engineering in new ways.

Information and Registration

VIRTUAL WORKSHOP: New Product Development (NPD) Processes

June 17 & 24 (8:30AM–12:00PM EDT/GMT-5:00)

Facilitator: Teresa Jurgens-Kowal, PhD

The Product Development Management Association (PDMA) is offering a virtual workshop that provides an overview of the most common NPD processes used in industry today, including waterfall, Agile, and emerging hybrid tools. Key takeaways include:

- Understanding degrees of risk in innovation
- Categorization of processes & frameworks
- Role of leaders in executing successful innovation projects

Information and Registration

CONFERENCE: International Conference on Axiomatic Design (ICAD 2021)

June 23-25, 2021 (Lisbon, Portugal & virtual)

Keynote speakers: Dominik Matt, Goran Putnik, Christopher Brown, Julia Seixas, John Thomas, Gabriele Arcidiacono

Axiomatic Design is a systems-design theory that uses matrix methods to systematically analyze the translation of customer needs into functional requirements, design parameters, and process variables. The method takes its name from the use of design principles, or design axioms, to govern the analysis and the design decision-making process in the development of high-quality products, processes, and other systems.

Information and Registration

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.

Highlights for 2021 include:

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

Information and Registration

XKCD

https://xkcd.com/2456/

SEE YOU THERE!

Project Performance International (PPI) will be a virtual exhibitor at the 31st Annual INCOSE International Symposium.

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	Turkey	8:00 TRT (UTC +3:00)	May 17-21, 2021
Systems Engineering	Saudi Arabia	8:00 AST (UTC +2:00)	May 17-21, 2021
Requirements, OCD & CONOPS in Military Capability Development	Europe	9:00 CEST (UTC +2:00)	May 17-21, 2021
Requirements, OCD & CONOPS in Military Capability Development	United Kingdom	8:00 BST (UTC +1:00)	May 17-21, 2021
Requirements, OCD & CONOPS in Military Capability Development	South Africa *[only]*	9:00 SAST (UTC +2:00)	May 17-21, 2021
Interface Engineering & Management	Europe	8:30 CEST (UTC +2:00)	May 18-19, 2021
Interface Engineering & Management	United Kingdom	7:30 BST (UTC +1:00)	May 18-19, 2021
Interface Engineering & Management	South Africa *[only]*	8:30 SAST (UTC +2:00)	May 18-19, 2021
Requirements Analysis and Specification Writing	Asia	6:00 SGT (UTC +8:00)	May 24-28, 2021
Requirements Analysis and Specification Writing	Oceania	8:00 AEST (UTC +10:00)	May 24-28, 2021
Requirements, OCD & CONOPS in Military Capability Development	Asia	6:00 SGT (UTC +8:00)	May 24-28, 2021
Requirements, OCD & CONOPS in Military Capability Development	Oceania	8:00 AEST (UTC +10:00)	May 24-28, 2021
Requirements Analysis and Specification Writing	Europe	9:00 CEST (UTC +2:00)	May 31 – June 4
Requirements Analysis and Specification Writing	United Kingdom	8:00 BST (UTC +1:00)	May 31 – June 4
Requirements Analysis and Specification Writing	South Africa *[only]*	9:00 SAST (UTC +2:00)	May 31 – June 4

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/.

Reconciling Enterprise Architecture and Systems Engineering

These two disciplines have both shared history and shared opportunity to improve the functioning of organizations.

By Thomas Manley

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Abstract: Enterprise architecture (EA) and systems engineering (SE) have similar history, but there is present-day inconsistency in their descriptions, associated job titles, and perceived relationship. Usage of the terms, "architecture" and "engineering" is widely variant and often ambiguous, further fueling uncertainty as to whether EA is "merely" a sub-discipline of SE. Side-by-side comparison of EA, SE, and project management (PM), aligned against a hierarchical model of an enterprise, reveals the fundamentally complementary nature of EA and SE. Combining EA and SE creates a conceptual methodology that leverages both to achieve desired transformation within the enterprise.

Introduction

The term, "architect" has emerged as a job title within the technology industry in recent decades, typically prepended with a descriptor that identifies either the object or the purpose of that architecture. There has been some confusion as to the actual meaning of these titles, as they are applied inconsistently, and their associated role descriptions vary greatly. Particularly, there is confusion surrounding the distinction between enterprise architects, enterprise engineers, and systems engineers. Is enterprise architecture a discipline or just a sub-discipline within systems engineering?

Etymologies and Geneologies

Architecture in the more traditional sense (the design of buildings and structures) has been around as a human activity since the end of the last ice age (and possibly before). The earliest known structures are the ruins of Göbekli Tepe in Turkey and date from around the 10th millennium BC. As we can see from Figure 1, the word, "architect" has its origin in the mid-16th century, from French *architecte*, from Italian *architetto*, via Latin from Greek *arkhitektōn*, from *arkhi-* (chief) + tektōn (builder). This suggests that the activities of architecture and engineering (at least of

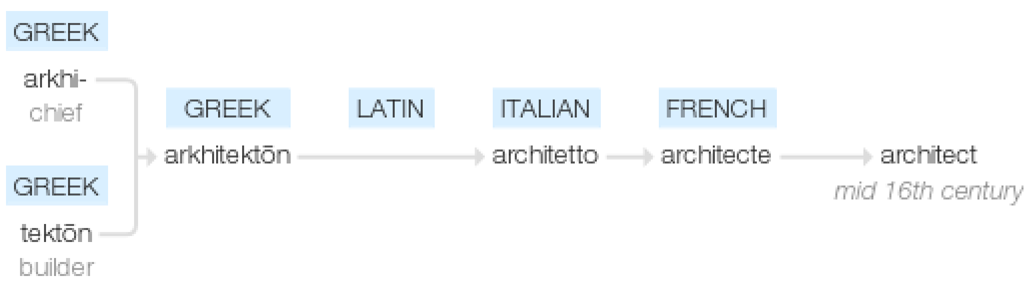

Figure 1: Etymology of "architect"

structures) were not originally distinct. For most of that time, the transfer of knowledge between people would have occurred mainly through verbal communication and demonstration rather than formal education.

The term, "engineer" has its origin in Middle English, denoting a designer and constructor of fortifications and of weapons (formerly also as *ingineer*). It derives from Old French *engigneor*, which derives from medieval Latin *ingeniator* (*ingeniare* = "to contrive or devise"; *ingenium* = "clever"). Engineering effectively separated from architecture when it became a profession around the 18th century.

As technology advanced, engineering branched into the several disciplines that are known today. Of those, systems engineering (SE) is relatively new. The term first appeared in Bell Telephone Laboratories in the 1940s; the first SE course began in 1950; and the first SE book was written in 1957 (Buede, 2016).

Meanwhile, the term, "system" was popularized in the rather specialized context of computing and software. The ANSI/IEEE Std 729-1983 *IEEE Standard Glossary of Software Engineering Terminology* (IEEE, 1983) defined system architecture as, "The structure and relationship among components of a system… may also include the system's interface with its operational environment." Similarly, the term, "architectural design" was defined as, "(1) The process of defining a collection of hardware and software components and their interfaces to establish a framework for the development of a computer system. (2) The result of the architectural design process." This suggests that the concept of architecture was already in common usage within the information-technology (IT) industry prior to 1983.

When John A. Zachman, often regarded as the father of enterprise architecture, published his *Framework for Enterprise Architecture* in 1987 (Urbaczewski, 2006), it was initially called the *Framework for Information Systems Architecture*. Zachman had worked in the marketing division of IBM since the 1960s, so it is not surprising that enterprise architecture (EA) emerged from the need to understand how to build information systems within organizations (The Open Group, 2015). Subsequently, the US Department of Defense's (DoD) *Command, Control, Communications, Computers, Intelligence, Reconnaissance, and Surveillance (C4ISR) Architecture Framework* (CAF) version 1.0 was released in 1996 (Blevins, 2010) – the precursor to Department of Defense Architecture Framework (DoDAF). Similarly, The Open Group Architecture Framework (TOGAF) was published in 1995, based upon the DoD's Technical Architecture Framework for Information Management (TAFIM) that was ultimately cancelled in favor of the DoDAF.

It's less clear where or when the concept of architecture came to be used in the context of systems engineering. Draft MIL STD-499A *Systems Engineering* (US DoD, 1994) defined functional and physical architecture as a "hierarchical arrangement" of "functions" and of "people, product, and process solutions". Therefore, at the least, the term, "architecture" has been in use within systems engineering for almost 30 years since 1994.

Types and Roles of Architecture

As might be expected when definitions of architecture vary over time and across present-day usage, there are multiple elaborations and specifications of what constitutes architecture.

Architecture is defined in ISO/IEC/IEEE 42020 *Software, Systems and Enterprise – Architecture Processes* as, "Fundamental concepts or properties of an entity in its environment and governing principles for the realization and evolution of this entity and its related life cycle processes." In this definition, the keyword is <entity>, as this provides contextual flexibility. Architectural entities are then the "thing being considered, described, discussed, studied or otherwise addressed during the architecting effort". This allows the term, "architecture" to be prepended with a contextual term of the forms (IEEE, 2019):

- *<entity> Architecture*, where <entity> = {enterprise, organization, solution, system, business, data, application, mission, product, service, software item, hardware item, network, information systems, technology, etc.}

- _<subject> architecture_, where <subject> = {security, functional, physical, execution, operational, etc.}
- _<purpose> architecture_, where <purpose> = {integration, coherence, design-control, reference, etc.}

Such a flexible construct contributes to the diverse ways in which the term, "architecture" is used in the definition and application of processes and of responsibilities.

For example, the US's Department of Defense Architecture Framework (DoDAF) V2.0 describes two major types or layers of architecture (US DoD, 2010):

Enterprise architecture: This defines the mission, the information, and technologies necessary to perform that mission, and the transitional processes for implementing new technologies in response to changing needs of that mission.

Solution architecture: This defines the elements (and their interrelationships) of a particular project to create, update, revise, or delete activities within the DoD. Essentially, this is a response to the problem-domain statement that was posed in an EA, and it is the most common architecture developed in the DoD.

These two layers of architecture within DoDAF correspond approximately to the three layers of The Open Group Architecture Framework (TOGAF):

Business architecture: A representation of holistic, multi-dimensional business views of capabilities, end-to-end value delivery, information, and organizational structure, as well as the relationships among these business views and strategies, products, policies, initiatives, and stakeholders.

Information-systems architecture: This includes:

- Data architecture: A description of the structure and interaction of the enterprise's major types and sources of data, logical data assets, physical data assets, and data management resources.
- Application architecture: A description of the structure and interaction of the applications as groups of capabilities that provide key business functions and manage the data assets.

Technology architecture: A description of the structure and interaction of the technology services and components.

As seen in Figure 2, the layers both of DoDAF and of TOGAF correspond approximately to the processes of ISO/IEC 15288:2015 *Systems and Software Engineering — System Life Cycle Processes* (IEEE, 2015). All three models take a somewhat deconstructive approach through successive hierarchical levels: understanding the problem at a particular level; crafting a solution for it that thereby becomes the problem to solve for the next level; and progressing recursively until the concrete, particular solution emerges at the end.

According to ISO/IEC 15288, the purpose of the architecture-definition process is, "to generate system architecture alternatives, to select one or more alternative(s) that frame stakeholder concerns and meet system requirements" – which would fall into the solution domain.

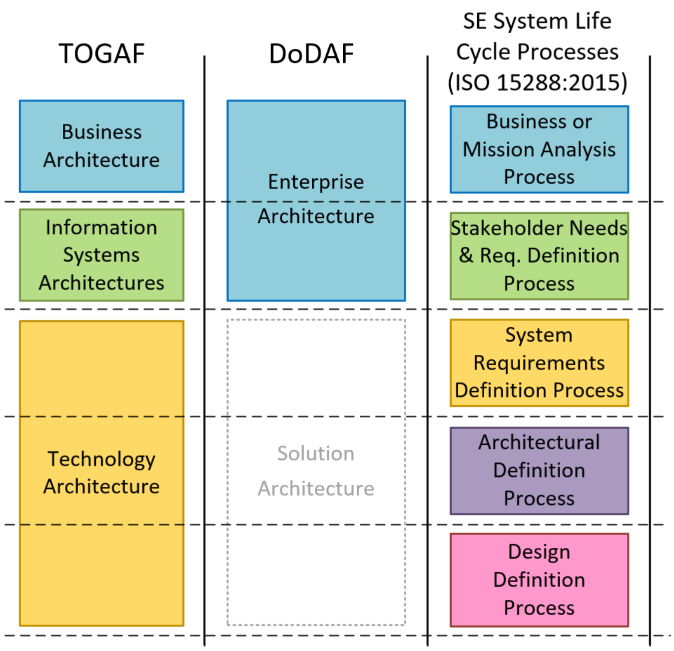

Figure 2: Comparing TOGAF, DoDAF, and ISO/IEC 15288:2015

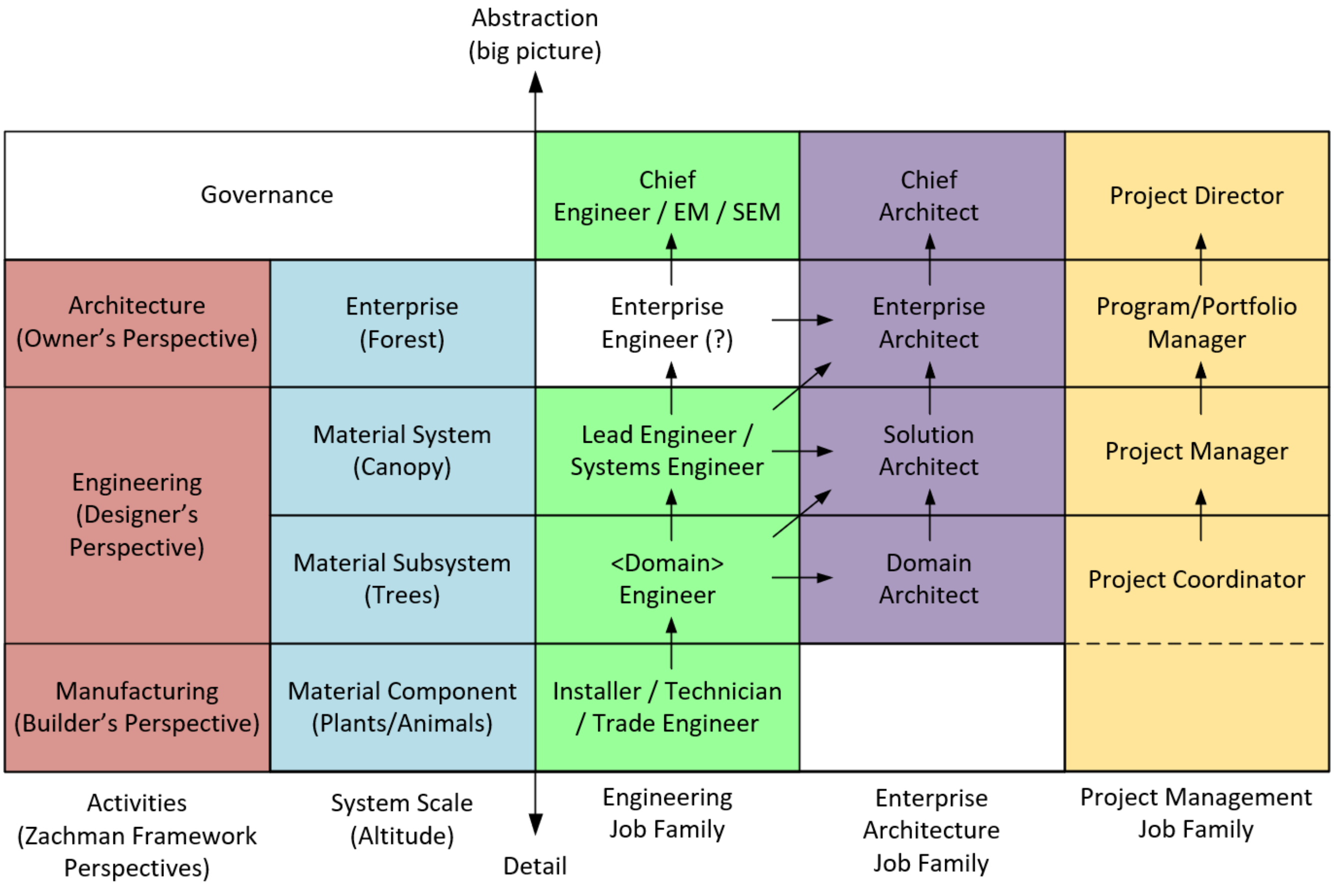

Figure 3: Comparing career hierarchy across multiple related job families

Comparing Career Progressions

Figure 3 aligns the progressions of some typical responsibilities within engineering, enterprise architecture, and project management – all against a system scale within the enterprise (using the forest analogy of "altitude") and correlated to the three distinct activities that were identified by Zachman (Zachman, 1987). These activities (and the corresponding perspectives that they capture) include:

- Architecture (owner's perspective)
- Engineering (designer's perspective)
- Manufacturing (builder's perspective)

In EA, at the entry level are domain architects who have specific "in-depth knowledge within the particular domain [such as collaboration] of their expertise" (Visual Paradigm, 2021). There exists a natural progression from their scope of responsibility to that of solution architects (who are multi-domain), to that of overall enterprise architects, and eventually to that of a chief architect who provides coordination and governance. (Note the use of "enterprise architecture" to represent both the discipline in general and the scope of one of several specific responsibilities within that discipline.)

Similarly, entry-level engineering jobs include installer, technician, or trade engineer, later progressing to a <domain> engineer (such as electrical engineer), then to either a lead engineer (domain-specific) or to a systems engineer (transdisciplinary), and finally to a chief engineer, engineering manager, or systems engineering manager (SEM).

For comparison, the project-management (PM) job family has project coordinators, project managers, program/portfolio managers, and project directors whose typical responsibilities encompass increasingly broad sections of the enterprise (roughly aligning to system scale).

While this model suggests that an "enterprise architect" might operate at a more strategic level than would an engineer within an enterprise, it leaves open the possibility of equally strategic "enterprise engineer" between the lead engineer and the chief engineer.

Comparing Focus

Clearly, the focus of enterprise architecture is the enterprise itself, and its work product is the macro architecture of the enterprise. However, the focus of systems engineering with respect to an enterprise is less obvious. When SE constitutes the design and development of systems (typically technology-based) within the enterprise, SE tends to be more technical and operational, while EA attends to the functional and strategic. However, if SE is undertaking the enterprise itself as the “system of interest”, EA and SE begin to merge. For this reason, there is overlap in the focus of these two practices, as seen in Figure 4.

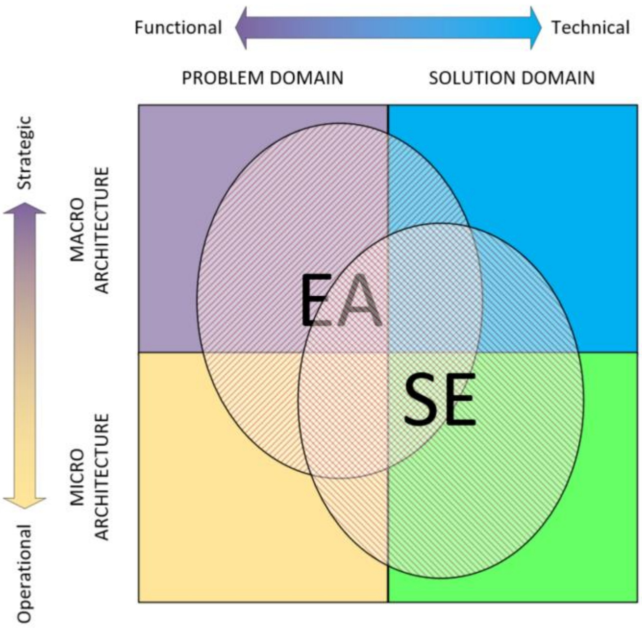

Figure 4: Relating EA to SE through quadrants

This synergy between EA and engineering (in the enterprise context) is evident in a 2015 interview with John A. Zachman, author of the Zachman Framework. “According to Zachman, Walker had figured out how to transcribe enterprise strategy in such a fashion that engineering work could be derived from it.” (The Open Group, 2015). This is a view that is shared by Bellman (2021): “EA is relevant in the initiation of transformation projects, which in turn are handed off to systems architects who in turn provide these models and descriptions to SE implementers”.

This suggests that, when seeking to transform an enterprise (or organization), application of a complementary combination of EA and SE may provide the most value. Initially, EA can assess the current state of business functions and applications, then perform capability-gap analysis against corporate strategy. In turn, this can generate candidate SE projects that could advance the enterprise towards its desired target state by creating or improving systems (technical or sociotechnical) within it. Figure 5 uses TOGAF to illustrate this process.

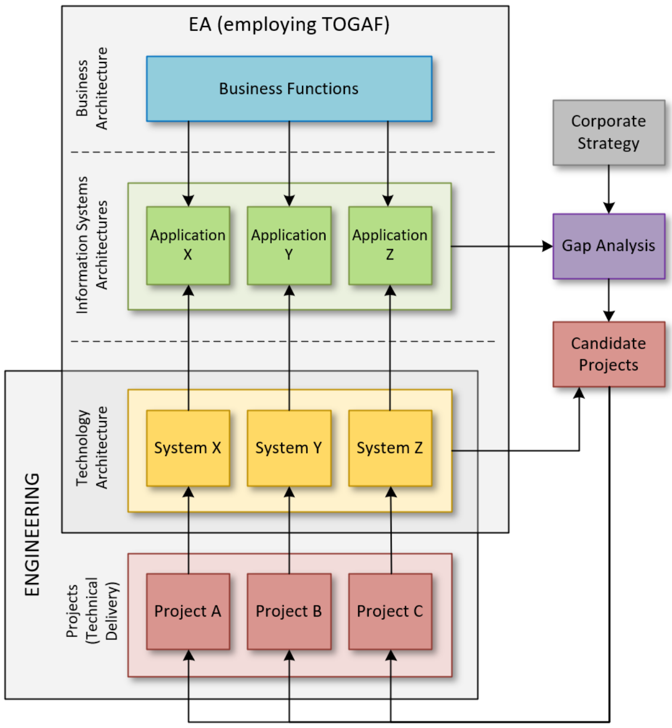

Figure 5: Sequential and complementary nature of enterprise architecture and systems engineering within an enterprise, with focus on technical projects

Of course, SE exists throughout the lifecycle of a system, from conceptualization to disposal, not just within the bounds of active projects. Additionally, systems are not required to be framed by the enterprise within which they exist (even if one can be identified). Similarly, projects do not require an EA activity to trigger their establishment.

Further, EA can be regarded as the application of SE when the system of interest happens to be an enterprise. This line of thinking supports the argument that EA is a sub-discipline of SE, or “an engineering method but applied at higher level of IT organization" (Ros, 2019); that is, the subset for which the system-of-interest happens to be an enterprise. Ros contends that enterprise architecture is a sub-discipline of enterprise engineering which is a sub-discipline of systems engineering. This is likely to be a hotly contested viewpoint, however, as many EA practitioners do not have a background in SE (Bellman, 2021).

Summary and Conclusions

In the context of an enterprise, SE typically (but not always) focuses on micro-architecture of a subsystem of an enterprise in the solution domain, while EA tends to focus on the macro-architecture of an enterprise itself in the problem domain. The two can function in a complementary and sequential manner: EA can identify candidate projects that, if funded, can trigger an SE body of work to deliver new or enhanced systems. Additionally, SE (or engineering more broadly) is not limited to the enterprise context, and systems engineers often can perform the role of an enterprise architect; the reverse is not necessarily true due to the technical nature of SE as an engineering discipline, particularly in the increasingly common case where professional accreditation is required.

There can be "name-space collision" between disciplines and job titles within them. It could be helpful to regard systems engineering more as a discipline than as a specific job title, role, or activity. Similarly, there is questionable value of using job titles of the form "<entity> architect", due to the present inconsistency of such usage and conflation with engineering-related job titles.

Ambiguous job titles tend to exacerbate the ongoing debate as to whether EA is a sub-discipline within SE or a discipline of its own. Since both their pasts and their futures seem inextricably intertwined, perhaps the debate on terminology and hierarchy can be set aside, to allow focus on the collaborative synergy of EA and SE in improving the effectiveness and the efficiency of enterprises and of organizations.

List of Acronyms Used in this Paper

Acronym	*Explanation*
C4ISR	Command, Control, Communications, Computers, Intelligence, Reconnaissance, and Surveillance
CAR	C4ISR Architecture Framework
DoD	Department of Defense (US)
DoDAF	DoD Architecture Framework
EA	Enterprise Architecture
PM	Project Management
SE	Systems Engineering
SEM	Systems Engineering Manager
TAFIM	Technical Architecture Framework for Information Management
TOGAF	The Open Group Architecture Framework

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FEEDBACK

What do you think: Is enterprise architecture (EA) effectively a sub-discipline within systems engineering (SE), or is EA an independent discipline?

Do you have further historical (or personal) perspectives into the early development of SE or EA, or into the adoption of the term, “architecture” within engineering and EA?

Let us know: PPISyEN@PPI-Int.com

Theoretical Foundations and Practical Application of Purposeful Human Activity Systems

Reframing organizations as complex systems enables a systems approach to identifying which methodologies to utilize for their design and management.

By Javier Calvo-Amodio

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Introduction

As our ability increases to engineer systems[(1)] that exhibit high degrees of complexity, it is imperative to increase equally our ability to design and to manage the organizations that support these complex systems throughout their lifecycles. Unfortunately, we have not consistently achieved balance of sophistication and robustness in our methods for engaging with those organizations. There are several challenges that makes this so:

- Complex engineered systems exhibit a high degree of variability (intentional or not) in their behaviors and processes, requiring the managing organizations to have even greater variability in their own responses. However, the changes to support such complexity in organizational design can be difficult to identify, making their costs difficult to assess and to justify.
- Typical multidimensional organizations are designed to support their core enterprise systems and processes, and those designs often lack the flexibility and adaptability to support multiple complex engineered systems, each with significant differences in resource requirements, lifecycles, etc.
- Complex organizations exhibit VUCA characteristics (volatility, uncertainty, complexity, and ambiguity) where physical and socially constructed elements interact.

There are various successful management methodologies, tools, and theories that can help us design and manage portions of these organizations. However, these solutions tend to be designed for specific contexts, problems, or subsets of organizational behaviors, and any one of them is unlikely to provide sufficient insight or efficacy across the organizational system as a whole to be effective in practice.

An accepted and successful approach to select and to integrate different methodologies in the pursuit of designing complex organizations can be found in critical systems thinking [1]. In it, Jackson proposes that one can engage with complexity using complementarily different approaches, systemic or not, through a critical awareness of the strengths and weaknesses of these approaches. However, in doing so, embracing a systems approach is key engaging with complexity successfully in organizations.

Theoretical Foundations of Purposeful Human Activity Systems

To embrace such a systems approach, I have proposed defining organizations as Purposeful Human Activity Systems (PHAS) [2, 3]. Such a definition invites systems engineers to take established models and methodologies from the engineering of complex systems, then to apply those to the organizations that support those systems. This can make it easier to identify which methodologies to utilize when designing and managing organizations. The following sections provide a brief overview on the foundational theories and concepts that inform a PHAS.

Human activity system: Vickers [4], and building from Vickers' work, Checkland [5], put forward that human systems differ from engineered systems, as they include people's complexities. However, it is possible to align (at least in part) people's experiences of complexity through the ways in which they know – appreciate – the system. (A limitation of this approach stems from the constructivist perspective [6] of Vickers and Checkland: a human activity system only exists in a person's mind as a model, and such an imaginary entity may or may interact with engineered systems.)

General scientific system principles: Rousseau [7] introduced these to present some of the most fundamental concepts about how and why systems emerge, transform, and evolve.

- The first principle, conservation of properties states, "emergent properties are exactly paid for by submerged ones". It captures the relationship between a system's emergent processes, behaviors, structures, and/or meanings; and its parts' submergence of their capabilities, boundaries, and significance, as stability of the newly emerging system is achieved [2].
- The second principle, universal interdependence states, "system properties represent a balance between bottom-up emergence and outside-in submergence". It acknowledges that systems are part of higher domain systems that condition their potential. In other words, the system's parts possess a determined potential to create an emergent system, but the higher domain system will determine how much of that potential can be realized.
- The third principle, complexity dominance states that the impact of submergence on a part is proportional to the variety differential between the part and the whole. In other words, it establishes that the balancing between a system's inherent emergence potential and its contextual suppression by the higher-order system is not always in equilibrium. Therefore, this principle encourages us to consider the significance of the difference between kinds of complexity and degrees of complexity systems have.

These principles provide deep insights about how and why systems emerge and interact with their environments; however, they are too general and abstract to be easily relatable in application.

Coordination, control, and agency in organizations: Beer introduced the viable system model: a cybernetics-management model composed of five specialized systems of functions [8], interacting via a two-dimensional control system composed of a vertical command system and a horizontal operational system [9]. The vertical command system and the horizontal control system provide the mechanisms through which the processes, structures, behaviors, and meanings in a system interact and are managed. The goal is to find the right balance between centralized control and flexibility at the operational level. The viable system model has proven to be powerful; however, its focus on exerting or maintaining control pays little attention to people and their effects on an organization.

INCOSE definitions of system: The INCOSE fellows conducted a project to propose fundamental system definitions (now adopted by INCOSE) [6, 10]. Those definitions include:

- In the most general sense, a system can be "a persistent region of low entropy (high organization) in physical or conceptual space-time. Then, it would follow that systemness is the phenomenon that allows regions of organization to persist in a dissipative universe" [10].
- In a SE general sense, a system "is an arrangement of parts or elements that together exhibit behavior or meaning that the individual constituents do not."
- The notion that systems can be physical (concrete(2)) and/or conceptual helps to

identify the persistent properties that emerge from physical and/or conceptual elements interactions.

Here we find key insights into what human activity systems can be: organizations are sociotechnical systems, composed of concrete (physical) elements that create persisting behaviors, and/or of conceptual elements that create persisting meanings. Therefore, an organizational system must be capable of creating persistent behaviors and meanings while maintaining its existent stable.

Categories and concepts of the human activity system: Rousseau, Billingham, and Calvo-Amodio [11] introduced an ontology (defined as a term-base) to assist the development of specialized systemic frameworks to organize knowledge about systems. From that concept-framework, Calvo-Amodio and Rousseau derived a human activity system concept-framework [2] as shown in Table 1, which can be used to perform an initial exploration of what a human activity system is and/or should be. A SE can use the information component questions to identify all relevant human activity system elements, whereas for a current state analysis or definition of future state human activity system elements. It is worth highlighting that in this framework, we can see that purpose appears in different inquiry domains, hinting at its importance in a human activity system.

A Purposeful Human Activity System

In accordance with Vickers and Checkland's views, a human activity system must have a shared experience of complexity, and as shown in Table 1 this can be achieved by sharing a purpose: something that will help people align interest and want to pursue success – typically the success of the complex engineered system throughout its lifecycle. As such, purpose shall not be separated from the concept of a human activity system: thus, the Purposeful Human Activity System terminology.

Table 1. Top Categories and Concepts of the Human Activity System Ontology Development (from [2])

General Inquiry Component	**Information Component Questions**	**Human Activity Systems Concepts**
Ontology of human activity systems	What are human activity systems? How can we recognize a human activity system?	Boundaries, relationships, process, context, perspective (weltanschauung), concrete, conceptual, parts/elements, structure, emergence, interdependence.
Metaphysics of human activity systems	What is the nature of a human activity system? What makes a system a human activity system?	Purpose, flexible, adaptive, collaborative, learning, appreciative.
Cosmology of human activity systems	How and why do human activity systems emerge and evolve? How and why are human activity systems organized? How and why do they change?	*Physical systems*, sapient systems, socio-technical systems, *Conceptual systems*, systems of systems, goal seeking, transitions (transformation), self-organization, evolution, stability.
Axiology of human activity systems	Why are human systems important to systems engineering practice? What makes a good human activity system?	Effective, efficient, efficacious, ecological, robust, resilient, agile, evolvable, coherent, productivity, external compatibility.
Praxeology of human activity systems	What is the purpose of a human activity system? How is its purpose achieved?	*Concrete purposes*: survival, competition, evolution, transformation, innovation, learning. *Conceptual purposes (meanings):* persuasion, motivation, anticipation.
Epistemology of human activity systems	How do we know a human activity system is successful? How can we obtain knowledge about human activity systems?	Models and principles; isomorphisms, system analysis, measure of success.

"A successful PHAS is a stable system with low entropy that maintains its progression along the best available to achieve its purpose. A PHAS will maintain homeorhesic control towards fulfilling its purpose while maintaining a homeostatic state when 1) its purpose is well understood by all stakeholders and 2) the required causal powers needed to conduct purposeful activities are present." [2]

Table 1 presents a means to identify relevant PHAS elements and/or concepts; however, it does not provide a means to establish their interrelationships in a coherent manner. To assist identifying how system elements interrelate, we propose a set of PHAS principles [2]. Table 2 introduces a set of relevant principles that define the essential aspects of a PHAS. In the table, I include examples of a generic purposeful human activity systems listing concepts, elements, behaviors and the nature of their potential interactions and their mapping to each principle.

Note that Table 1 and Table 2 can be modified, based on the concept map presented in [11] to represent the complex engineered system of the target as well. Doing this can facilitate matching (conceptually and in practice) the purposeful human activity system and the complex engineered system.

Brief Overview of Application in Practice

As an example, let us consider that a large engineering firm wins a contract for overseeing the lifecycle of a complex engineered system, and the program for that contract is added to the firm's portfolio of programs. How can the firm determine what changes are necessary, feasible, and desirable to accommodate the incremental demands of this new program?

Figure 1 illustrates the process:

- Build tables based on Table 1 and Table 2, guided by [2], to represent the organization (PHAS) in its present form.
- Build tables based on Table 1 and Table 2, guided by [11], to represent the target system of the new program.
- Conduct a gap analysis to identify systemic misalignments between the target system and the organization, based upon PHAS principles and Rousseau's 3 general scientific principles.
- Utilize critical systems thinking [1] to facilitate the identification and selection of the management methodologies that are most appropriate to enact the necessary changes to close the respective identified gaps, thereby to align the organization (PHAS) to the target system and therefore to integrate and manage the interactions between them.

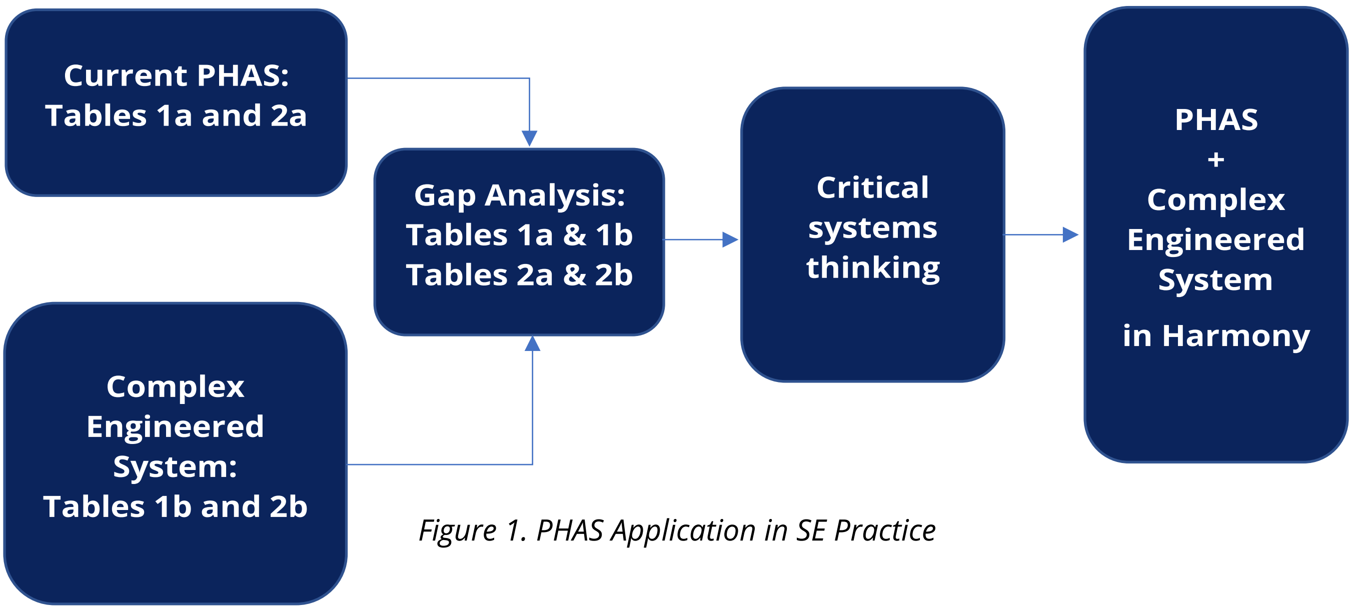

Figure 1. PHAS Application in SE Practice

Table 2. Purposeful Human Activity System Principles and Elements Interactions

Component: Relevant Principle	Concepts, Design Elements, Behaviors/Actions, and Interrelations
1. **System**: Human activity systems have parts	
1.1. The parts can be conceptual or concrete	*Concrete parts:* People, computers, software, furniture, whiteboards, etc. *Conceptual parts*: Beliefs, theories, perceived value of work, organizational culture, camaraderie, etc.
1.2. The parts interrelate to produce persistent structures, processes, and meanings of the purposeful human activity systems.	*Persistent structures*: computer vs. user interaction, user interfaces, office layout, furniture, etc. *Persistent processes*: communication, design process followed, decision making process, regulations, etc. *Persistent meanings*: perceived value of work, organizational culture, team camaraderie, theoretical foundations used, etc.
1.3. The parts interrelations are conditioned by the kind, capability, and structure of the purposeful human activity system.	*System kind*: in-person, interdisciplinary, multimedia environment (computer, whiteboards, etc.) *System capability*: level of expertise, technical knowledge, technology available, etc. *Parts interrelations*: social and concrete networks and communication channels
2. **Purpose**: Purposeful human activity systems exist to fulfill a purpose or a set of purposes.	*Purpose*: design a multipurpose and modular high-tech widget.
2.1. Purposeful human activity systems possess inherent causal powers to fulfill their purpose.	*Causal powers*: technology, knowledge, and design decision authority are present.
2.2. The purposeful human activity system design is commensurate with its purpose	*Commensurability of purpose*: Experienced engineers possess sufficient experience to make design decisions; technology provided assist decision making.
2.3. Purposeful human activity systems are aware of their purposes and pursue them intentionally.	*Purpose awareness*: purpose of team is communicated clearly and acknowledged by team.
3. **Boundary**: A purposeful human activity systems mediates its interactions with its environment through its boundary.	*Concrete boundaries*: beyond people involved; servers hosting software and data, office walls. *Conceptual boundaries*: repository of knowledge, organization team belongingness, etc.
3.1. A purposeful human activity system submerges to its environment.	*Submergence*: team members focus on task and role at hand. Other roles and tasks are formally suspended while working with team.
3.2. A purposeful human activity system influences its environment.	*Environment*: if modifications to decision making processes are found, experience engineers can enact changes in organizational procedures and regulations.
4. **Relationships**: Context and language modulate the relationships in a purposeful human activity system	
4.1. The magnitude and kind of the two-way relationships between the parts of the PHAS, purpose, and boundary vary according to the context.	*Context*: The organizational structure is a loosely coupled organic network, where each team possesses freedom and flexibility to organize and disband.
4.2. The magnitude and kind of the two-way relationships between the parts of the PHAS, purpose, and boundary are attenuated by the language used.	*Language*: being a transdisciplinary PHAS, members are not accustomed to each other's technical terminology, complicating effectiveness of interrelations between members, their boundaries, and pursue of purpose.

Conclusion

I have presented an overview of how a set of principles can be used to define organizations as purposeful human activity systems (PHAS). Such definition facilitates a systemic approach to gap analysis between an organization and the complex engineered systems that it seeks to design, cost, and manage. The results of such gap analysis can inform the selection of specific management methodologies that improve the capability of those organizations to support their complex engineered systems throughout their lifecycles in a principled way.

Endnotes

(1) For brevity and clarity when referring to systems, I am considering all levels of complexity, including systems of systems.

(2) I use “concrete” instead of “physical” to contrast “conceptual”, since not all elements that can be experienced in a PHAS are physical.

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About the author

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Culture, Structure, Learning, and Disappointment in Organizations as Systems

Process and technology form only a portion of these complex, adaptive, sociotechnical systems of systems.

By Kevin Nortrup

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Abstract: The complexity of modern organizations (and their products/services and environments) demands a systemic approach to their design, operation, and improvement. Failure to approach this complexity systemically is the root cause of most of the problems facing organizations today. A conceptual model of an organization is proposed, featuring five orthogonal elements – culture, structure, process, technology, and learning – that must be understood, approached, and managed as interdependent components of a complex, adaptive, sociotechnical system of systems. This model can be broadened, distilled, and simplified into a mindset and methodology that enables everyone throughout an organization to become agents for its continuous improvement.

Introduction

Practically everything about systems engineering, from conceptualization through decommissioning, happens within organizations. Purpose-driven, collaborative, human undertakings are the contexts and meta-systems that surround the design and utilization of systems of every type. However, it's difficult to avoid the conclusion that something is terribly, pervasively amiss with our modern corporate endeavors. A handful of recurring failure-mechanisms, in various guises and with situationally specific details, emerge time and time again across industries, markets, and sectors.

It's almost as if something were systemically malfunctioning in our organizations – as if we haven't acknowledged, designed, and operated them – as systems.

As William Donaldson writes in his book, *Simple_Complexity*:

I have commonly asked owners, managers, and board members if their company is a system. Invariably, they answer, "Yes, my company is a system." I then ask them if they have ever read about or studied systems thinking. The answer is almost invariably, "No." In my experience, they seem to grasp intuitively that their business is a system, but they have no language or models to guide their thinking.

Certainly, organizational improvement is not an unexplored frontier. A variety of disciplines can add substantial value as they grapple with understanding and improving organizations. However, with ever increasing complexity in everything that we undertake as human beings, most problems arise in the gaps, overlaps, and interfaces between the conceptual silos that we have erected.

In place of such a reductionist approach, we need a more holistic, integrated, systemic approach to understanding, designing, and improving organizations.

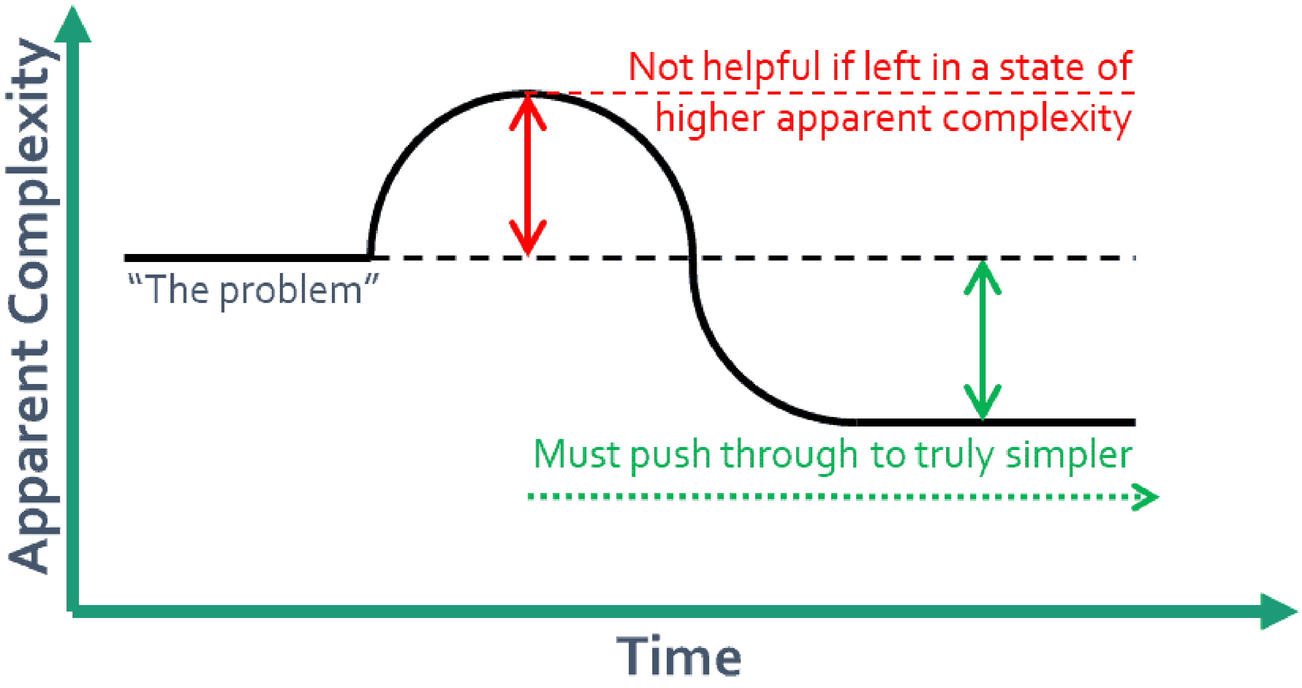

Figure 1. The equivalent of a thermodynamic diagram for complexity

Unfortunately, sometimes we systems people can get lost in the proverbial weeds of theory and artifice. The application of systems thinking, science, and/or engineering to a problem usually adds apparent complexity to it initially. Pushing through to a state of lesser complexity fulfills the promise of facilitation and justifies the application. However, too often, the perception (accurate or otherwise) of onlookers is that the net effect is greater complexity – not at all what is needed.

Figure 1 illustrates adding complexity to a problem, then either leaving it in a more complex state (not helpful to its solution) or working further to render it less complex (simpler and easier to solve).

As George Box is quoted as saying, "All models are wrong, but some are useful." Generally, the usefulness of a model is judged by how well it explains the past and present, predicts the future, and – perhaps most importantly – facilitates the desired. Good models allow practical theorists to equip theoretically-sound practitioners with effective mindsets and methodologies to think and to act systemically in performance of everyday responsibilities.

We need such models for organizations.

Background and Method

My academic and early industrial experience was with technological systems. When my (and others') technological endeavors began being thwarted by non-technical issues, I utilized my technical troubleshooting skills and sensibilities to investigate the phenomena. In the process, I came to realize that these issues were systemic symptoms of fundamental flaws in the design (or lack thereof) of companies.

Initially, my focus was on corporate reporting-structure. I saw parallels between its design and that of electronics, digital logic, and software – and I came to realize that, if most reporting-structures were submitted as engineering exercises, they would receive failing grades for fundamental design flaws. Gradually, additional experience and research encouraged the identification and inclusion of additional orthogonal elements into my model.

Still further experience and research brought the realization that companies are just part of the still larger family of organizations: purpose-driven, complex, adaptive, sociotechnical systems of systems that comprise people, processes, and technology. In addition to

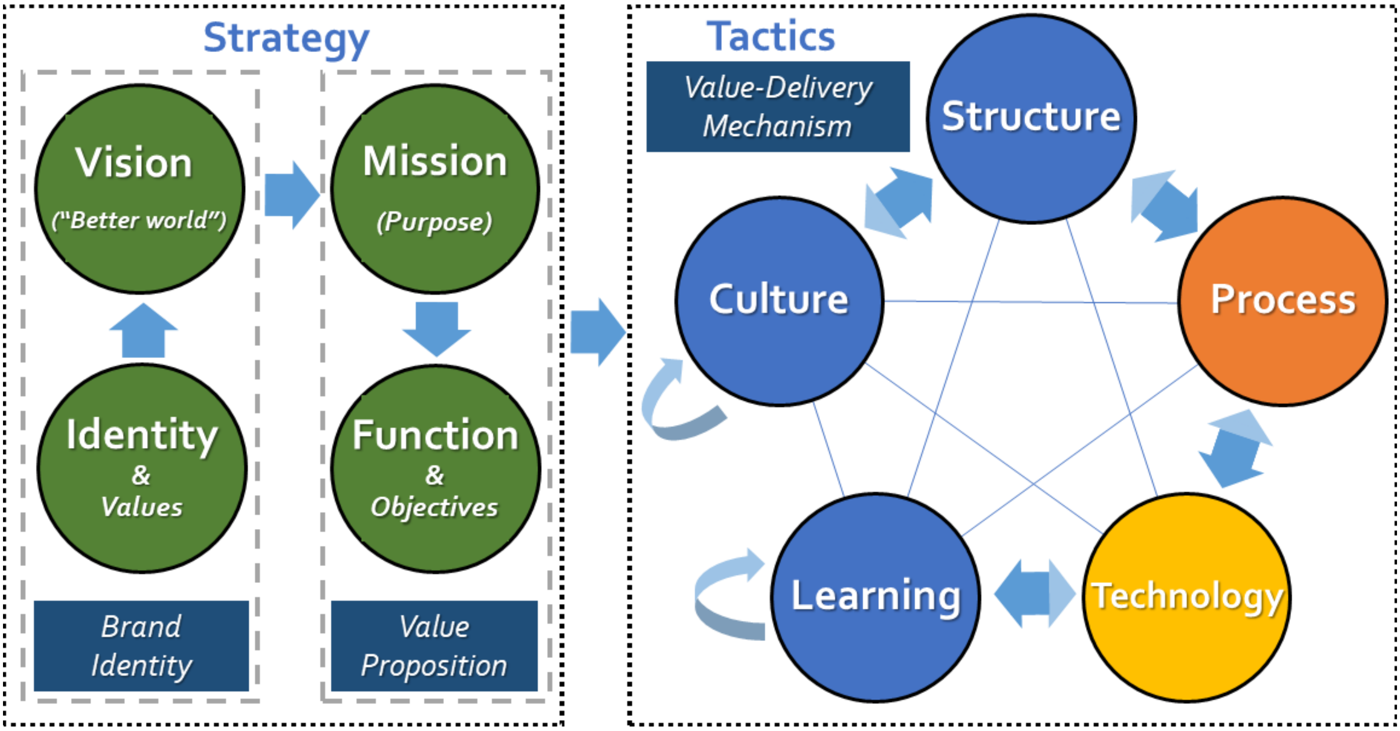

Figure 2: Top-level view of the proposed model for organizations as sociotechnical systems

companies, these include hospitals and other institutions, professional societies, hobby clubs – and, on a larger scale, industries, markets, societies, economies, and governments.

A Broader Model of Organizations

Figure 2 depicts the model that I'm currently favoring. The left-hand portion shows familiar elements of strategy; each drives the next.

- Identity specifies an organization's self-image and values.
- Vision articulates the organization's view of how the world could be a better place.
- Mission defines the organization's role in actualizing that better world, their purpose.
- Function describes the top-level activities by which the organization produces goods or services that accomplish their mission.

The strategic subsystem of the organization provides requirements and objectives that drive the design of the tactical subsystem, which essentially is the mechanism through which the organization delivers the value that its mission and function articulate.

The top-level elements of the value-delivery mechanism are organizational culture, structure, process, technology, and learning. Their proper individual operation and synergistic interoperation are essential to maximize the desired emergent behaviors of the larger system – performing its function and accomplishing its mission – while minimizing undesired emergent behaviors. It is important to appreciate the orthogonal nature of these elements when designing or troubleshooting an organization: for example, no amount of process-improvement can fully overcome toxic organizational culture, adversarial structure, unreliable technology, insufficient learning – or poor interoperation between them.

There is a natural cascade of influence and of prioritization, shown by the arrows in Figure 2.

- The strategy identifies the objectives to accomplish and the value to deliver, and it strongly influences the culture.
- Culture is the superset of actual corporate beliefs, values, and priorities -- which may not align with official or published policies. Culture is defined and communicated by the directions chosen, the decisions made, and the behaviors prohibited, tolerated, or rewarded. It establishes "balancing points" between pairs of values, such as: individual initiative versus directed effort; process flexibility versus strict methodology;

accountability versus forgiveness; etc. Beliefs create values, which establish priorities, which drive decisions, which result in actions, which form behaviors.
- Strategy and culture drive the structure, which is the fundamental division of labor: who does what, directed/coordinated by whom, dependent upon whom. As with software engineering, excellent or poor structure can make or break, respectively, an organization by how responsibilities are partitioned, balanced, and coordinated.
- Mission, culture, and structure drive the process (workflow), which is the familiar prescriptive description of the flow of data and work-product between operational steps; the operations and value-added that occur at each step; and the sequence and timing of those steps. Process should always serve culture and structure, not the other way around.
- Process drives the choices of technology and infrastructure (including the layout of workspaces, storage, and buildings, for examples). On rare occasion, process may need to accommodate innovative or legacy technology, but generally technology should empower people to perform specified process.
- Everything else informs the scope and nature of learning, some of which directly improves individuals' capability to perform their responsibilities within the structure and their contributions to the process – and some of which cultivates their personal growth, wellness, and capabilities in ways less directly tied to their work. (cf. Peter Senge's work on the "learning organization")

Although that natural cascade is initially in the sequence described above, it also reverses direction, working back and forth along the sequence, adjusting as needed to ensure that all elements are aligned and in order. This should be an important part of continuous improvement (monitor, assess, and adjust).

Illustration of the Model

"Alarm fatigue" is a healthcare phenomenon wherein caregivers become desensitized to alarms from patient-monitoring devices, due to the frequency (even omnipresence) of spurious alarms. Patients have died from the resulting inattention to genuine alarms. Such incidents are devasting not only to the patient's family but also to the hospital and caregivers.

It can be tempting to blame the individual caregivers as deficient. However, if one assumes that the caregivers genuinely want to take proper care of the patient, what else might have gone wrong? Looking at each of the organizational elements, where might the system have failed to make it easy to do "the right thing" while making it difficult to do "the wrong thing?"

- Does the technology have the necessary adjustability to accommodate the necessary range of patients and conditions? Is such capability a "must-have" of the purchase specification?
- Does process include: verifying incoming devices for proper adjustability of alarms; placing them into inventory with known, generally valid default settings; confirming and adjusting the specifically relevant alarm settings when placing the device into service for each and every patient; quickly investigating every alarm event as a potentially life-threatening emergency; and performing root-cause analysis and remediation for every false alarm?
- Does structure place people who receive, inventory, and service devices into a department separate from the clinicians, possibly with vague delineations of who has what responsibilities, or even with conflicting or adversarial objectives and metrics?
- Does culture tolerate, even cultivate, self-protective behaviors and sentiments, such as, "Yes, that's what it says we're supposed to do, but if we did that, it'd drive us crazy"?
- Does training clearly reinforce the cultural values and expectations, articulate the structural allocation of responsibilities, illustrate the mandatory steps in every process, and instill operational expertise in applicable technology? Does development

equip individuals with skills for coping with stress and for responding assertively, actively, and decisively to potential hazards?

- Should the strategic goals be amended to include the remediation of any above-mentioned issues?

An understanding of the organizational elements, their individual contributions, and their collective interoperation gives greater granularity and specificity, both to design and to troubleshooting.

Understanding Quality in a System

Quality management, process improvement, and similar disciplines have had demonstrable success in addressing emergent issues and increasing efficiency in mass-production systems. However, as those systems and their contexts grow in complexity, the disciplines and supplemental mechanisms that seek to manage and to improve those systems also become more complex – with growing risk of unintended consequences from such compounded complexity.

Furthermore, traditional quality-management and process-improvement efforts tend to focus upon imposition of external, compensatory structure by experts with specialized skill sets. Those specialists are often cloistered in separatist departments whose objectives and initiatives may not align with those of other departments. This can create adversarial objectives and "us-versus-them" atmosphere within the organization, often disenfranchising workers whose connectedness and motivation may already be limited by organizational silos and bureaucracy.

Many such efforts rely heavily upon episodic intervention after a (potentially significant) problem occurs, with insufficient emphasis on ongoing preventive cultivation, and with too many initiatives pursuing localized or irrelevant optimization. As Peter Drucker noted in *The Effective Executive*, "Efficiency is doing things right; effectiveness is doing the right things."

Much of current quality practice is not sustainable. Therefore, just as human healthcare is now shifting its emphasis from episodic intervention to organic prevention – from remediating disease to cultivating wellness – organizations must shift their focus from forcibly imposed quality to organically cultivated quality. As a confluence of people, process, and technology, an organization can be imagined as an artificial life form, and its immune system and capacity for self-healing must be cultivated and restored: everyone throughout the organization must accept distributed, contributory responsibility for continuous, organic improvement of quality.

Such a transition requires a simpler, more efficient, yet highly effective concept of quality. The traditional, quantitative concepts and methods of quality remain extremely powerful, but they are out of reach for most people in an organization. Figure 3 illustrates a qualitative concept of quality that applies easily and equally to any organization (or other system):

- Quality is the degree to which Experience meets or exceeds Expectations.
- Experience < Expectations : Disappointment (low quality)
- Experience >= Expectations : Satisfaction (high quality)

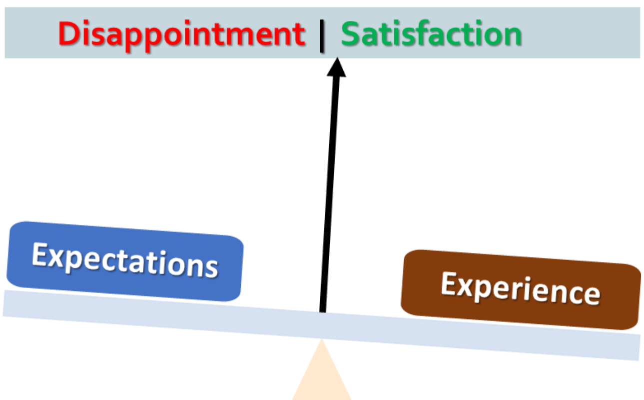

Figure 3. A conceptualization of qualitative quality

Improving quality can be accomplished by increasing (improving) experience and/or by decreasing (managing) expectations.

The power of this model becomes apparent in revisiting an organization as a system. At any interface between two nodes or elements – of any type, at any hierarchical level – there is some exchange of material or information: an event in one direction generates a response in the other. That response (experience) may or may not match the expectation (specification) (cf. "intended results" & "actual results" in process-control). See Figure 4.

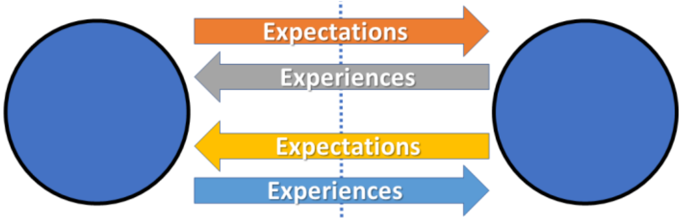

Figure 4. Expectations and experience at interface

In human interactions, disappointment occurs when experiences are less than expectations at any interface: between individuals; between an individual and a group (department, company, etc.); or between groups. This applies bi-directionally at every interface (external and internal): both parties have both expectations and experiences of the interaction's unfolding.

A customer's experience of "poor quality" may occur at the interface between the individual (customer) and the group (company) – but the cause of that disappointed expectation could originate at any interface deep within the organization – or even within the customer's own (perhaps unfounded) expectations. Furthermore, that triggering disappointment was likely caused, enabled, or foreshadowed by disappointment even earlier and elsewhere. As Peter Senge notes in one of his 11 Laws of the Fifth Discipline, the cascade of experiences not meeting expectations (poor quality) may have begun far away in time and space.

This understanding of quality both demands and facilitates a substantial shift in paradigm:

- "Quality" is not an esoteric alchemy with specialist wizards and separatist departments; instead, it is a cultural commitment that experience will meet or exceed expectations!
- A "Quality System" is not a department or process that imposes quality onto an otherwise deficient organization; instead, it is an organizational system of inherently high quality!

Harnessing Disappointment to Improve Quality

If quality is fundamentally inherent and distributed (rather than supplemental and localized), then the monitoring and remediation of potential threats to quality must also be inherent and distributed. A qualitative definition of quality – "ensuring that experiences meet or exceed expectations" – enables everyone throughout the system to have such ability.

Wherever and whenever experience falls short of expectations, the resulting disappointment serves as a "check-engine" light that invites investigation into a part of the organization whose proper operation is suddenly in question. Disappointment can be a valuable resource: it is an embryonic problem-statement. Harnessing disappointment can drive and fulfill the promise of continuous improvement, by utilizing everyone throughout the organization as agents of change.

This requires a cultural climate of trust, safety, and unity of purpose. The culture must value honest discussion, appreciative inquiry, root-cause analysis, continuous experimentation, ongoing adjustment and improvement, and the restoration of collegial professional relationships. The process must facilitate comfort in expressing and addressing disappointment, while acknowledging potential emotional implications and moderating potential drama. Leadership's objectives must include cultivation of open dialog and genuine responsiveness throughout the organization.

No disappointment is too trivial to investigate; it is better to "nip it in the bud" before it cascades into a significant quality problem or devolves into frustration, anger, or bitterness. Many instances of disappointment will be resolved simply between the individuals involved; some situations will require mediation by a facilitator or escalation to higher authorities; and larger systemic issues may require more extensive troubleshooting by a supplemental team.

Investigation into the disappointment can begin with an examination of expectations and experiences, perhaps with the guidance of a facilitator who can coach the process of seeking consensus between relevant parties.

Expectations

- Which elements of expectations are reasonable or have reasonable, alternatively achievable roots – and which need to be made more realistic?
- What causal chains led to expectations needing management, and how might those causal chains be addressed?

Experiences

- Which elements of perceived experiences are objectively accurate – and which need to be clarified or reconciled with reality?
- What causal chains led to perceptions needing adjustment, and how might those causal chains be addressed ?
- Which elements of actual experience were reasonable – and which legitimately need to be improved in the future?
- What causal chains led to experiences (results) needing to be improved, and how might those causal chains be addressed?

When investigating the causal chains that underlie needed improvement, examine each of the five tactical elements of the systems model (culture, structure, process, technology, learning) for potential contribution.

Reflections

Some might claim that science and engineering cannot deal with human beings as they would with hydraulic fluid or electrical current: people are highly complex, adaptive, variant, and even chaotic. However, people are not random: psychology, sociology, economics, game theory, and many other disciplines endeavor to characterize and to bound human behavior. Furthermore, the "certainty" of most science and engineering rests upon abstractions and assumptions that are invalid at deeper levels.

General Systems Theory initially sought to provide new models for human organizations, even as it recognized applicability to cybernetics long before the complexity of technology mandated systemic treatment. Inclusion of people as essential internal elements of "the system" (not merely as stakeholders or interfaces to it) is not only permissible but essential – a return to the foundations. Organizations are systems, and we disregard that reality at our own risk.

INCOSE has an Enterprise Systems Working Group (full disclosure: I'm presently chair) that undertakes to promote "Enterprise Systems Engineering." The reasoning is straightforward: an enterprise (for now, assume synonymous with "organization") is a sociotechnical system; and we should design, implement, and operate such systems with great care and intentionality, to maximize desired emergent characteristics and behaviors while minimizing undesired ones.

However, this terminology carries some semantic baggage. To many people, "Enterprise Systems" constitutes information technology for business, and "Systems Engineering" encompasses designing and administrating computer networks. To many other people, "Systems Engineering" is synonymous with massive technical projects in aerospace and defense. Therefore, as appropriate, intuitive, and attractive as its construction might be, "Enterprise Systems Engineering" battles public preconceptions.

I've recently been drawn to the label, "Organizational Engineering." It's nicely and concisely descriptive: the intentional, methodical design of organizations. It bypasses the preconceptions about "Enterprise Systems," "Systems Engineering," and even "systems" by avoiding such terminology.

Furthermore, I appreciate the commonality between "organization" and "organism." Although it is helpful to model an organization as a system, I also find useful parallels when modeling it as an artificial life form: it has a technical component that must be intentionally designed and an organic component that must be intentionally cultivated.

Summary

Organizations are man-made, complex, adaptive sociotechnical systems of people, process, and technology. We should design, implement, and operate them with great care and intentionality, as systems – thereby maximizing their desired emergent characteristics and behaviors, while minimizing undesired ones.

The proposed model establishes organizational culture, structure, process, technology, and learning as elements of such systems. These provide a series of lenses through which to perform design and troubleshooting. Within this systemic context, a qualitative definition of quality allows every individual throughout the organization to be an agent of its positive change, by harnessing their disappointment to investigate and to remediate the early roots of potential quality issues.

An organization is the pattern through which we accomplish almost anything of importance: not just processes and products of systems engineering, but the fruits of any purpose-driven, collaborative, human undertaking. When we fail to design and operate organizations skillfully and deliberately as sociotechnical systems – when we fail in their care and feeding as artificial life forms – we jeopardize the effectiveness, efficiency, sustainability, scalability, reliability, and resilience of our endeavors. We need discussion, collaboration, and coalescence of organizational initiatives into a holistic approach to cultivate healthy organizations – and that is what the proposed model aspires to do.

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Technical Leadership: Essential to Effective Systems Engineering

In addition to following methodologies and processes, systems engineering often requires building consensus and collaboration toward technical goals.

By Don S. Gelosh

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An Overview of Technical Leadership

Systems engineering doesn't take place in a vacuum. From eliciting and prioritizing stakeholder requirements, to coordinating and integrating the work-products of others, systems engineering often requires the ability to motivate a group of people to act toward achieving a common goal that involves technology. This combination of leadership skills and technical expertise is technical leadership.

The International Council on Systems Engineering (INCOSE) asserts in their *Vision 2025* (INCOSE 2014), "The technical leadership role of the systems engineer on a project will be well established as critical to the success of a project." Accordingly, the INCOSE Institute for Technical Leadership developed a model (Godfrey, 2016) that identifies six interrelated capabilities that technical leaders must master to successfully lead through influence. Each capability, described below, includes a question that technical leaders should ask themselves continually as they seek to lead.

Holding the Vision – A vision is an aspirational statement that defines who we are and where we want to go. It provides an impelling purpose that energizes people to do more than they thought they could or would. To accomplish this, however, a vision must be more than just a statement posted on the wall; it must be the start of a continual and ongoing conversation that systems engineers are well positioned to support, reinforce, and encourage.

Question for technical leaders: "What outcome are we striving to achieve, and how is what I am doing right now advancing that vision?"

Thinking Strategically – Strategic thinking is long-term thinking, rather than short-term, tactical thinking. It must be continuous and ongoing, not a one-time, up-front event. Technical leaders formulate a hypothesis before acting, treat the action as an experiment to test their hypothesis, and based on the results they observe, continue along the path they are on or formulate a new hypothesis and begin the testing anew. This is the scientific method applied to everything technical leaders do.

Question for technical leaders: "What patterns are emerging as a result of my actions, and what are the implications for what I should do next?"

Fostering Collaboration – Complex problems cannot be solved by individuals working alone; their solution requires the efforts of many. Individual contributions must be woven together into a collective enterprise for which success means success of the whole, not just of any individual part. This enterprise represents a vast social network, and systems engineers play a vital role in building, maintaining, and strengthening these networks. The goal should be to foster not just tradeoffs that compromise between competing alternatives, but collaboration that allows new ideas to emerge through creative conflict and experimentation.

Question for technical leaders: “What relationships am I building today for myself and for others?”

Communicating Effectively – Technical leaders must be able to write, speak, and present effectively, learning and using the language of those whom they seek to influence. However, truly effective communication strives first to understand, then to be understood; therefore, good technical leaders strive to improve their “receivers” as well as their “transmitters”. Active listening requires attention both to the content that is being spoken and to its context of intonation, timing, and body language, then offers verifying feedback in the form of accurate paraphrasing of what was said.

Question for technical leaders: “Whom am I trying to influence, and how do they describe their greatest challenge?”

Enabling Others to Succeed – Since systems engineers must most often lead through influence, the outcomes they seek to achieve will necessarily be accomplished by others. The leader’s role is to influence, guide, encourage, and support those who produce those outcomes. This requires a sense of humility and a deep respect for the people they seek to lead. Technical leaders must trust the abilities of others and their capacity to learn through discovery, not just through lecture. The leader’s success will derive from their success and from their acknowledgement that the leader facilitated it.

Question for technical leaders: “What obstacles are preventing others from acting, and how can I help to remove those obstacles?”

Demonstrating Emotional Intelligence – Emotional intelligence is the capability to recognize one’s own emotions and those of others, to use emotional information to guide thinking and behavior, and to adjust emotions to adapt to environments. To lead others, technical leaders must first understand themselves and where their expectations, assumptions, and mental models may differ from those of others. If they fail to recognize and to address those differences, they risk talking past others or having their input rejected completely. Leaders must continually seek feedback to decrease their blind spots, and they must be willing to reveal things that help others know them better. While such openness might make them uncomfortably vulnerable, the payoff will be well worth the effort.

Question for technical leaders: “What am I afraid of admitting to others, and how might disclosing it improve our relationship?”

The Impact of Technical Leadership

The whole of technical leadership is more than just the sum of leadership skills and technical expertise. All systems engineering activities can benefit from the synergy of these skillsets.

Effective systems engineering requires effective teamwork, with everyone understanding their current deliverables as well as the vision, long-term objectives, and overall strategy for the project. Such teamwork is facilitated when the technical leader holds the vision for the project, thinks strategically about its execution, and coordinates that execution through effective communication that demonstrates emotional intelligence – all within the framework of understanding the technical requirements, processes, and deliverables. This, in turn, fosters better relationships, communication, and collaboration among team members, enabling everyone on the team (and the project itself) to succeed.

INCOSE *Vision 2025* (INCOSE 2014) states, “Systems engineers need to be well versed in a broad set of socio-technical and leadership skills, serving as a central, multi-disciplinary focal point for systems development with stakeholders from all walks of life.” Further, the INCOSE *Systems Engineering Competency Framework* (INCOSE, 2018) describes 36 competencies across five major categories: Core, Technical, Management, Integrating, and Professional. The Professional category of competencies, which was not included in previous versions of the framework, is of particular importance to the technical leader (Gelosh, 2017). This category recognizes that effective systems engineering requires skills such as communications, ethics, leadership, negotiation, team dynamics, facilitation, emotional intelligence, and mentoring.

The skills and competencies of technical leadership should be understood as essential for all systems engineers. The Professional Competencies at its core serve as guides to working more effectively with people in any systems-engineering activity, even when one is not in a designated position of leadership.

As with most engineering capabilities, technical leadership requires a balanced combination of theory and practice to be most effective. Learning theoretical underpinnings is an important first step, but experiential practice is essential to full mastery and benefits. After studying a book, attending a workshop, or taking a course, one must actively pursue opportunities to put new knowledge and skills into action. It is also important to seek feedback from others, especially from mentors who can accelerate the learning curve and help to minimize missteps along the way.

Conclusion

Systems engineers must be life-long learners, with a continuous cycle of identifying a need in their skillset, learning the theory behind a new skill, developing the practice to implement it, and receiving and incorporating feedback for refinement. This process works for leadership skills as well as for technical expertise, and the two naturally complement each other in pursuit of effective systems-engineering outcomes. A true technical leader continually hones both.

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SYSTEMS ENGINEERING SAMPLER

Selected examples of systems engineering in theory and in practice

WEBINAR: How Can a Systems Approach Help Critical Civil Infrastructure Become Smarter, More Sustainable and Resilient?

On April 28th, 2021, the Systems Engineering Research Center (SERC) hosted a webinar that highlighted the necessity of systems thinking to address the challenges faced by modern cities in providing sustainable and resilient infrastructure, as part of their SERC TALKS series.

Michael Salvato, Vice President, Infrastructure Advisory Practices at Mott MacDonald, emphasized the need for cities to reimagine the infrastructure services that they provide and to design deeply interconnected technological, social, and environmental systems to do so. Salvato promoted the movement toward a set of capabilities known as "Infrastructure 4.0", comprising not just physical assets and digital twins but also an interconnected web of social, institutional, and ecological systems. Such emerging socio-technological systems will require a synthesis across traditional disciplines of engineering, information technology, environmental science, and policy.

Some quotes highlight Salvato's themes:

"The challenges and opportunities of the Anthropocene (Human age) are complex, systemic and interdependent."

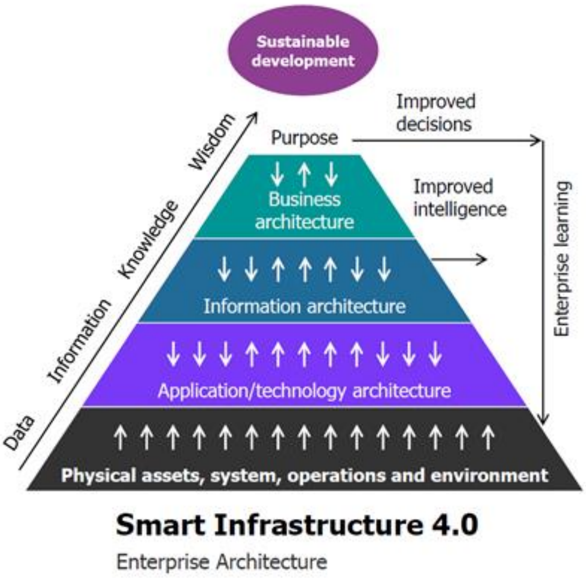
"One of the ways to look at the world is as a series of systems within systems within systems."

"Sustainability and resilience are emergent properties of a complex and dynamic socio-technical system that includes both hard and soft infrastructure in a symbiotic relationship with its environment."

"A smart, sustainable city is an innovative city that uses Information and Communications Technologies (ICT) and other means to improve quality of life, efficiency of urban operation and services, and competitiveness… while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental as well as cultural aspects."

"Smart infrastructure is a cyber-physical system that responds intelligently to changes in its environment, with the ability to influence and direct its own delivery, use, maintenance and support."

Salvato proposed a multi-layered enterprise architecture for Smart Infrastructure 4.0 that could be used to align physical assets, technology, information, and business models to achieve a common purpose, sustainable development:



Download the presentation here.

View the recording here.

VIRTUAL CONFERENCE: 14th Annual INCOSE Americas North-Central and Great Lakes Regional Conference (NC-GLRC14)

The twelve chapters of the Americas Sector North (North-Central and Great Lakes) Region of the International Council on System Engineering (INCOSE) conducted the 14th Annual INCOSE North-Central and Great Lakes Regional Conference (NC-GLRC14) as an all-virtual event, spread across portions of several days from April 9th through April 17th, 2021.

This year's NC-GLRC, hosted by the INCOSE Michigan Chapter, included more than 40 presentations and tutorials. Notable topics included: "Outcome: Rules-Based Training Development for System Modelers", by Michael Vinarcik; "Unlimited Potential: Leveraging the Power of Mind in Design", by Randall C. Iliff; "Risk in International Standards", by Paul Heininger; "'There is No Such Thing as Non-model-based Systems Engineering", by Zane Scott; and "Critical Soft Skills and Systems Engineers", by Rick Hefner. Additionally, there were several café sessions and the premiere of a student-career fair that enabled students to connect with showcased companies.

The previously planned hybrid event (in-person + virtual) at the Historic Westin Book Cadillac (Marriott Detroit) Luxury Hotel, downtown Detroit, Michigan is being rescheduled for a later date, currently planned for October 4th through the 8th, pending COVID restrictions.

For more information on both completed and upcoming events for the NC-GLRC, see here.

WEBINAR: What PMI and INCOSE are doing to advance the Future of PM-SE Integration

On April 21st, 2021, the International Council on System Engineering (INCOSE) and the Project Management Institute (PMI) described past and present activities within – and collaboration between – the two organizations. The INCOSE PM-SE Integration Working Group presented how it identifies and promotes opportunities for effective integration of the disciplines and their respective communities. A closing panel discussion explored how INCOSE and PMI could work together more closely, toward the shared objectives of equipping the designers of tomorrow with the interdisciplinary power skills for successful execution of complex engineering projects.

Download the presentation here.

View the recording here.

WEBINAR: What Does Digital Transformation Look Like from the C-Suite?

On February 24, 2021, the Systems Engineering Research Center (SERC) hosted a presentation by Dr. William (Willy) Donaldson, Assistant Professor and Director, Biotechnology and Management Program, and Director of the Luter Business Institute at Christopher Newport University. In his presentation, Dr. Donaldson noted that the inherent difficulties in digital transformation are often exacerbated by systematic resistance from the enterprise itself, because transformation means change – and change rarely happens easily.

Dr. Donaldson suggested that many of the fundamental processes and perspectives in the "C-Suite" may be systematic without being systemic. Digital transformation often requires addressing and changing an enterprise culture, developed over time, that tends to fear change, preserve siloes, and seek solutions that are locally acceptable but not systemically optimal.

See more information & download slides here.

WEBINAR: Systems Thinking: A Foundation for Product Development

On January 19, 2021, the Heartland (Iowa) Chapter of International Council on System Engineering (INCOSE) hosted a presentation by Dr. Rick Hefner, Program Director of the Caltech Center for Technology and Management Education, that emphasized the critical importance of understanding the systems that surround and underlie a product as an essential foundation for its development.

Systems thinking both compels and enables us to delve beneath the surface of events into the progressively bigger pictures of patterns of behavior, systemic structure, and mental models. Hierarchy, complexity, and emergent behavior from interrelating parts are essential to understanding how systems work over time and within the context of larger systems. Such perspective considers the impact from and upon the proposed product in much broader context, allowing developers to make better decisions earlier in the development lifecycle.

Download the presentation here.

View the recording here.

ARTICLE & PAPER: A Systems Approach to Infrastructure Delivery

In March 2020, the Institution of Civil Engineers (ICE) commissioned an investigation into why so many major infrastructure projects run over time and budget, often failing to deliver their intended outcomes for the owner and for society.

That review identified the need for a system approach: starting with the desired outcomes and working backwards from there; assessing all the interdependent elements and influences that must be successfully combined and managed to achieve the desired result; and then setting up the needed governance and processes to achieve those outcomes.

Andrew McNaughton, chair of the review, observes that modern infrastructure projects are quite complex, that infrastructure must plug into existing networks and ecosystems and cope with the rapid rate of technological developments. He further notes, “If we, as civil engineers, do not step up to the plate, we may find other professionals taking the lead... Other sectors have successfully adapted to this new paradigm. We must cast our net wide and steal with pride from them.”

Read the article here.

Download the commissioned review here.

Industrial and Systems Engineering Body of Knowledge (ISEBoK)

Compiled by the Institute of Industrial and Systems Engineers (IISE), the Industrial and Systems Engineering Body of Knowledge (ISEBoK) is a repository and taxonomy of essential concepts in industrial and systems engineering (ISE). Each of the fourteen knowledge areas includes an outline that defines what needs to be known to achieve a mastery in the field of ISE and a list of references and resources to obtain that mastery.

The fourteen knowledge areas include:

- Work Design & Measurement
- Operations Research & Analysis
- Engineering Economic Analysis
- Facilities Engineering & Energy Management
- Quality & Reliability Engineering
- Ergonomics & Human Factors
- Operations Engineering & Management
- Supply Chain Management
- Engineering Management
- Safety
- Information Engineering
- Design and Manufacturing Engineering
- Product Design & Development
- System Design & Engineering

Read more information and download the ISEBoK here.

GUIDE: US DOD Mission Engineering Guide Provides Framework for Work With Industry

The United States Department of Defense (DOD) is emphasizing the use of mission engineering (ME) to ensure that the department is identifying and pursuing the right set of capabilities, developing the right requirements, and prototyping and acquiring the right systems or technology. To provide practitioners within the DOD and within the industrial base a firm understanding of the main attributes, methodology and lexicon associated with ME, the department published the "DOD Mission Engineering Guide." The goal was to develop a methodological but tailorable ME process to assist users, both novice and experts, in formulating problem statements, characterizing missions, identifying mission metrics, and using models to analyze missions. This guide:

- Describes Mission Engineering as the technical sub-element of mission-integration management that provides engineering products to inform the requirements process, guide prototypes, provide design options and inform investment decisions
- Offers an understanding of the main principles involved in performing analysis within a mission context
- Establishes a standard set of ME terms and definitions to enable a more coherent and effective conversation
- Makes it easier for the industry and the department to communicate and collaborate across ME efforts, by providing users with a set of products to document and to portray results that guide, constrain, and inform capability and technology development

Read more information and download the "DOD Mission Engineering Guide" here.

SERC/INCOSE/NDIA MBSE MATURITY SURVEY

In 2019-2020, the National Defense Industrial Association – Systems Engineering Division (NDIA-SED) and the International Council on Systems Engineering (INCOSE) collaborated with the Systems Engineering Research Center (SERC) at the Stevens Institute of Technology to benchmark the current state of Digital Engineering (DE) and Model-Based Systems Engineering (MBSE) across government, industry, and academia. The team surveyed the systems-engineering community to assess the maturity of system engineering's "digital transformation," to identify specific benefits of MBSE and associated metrics, to identify enablers and obstacles to DE and MBSE adoption across the enterprise, and to understand evolving and necessary shifts in the systems engineering (SE) workforce. Reports from the results of that survey include:

- SERC-2020-SR-001 report: "Benchmarking the Benefits and Current Maturity of Model-Based Systems Engineering across the Enterprise," indexes the findings drawn from the MBSE Maturity Survey.
- The SERC-2020-SR-003 Summary Report on Digital Engineering Metrics focuses in on how organizations can categorize and measure Digital Engineering change. This report was developed from the survey data and additional research on enterprise change measurement.
- The SERC-2020-TR-002 Digital Engineering Metrics full research report includes the background research completed in support of the survey data analysis and the metrics recommendations.

Read about the project and its reports here.

PAPER: Practical Suggestions to Successfully Adopt the CMMI V2.0 Development for Better Process, Performance, and Products

Author: Mustafa Degerli

Presented at: 5th International Conference on Computer Science and Engineering (UBMK) – October 2020

The Capability Maturity Model Integration (CMMI) enables organizations to measure their development capabilities, thereby facilitating improvement and risk-reduction in their system-development processes. The CMMI Institute released version 2.0 in 2018, including changes that improve its accessibility and effectiveness for businesses in any industry.

This paper shares the relevant experiences of one organization's journey to adopt the new version of the model. It addresses practice areas that are new or significantly changed, and it details both a transition-plan template and a novel gap-analysis template to facilitate compliance. Its documentation may help other organizations in their own transition.

Read more and access the paper here.

ON-LINE BOOK: In The Loop: Leadership in the Fit Systems Enterprise

In today's world of volatility, uncertainty, chaos, and ambiguity (VUCA), the winners will be separated from the losers by their relative digital leverage. This new reality mandates a new paradigm of enterprise leadership, one with two core objectives: to generate new value continuously, just to stay even against a world of constant change and rising competitors; and to make the enterprise more adaptive, more resilient, more scalable, and more efficient.

Systems principles apply to all systems, including businesses and the ecosystems in which they operate. Just as digital technology and systems are driven by feedback loops, the leader of a successful digital enterprise must be a systems thinker and must learn to find, build, track, and act upon feedback loops throughout the enterprise and its ecosystem.

Leaders can't just work *within* their systems; they must also work *on* those systems, to equip those systems with the needed capabilities. This requires a deep, holistic understanding of the ways technology, people, workflows, and money interact inside the system. Technical systems are just components of socio-technical systems; they must serve their larger purposes.

Survey the book's chapters and read it here.

WIKI: INCOSE UK Model-Based Systems Engineering Wiki

This wiki includes the mission statements and activities of the INCOSE UK's MBSE Working Group and MBSE Interest Group, as well as publications and other resources on model-based systems engineering (MBSE).

Current activities include: Languages, Methodologies & Tools; MBSE & Architecture; MBSE & BIM; MBSE Patterns; MBSE Value; and Model Verification and Validation.

Access the INCOSE UK MBSE wiki here.

ORGANIZATION: The ASD-SSG Systems Engineering Interoperability Working Group

In 2008, the Aerospace and Defense Industries Association of Europe (ASD) established the Strategic Standardization Group (SSG) to share a common strategy for the development and deployment of interoperability solutions across the product lifecycle.

Interoperability of information processes is seen as key for both industrial and operational performance of aerospace and defense (A&D) products, as the full benefit of Model-Based Systems Engineering (MBSE) will be achieved only when MBSE platforms are interoperable. ASD-SSG's approach to interoperability is based on the broad adoption of standards, not on selection of a particular technology or tool.

One several working groups within the ASD-SSG, the Systems Engineering Interoperability Working Group exists to define industry needs and to drive development of interoperability solutions and their requisite standards. It currently embraces three activities:

- Systems modelling interoperability
- System simulation interoperability
- Collaboration interoperability

The Systems Engineering Interoperability Working Group has links with OMG, INCOSE, ISO/TC 184/SC 4 (ISO MoSSEC project), PDES MBSE WG, and LOTAR MBSE WG.

Read more information on ASD-SSG here.

ORGANIZATION: The MITRE Corporation

MITRE is a United States not-for-profit organization that works in the public interest with federal, state, and local governments, as well as in industry and in academia.

MITRE's objective is to bring forth innovative ideas in areas such as artificial intelligence, intuitive data science, quantum information science, health informatics, space security, policy and economic expertise, trustworthy autonomy, cyber threat sharing, and cyber resilience. MITRE operates federally funded research and development centers (FFRDCs), which are organizations that assist the United States government with scientific research and analysis; development and acquisition; and systems engineering and integration.

MITRE's researchers seek to transform the practice of systems engineering by developing new ways for its sponsors to meet their goals efficiently and effectively. MITRE is focusing on the development of co-engineering processes, computationally based tools, and reusable patterns that rapidly meet the needs of end-users throughout the systems-engineering life cycle and increase their satisfaction.

MITRE resources include papers on modeling and simulation, as well as a 500-page MITRE Systems Engineering Guide (SEG) that outlines the essentials of the discipline and offers insights into translating this knowledge into practice. Other resources include:

- A Systems Engineering Competency Model
- SE Training and Development Program
- Key Questions for Acquisition Success
- Risk Management Toolkit
- Standardized Technology Evaluation Process (STEP) toolkit

Read more information on MITRE's initiatives and resources for systems engineering [here](#).

ORGANIZATION: Systems Engineering Domain Special Interest Group of OMG

The Systems Engineering Domain Special Interest Group (SE DSIG) is a working group within the Object Management Group (OMG) that has the mission to support the evolution of model-based systems-engineering (MBSE) standards. It has the following goals:

- Provide a standard systems-modeling language to specify, design, and verify complex systems;
- Facilitate integration of systems and software-engineering disciplines;
- Promote rigor in the transfer of information between disciplines and tools for developing systems.

SE DSIG is working on the evolution of SysML, creating the requirements for the next generation of the language, SysML v2, to provide greater ease of adoption and more effective application to MBSE.

Read an overview of the SE DSIG [here](#).

ORGANIZATION: GfSE

The GfSE (Gesellschaft für Systems Engineering; or in English: Society for Systems Engineering) e.V. represents INCOSE in German-speaking countries. Its objective is to promote systems engineering in industry, research, and teaching, and to offer a forum for the dissemination and exchange of SE knowledge and experience.

The GfSE e.V., together with TÜV Rheinland®, developed the SE-ZERT® personal-certificate program for a vocational qualification to the "Certified Systems Engineers (GfSE)®". With equivalencies to INCOSE's SEP credentialling, it provides the participants the opportunity to establish competencies in systems engineering.

More information on GfSE [here](#).

More information on SE-ZERT® [here](#).

https://segoldmine.ppi-int.com/

DID YOU KNOW?

Project Performance International (PPI) offers a wide range of live, on-line training to align with local time zones worldwide.

Topics include:

- Systems Engineering
- Requirements and Specifications
- Project/Engineering Management
- Design
- Medical Device Risk Management
- Software Engineering

Learn more about PPI training

SYSTEMS ENGINEERING RESOURCES

TRAK Enterprise Architecture Framework

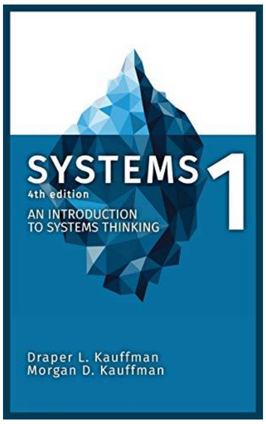
TRAK is a pragmatic, simple, general, system-centric enterprise architecture framework. It's simple, user-friendly, pragmatic, and not limited to IT. TRAK was released under open-source licenses and won an INCOSE Working Group award in 2010.

TRAK allows one to describe a system, its parts (which can include people, software, other systems, and physical things), and how it relates to the outside world. TRAK covers everything from the enterprise and its goals to its conceptualization, to the procurement of its solution via projects, to its introduction and withdrawal from service.

TRAK was based on the ISO/IEC/IEEE-42010 standard of architecture-description and tied to the systems-engineering lifecycle defined in ISO/IEC-15288. Although the original intent was to develop a rail-specific architecture framework, any domain-specific content was removed, and the resulting metamodel and viewpoints enable the representation of any complex system.

View its Wikipedia article here.

Visit its SourceForge project here.



Systems 1: An Introduction to Systems Thinking

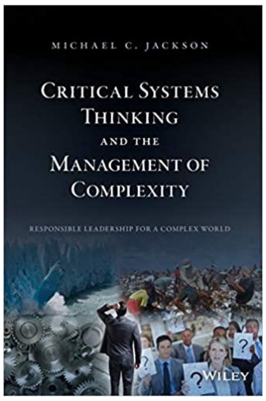
The first textbook on systems thinking for a broad audience, now updated for the modern reader, *Systems 1* is a perfect introduction to the complex systems making up the world around us.

Originally written in 1980, *Systems 1* has remained a classic and mainstay of workshops and classrooms around the world for 40 years. It has been used in courses for gifted middle schoolers as well as for graduate programs. It is the introductory text in the MIT course on systems theory for educators, and it has been incorporated into many business and military training programs.

It begins with a basic summary of systems theory, then proceeds through simple steps to help the reader understand the more complex systems with which we deal every day. It concludes with "Kauffman's Rules," 30 proverbs that every systems thinker needs to know.

The 4th edition has been completely updated, with an added chapter on exponential growth.

See this book on Amazon.



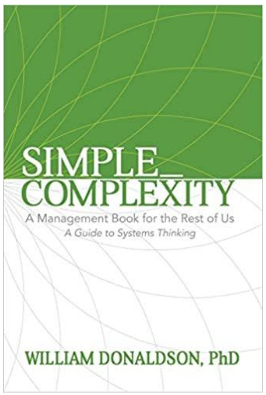
Critical Systems Thinking and the Management of Complexity

The world has become increasingly networked and unpredictable. Decision-makers at all levels are required to manage the consequences of complexity every day. They must deal with problems that arise unexpectedly, generate uncertainty, are characterized by interconnectivity, and spread across traditional boundaries. Simple solutions to complex problems are usually inadequate and risk exacerbating the original issues.

Systems thinking is an essential leadership skill for managing the complexity of the economic, social, and environmental issues of today's world. Decision-makers must utilize critical systems thinking, through understanding the strengths and weaknesses of various systems-thinking approaches and learning how to employ them in combination.

Making use of over 25 case studies, this book traces the development of systems thinking and of major efforts to apply the approach in real-world interventions. Further, it encourages the widespread use of critical systems practice as a means of ensuring responsible leadership in a complex world.

See this book on Amazon.

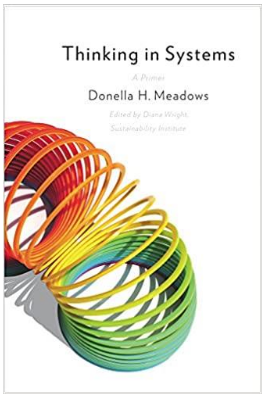


Simple_Complexity: A Management Book For The Rest of Us: A Guide to Systems Thinking

Every manager knows that their business is a system, yet very few have studied systems thinking or system dynamics. This is a critical oversight.

Simple_Complexity reveals the fundamental system archetype at work in an enterprise, and it prescribes new and exciting ways to re-invigorate management thinking. Picking up where the greats in management thought leave off, *Simple_Complexity* provides a systems context that powerfully enriches traditional management thought and practice.

See this book on Amazon.



BOOK: Thinking in Systems: A Primer

Thinking in Systems –is the classic, concise, and crucial book on systems thinking, offering insight for problem-solving on scales ranging from the personal to the global. It brings systems thinking out of the realm of computers and equations into the tangible world, showing readers how to develop the systems-thinking skills that thought-leaders across the globe consider critical for 21st-century life. Some of the biggest problems facing the world are essentially system failures: they cannot be solved by fixing one piece in isolation from the others, because even seemingly minor details have enormous power to undermine the best efforts of too-narrow thinking. While readers will learn the conceptual tools and methods of systems thinking, the heart of the book is grander than methodology. Donella Meadows was known as much for nurturing positive outcomes as she was for delving into the science behind global dilemmas. She reminds readers to pay attention to what is important, not just what is quantifiable; to stay humble; and to stay a learner.

In a world growing ever more complicated, crowded, and interdependent, *Thinking in Systems* helps readers avoid confusion and helplessness, the first step toward finding proactive and effective solutions.

See this book on Amazon.

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.

More information and registration

FINAL THOUGHTS

Syenna's Corner

I often think how much better our lives would be if service-based companies were to apply systems thinking and systems engineering to their service systems. In illustration, I share a series of true stories from a single hotel stay.

True story 1

On my way back out after checking into my hotel room, I notified the front desk of two faults in my room: the sink drain was almost completely blocked, so it drained slowly; and the drain-stopper didn't fit the drain-hole, so if they cleared the blockage, I would have a different problem. (A rare example of two faults that are partially self-cancelling)

The receptionist said that they would move my belongings to a new room during the day. When I got back, they said that I had been allocated a new room, but that they had not yet relocated my belongings, because my new room had some unresolved problems. I saved time for all, by complaining pre-emptively.

After a wait, I was told (with a glow of pride) that I could now go to a completely refurbished room. The improvements from the upgrade:

- The different type of drain-stopper (chained to prevent theft) still didn't fit the hole;
- The light switches were relocated to be operable from the bed (one good thing);
- The large-screen picture-tube TV was replaced with a tiny LCD TV.

True story 2

I got into the lift (elevator) on the ground floor. A lady got in, just before the doors closed. "Hello," I said, "which floor do you want?"

"2nd floor, thanks very much," was her reply.

I pressed the button for 2, and the lift started rising. When it stopped, the doors opened, and the lady started to exit. I observed, "I think you need to go another floor; it's showing that we're on the 1st floor."

"I know," she said, "but this is actually the 2nd floor, despite what the display says. I told the management about that, and they told me that that's just the way it is".

True story 3

I needed to get onto the hotel WiFi to check my emails. The paper instructions in the room read: "If you pre-paid for your WiFi, you will have received your password by email."

I thought to call the front desk, but there were no phones in the rooms. The instructions gave the landline number for the front desk, which I phoned from my mobile – four times over the next hour, each time ringing repeatedly then hanging up without opportunity to leave a voicemail. Eventually, I walked down to the front desk and showed them my call history on the phone. "Oh yes," they said, "it's been like that for a while now. Our phones here don't actually ring when people call them."

True story 4

The slogan printed on the room key-card was:

"Communication is **key**"

If you are still reading, then thank you for your sufferance.

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

Syenna

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