PPI SyEN

SYSTEMS ENGINEERING NEWSJOURNAL

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Solutions through a Systems Approach

VIRTUAL IMPLEMENTATION
SE during a global pandemic

QUALITY MODEL & HEURISTICS
Addressing non-functional requirements

PPI SyEN SPOTLIGHT
Interview with Kerry Lunney

PPI SyEN

EMAIL: PPISyEN@PPI-Int.com

PUBLISHER

PROJECT PERFORMANCE INTERNATIONAL

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

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

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

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WELCOME

Reflections on the INCOSE International Symposium 2021

I have a saying, "The two best ways of spending a week on systems engineering are firstly to participate in PPI's 5-day systems engineering class, and secondly, to attend (is that still the right word?) the annual INCOSE International Symposium (IS)". My participation in the IS over July 19-22, 2021 has not changed that view. The symposium, delivered virtually to 741 registrants from all corners of the world, was excellent!

Some trends identified in topics of papers and panels were:

- a further shift towards inclusion in the application of SE the engineering of socio-technical and social systems
- realization of economies through Product Line Engineering (PLE) techniques
- realization of the digital thread
- the application of AI, both in terms of impacts on SE
- principles and methods, and of application of AI to SE.

Some very good sessions were attended related to these and other topics.

The most rewarding IS session I attended was that on the path from SysML 1.7 to SysML 2.0. The panel dealt thoroughly with how much better in a myriad of ways SysML 2.0 will be compared with SysML 1.7 - a game-changer. SysML 2.0 is coming along nicely and is scheduled to be submitted to the OMG in September 2021, with formal release likely to be early in 2023. A prototype tool exists and is being used for language validation; predictions are that commercial tool support will mature over 2023 to 2025.

Other news and views from the IS 2021 appear throughout this edition, and more will appear in the September and October editions of PPI SyEN.

Regards to all who are trying to make the world a better place through better *problem definition* and better *problem solving* using a systems approach.

Robert

Robert Halligan FIE Aust CPEng IntPE (Aus)
Editor-in-Chief, PPI SyEN
Managing Director, Project Performance International

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 readers, authors, and contributors

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

ASA Video Series on Systems Engineering

By Robert Halligan

Editor-in-Chief, PPI SyEN
Managing Director, Project Performance International

NASA has available online a useful video series on aspects of systems engineering. The individual video titles are:

- Systems Engineering and the Project Life Cycle
- The Central Elements of Project Management
- How to Use Requirements
- How to Conduct a Review
- Systems Design vs. Engineering Design
- The Central Role of the Systems Hierarchy
- The Riskiest Part of Systems Design - Interfaces and Integration
- Concept of Operations
- Using Trade Studies to Make Systems Decisions
- Integrating Reliability, Safety, and the Other Specialties
- Verification - How to be Sure You Got What You Needed.

In contrast to the view reflected in the NASA videos, PPI holds the view that all engineers should be systems engineers in the sense of practicing systems engineering within the scope of their assigned responsibilities, not be a breed apart as represented in the video series.

Also, unfortunately, Video 8 claims that a Concept of Operations (CONOPS) and an Operational Concept Description (OCD or OpsCon) are synonyms, whereas this is not so (reference PPI, ISO and INCOSE publications). For an Operational Concept Description, OCD (also called CONUSE, CONEMP, Statement of Operating Intent, Intended Use Description, etc.), the focus is a system-centric description of intended use of the subject of the OCD in terms of users and their relevant characteristics, uses with respect to each user, how the system is to be used for each use, and the expected or interned external conditions during use. A CONOPS for the same system is an operational solution description.

Furthermore, the focus of Video 8 is indeed (system) Verification, but verification does not ensure that you got what you needed as claimed in the video, that is validation.

The video series nevertheless contains some valuable content, which may be viewed here.

Robert

What is System Dynamics?

By Alwyn Smit
PPI Principal Consultant and Course Presenter

In the early part of my career, I had a very superficial understanding of system dynamics. It is about the fact that no system exists on an island, and in real life, it has multiple interactions with other systems that play a significant role in its emergent behavior, right?

How does one deal with those interactions in the engineering of our systems, keeping in mind that some of those interactions may even be unintentional? Add to that the fact that they can have time delays and feedback loops, and you have a real mess on your hands.

It was not until I attended a System Dynamics Modeling course that I could quantify and at least attempt to understand and predict possible system behavior in real life.

From the systemdynamics.org website: “While closely related to simulation research in management science and beyond, the System Dynamics approach to modeling has a few distinctive features. It is characterized by a focus on endogenous explanations for dynamic phenomena. Dynamics are explained as arising primarily endogenously within the boundary of a model from the interactions among the elements and actors in the system, rather than from exogenous inputs. Every attempt is made to represent these causal processes realistically, consistent with available empirical evidence, and robust to extreme inputs outside of the historically observed range.” and “The effort is to uncover the sources of system behavior that exist within the structure of the system itself.“

The simulation tools available to use to build and execute these models are fantastic. The ability to simulate what-if scenarios is a powerful tool in decision making to help us decide if the intervention that we are about to make in a complex system even has a chance of having the desired outcome that we intend. During these initial studies, we built many elementary models in class and often, the result was: “Wow! – didn’t expect that!”

If we humans have such a limited capacity to understand complex system behavior, why do we not make much more extensive use of these tools? It certainly is not a replacement for common sense but goes a long way towards making informed system interventions. If the systems we consider include humans with unpredictable behavior and hidden agendas, you are in even deeper trouble.

My opinion on the System Dynamics Modeling course that I attended, even though I do not do System Dynamics Modeling daily, is that it was hands down the course that made the most significant change in how I perceived the world. I remember a closing comment I made at the end of the course: “If this is the value, all politicians should undergo this training”. Maybe then we will see more policy decisions for the greater good of humanity and fewer kneejerk reactions that send the system into violent oscillation.

Alwyn

> *“The best principles and processes forced on an unwilling constituency are destined to fail. Win hearts and minds.”*
>
> *Robert John Halligan*

FEEDBACK

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

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

SYSTEMS ENGINEERING NEWS

Recent events and updates in the field of systems engineering

ISO/IEC/IEEE 15288 Systems Engineering-System Life cycle processes Update

ISO/IEC/IEEE 15288:2015 Systems Engineering-System Life cycle processes is being updated as a part of the normal ISO process for standards. The update is well-advanced, currently in the Committee Draft (CD) stage as ISO/IEC/IEEE CD 15288 (Ed2) System Life cycle processes. The CD was voted on in May 2021.

The purpose of the project is to update this standard to align with changes to related standards in SC 7, to maintain harmonization of the portfolio of ISO/IEC JTC1 SC 7 standards, as well as to address feedback from users, results of analyses/studies, and the advancement of system-related technologies and approaches. This technical standard needs to reflect the state of current practice and changing needs of the users. It also needs to maintain alignment with changes in processes made in the revisions of associated standards.

PPI will publish an Application Guide to the update to ISO/IEC/IEEE 15288:2015 after public release of the update. A 25-page Application Guide to the current (2015) version may be downloaded from PPI here.

AI4SE/SE4AI Workshop extends abstracts call

The 2021 AI4SE/SE4AI Workshop, to be held October 20-21 virtually, is extending its call for abstracts through August 16, in search for actionable applications of Artificial Intelligence for Systems Engineering (AI4SE) and of Systems Engineering for Artificial Intelligence (SE4AI).

Abstracts are sought for presentations and panels from government, industry and academia addressing key Artificial Intelligence (AI) and Systems Engineering (SE) initiatives. All abstracts and presentations must be approved for public release. Selected abstracts will be invited to present and/or attend the workshop. Participation is limited to US citizens only and will be by invitation.

More information can be found here.

Call For Papers: Digital Engineering: Enabling Digital Transformation of Engineering, Processes, and Enterprises

Digital Engineering, the digital transformation of engineering, is an emerging effort with a variety of names and focuses. The US Department of Defense (DoD) launched their Digital Engineering Strategy in 2018, defining digital engineering as "...an integrated digital approach that uses authoritative source of system data and models as a continuum across disciplines to support lifecycle activities from concept through disposal."

This special issue of *Systems Engineering* solicits high-quality papers on the theme of digital engineering and digital transformation, broadly defined. The special issue accepts the following types of papers: 1) research papers, 2) case studies or projects on digital engineering, 3) literature review, and 4) communications as position papers. This special issue seeks papers on principles, theories, paradigms, models, methodologies, and applications of digital engineering.

More information can be found here.

INCOSE Sectors host numerous regional conferences

INCOSE sectors around the globe enjoyed a busy second quarter of 2021, hosting numerous regional conferences and virtual meetings to advance the practice of Systems Engineering.

The INCOSE Beijing chapter co-hosted the 4th International Complex Systems Design & Management Asia Conference (CSD&M Asia) in Beijing on 12-13 April. Over 150 in-person participants, plus virtual attendees, were exposed to advances in Systems Engineering through a mix of keynote addresses and more than 40 paper presentations. Proceedings have been published and are available for purchase through Springer.

The INCOSE Heartland (U.S.) chapter, collaborating with the Michigan and Three Rivers chapters, has hosted eight virtual chapter meeting since October, 2020 and enjoyed an average attendance of over 80 participants per session. Access the meeting flyers, slides and Zoom recordings here.

The INCOSE India chapter collaborated with the Aeronautical Society of India (AeSI) to organize India's first MBSE Summit on 15-16 April. The virtual summit brought together MBSE and systems engineering experts from across the aerospace community in India and the globe, to collaborate, educate, and discuss the need for MBSE, its current applications, and its future in the industry. The 200+ participants look forward to making the MBSE Summit an annual event to continue the collaboration and learning. Contact Aparna Kansal, aparna.kansal@boeing.com for more information on the MBSE Summit.

Complementing this effort, the India chapter launched an MBSE Study Group in December 2020 and has conducted 11 meetings so far to help participants learn MBSE in a supportive peer and practitioner environment. Contact Kalpesh Sawant, sawantkalpeshk@gmail.com for additional information on the MBSE Study Group.

The Israeli Society for Systems Engineering held the 11th Israeli International Conference on Systems Engineering online on the 16th and 17th March 2021. The theme of "Systems Engineering in the Age of Disruptions and Transformation," signified both the influence of COVID-19 on the 200 participants' way of thinking as well as significant technologies transforming the systems they design and the way they design them. Contact Yoram Reich, yoramr@tauex.tau.ac.il for more information.

INCOSE UK continued their Meet the Author online sessions on 9 April with Paul Davies sharing about his book, Don't Panic! The Absolute Beginners Guide to Managing Interfaces. Sign up for future Meet the Author sessions here.

PDMA Innovate Carolina: Capturing the Silver Lining: Delivering Opportunities from Disruption

The Product Development Management Association (PDMA) Carolinas chapter hosted their 12th annual local conference, Innovate Carolina, on April 22-23, 2021. The conference focused on the idea that businesses must be more prepared to face recurring disruptions and learn to innovate during and after significant disruptions.

Twelve video recordings from industry experts and student-led innovation teams addressed the following themes:

- How can leveraging scenario planning help?
- How to prepare for the next disruption and become comfortable (or even excited)
- Change how you see the landscape to "see" those opportunities early
- How do we take advantage of the disruption and emerging opportunities?
- Convince others in your business who may be more interested in "staying the course" or waiting for things to "go back to normal"
- How do you build the skills to pivot your thinking, shift your business model to new realities and opportunities?

- Building the skills to pivot your thinking, shift your business model to new realities and opportunities.
- Case studies about companies that successfully innovated during a disruption

Access the conference videos here.

Chinese translation of CPRE Foundation Level syllabus 3.0 available

The International Requirements Engineering Board (IREB) has now published the Chinese translation of the version 3.0 syllabus of the Certified Professional for Requirements Engineering (CPRE) Foundation Level, which outlines requirements and details contents for candidates to pass the Foundation Level exam and become a CPRE.

The aligned practice exam is also now available in Chinese, as is the CPRE Glossary v2.0.

In addition to Chinese, the 3.0 syllabus is available in English, German, Dutch, French, Persian, Portuguese (Brazilian), and Russian.

More information is available here.

Extended Call for Nominations: SE Excellence Award

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

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

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

The deadline for nominations has been extended until **August 13, 2021**.

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

Logical Decisions® is now free!

Logical Decisions is an excellent software tool for doing trade-off studies using Multi-Objective Decision Analysis (MODA). Its approach is based on the immensely sound Multiple Attribute Utility Theory that has been used and taught by PPI in its systems engineering training for many years. Books and articles that discuss the decision science on which Logical Decisions is based are listed here. The 453-page User Manual is downloadable for free from the same page. This manual is recommended as an excellent tutorial on the sound, efficient conduct of trade-off studies. This soundness compares favorably with problematic methods such as Saaty's Analytic Hierarchy Process (AHP) and Analytic Network Process (ANP), and the well-marketed Quality Function Deployment (QFD).

As of January 1, 2021, Logical Decisions is now freeware. Version 8.0 is now free of charge and contains all the features of the professional, group and portfolio versions and does not require a license key. It is released under the MIT license. To get your free copy of Logical Decisions, create an account, select the Logical Decisions v8.0 free download and check out. You can also download the software and manuals without creating an account at www.logicaldecisions.com.

INCOSE announces "Best Paper" awards from its SE journal for 2020

The Editorial Board of INCOSE's *Systems Engineering Journal* has recognized five papers to be among the best from 2020. These will be available through a special Wiley Online Virtual Journal until September 2021.

Learn more and access the papers here.

INCOSE releases Annual Impact Statement

INCOSE has released its Annual Impact Statement for the first six months of 2021. Now in their 31st year, INCOSE works to enhance the state of the practice, to inspire the state of the art, and to serve both the global community and their members while cultivating interest in systems engineering.

Learn more and download the statement here.

INCOSE Certification Program Application Fees Revised

Effective 21 August 2021, fees under INCOSE's Certification Program will become:

- ASEP application fee = 180 USD (Associate Systems Engineering Professional)
- CSEP application fee = 350 USD (Certified Systems Engineering Professional)
- ESEP application fee = 630 USD (Expert Systems Engineering Professional)

Further details of the new fee structure and related conditions are available here.

Take training to pass the ASEP/CSEP Knowledge Exam from PPI subsidiary company Certification Training International (CTI). See https://certificationtraining-int.com/. Take the advanced training provided by PPI on systems engineering and its various facets for PDUs necessary to maintain CSEP certification, and most importantly, to improve your own SE capability and that of your company. Or provide this training to your staff. See https://www.ppi-int.com/

PPI SE Courses for the Americas go Monthly

PPI's 5-Day systems engineering course (SE5D) has always been popular in the Americas - the United States, Canada, Brazil, and other South American countries. This popularity is due to a strong orientation of the training towards how to successfully engineer systems with intensely practical, very efficient and effective methods for requirements capture and validation, physical and logical design, the conduct of trade-off studies and other important aspects of systems engineering practice. So confident is PPI in the quality and novelty of this training that we provide a money-back guarantee: a guarantee that participants will learn new techniques and gain new understandings that they regard as valuable for the engineering of systems/products, regardless of age and experience, or a no-questions-asked refund. We have never received a request for a refund!

Starting this August, the SE5D course will be delivered monthly for the Americas, alternating between USA East Coast and Mountain time zones. The link below leads to a detailed description of the course content, course FAQs, schedule, and facilities for you or your colleagues to register. Upcoming dates for 2021 are:

20 - 24 Sep 2021 | North America UTC -6:00 (MDT 8:00)

25 - 29 Oct 2021 | North America UTC -4:00 (EDT 8:00)

15 - 19 Nov 2021 | North America UTC -7:00 (MST 8:00)

6 - 10 Dec 2021 | North America UTC -5:00 (EST 8:00)

Whether your company is a fellow INCOSE CAB member, a Fortune 100 company, or a startup, you and your staff can benefit from this PPI training. Further details can be found here.

CTI Welcomes Celia Wan

PPI subsidiary company Certification Training International (CTI) continues to expand in China with the addition of Celia Wan to the team. Celia is very skilled in translation, a great organizer and is assisting Victoria Huang and the delivery team towards CTI's mission to deliver highest quality INCOSE SEP Exam Preparation training throughout China.

PPI participation at the INCOSE IS-2021

PPI recently participated and was one of the sponsors of the annual INCOSE International Symposium 2021, over 17th - 22nd July. As always, it was a great pleasure to be part of this rich event. PPI was well represented at the INCOSE IS 2021, with five of our team members participating over July 19-23, 2021, along with 736 other registered professionals.

If you visited the IS PPI showcase webpage, you saw a list of PPI's upcoming systems engineering and related training and '6 Myths of Systems Engineering' presentation video by PPI Managing Director Robert Halligan. PPI's INCOSE IS showcase page received many visits, and the joint PPI and INCOSE Systems Engineering Tools Database (SETDB), released for the IS, was also quite a hit.

PPI Managing Director Robert Halligan also presented "3 SE Tools That Can Change a Company" on the 19th of July. INCOSE asked Robert and a group of Fellows to undertake an effort to identify heuristics useful in systems engineering today. The panel "Heuristics for Systems Engineering: Useful or Dangerous? Outdated or Enduring?" covered various viewpoints on this question, addressing insights and nuances that make the difference between a useful heuristic and one that may be dangerous to apply. Read more at page 33.

Other PPI team members who attended the IS also found the event to be well worth while attending. Some of their thoughts and experience about the IS are included in this edition of PPI SyEN and the next.

Here are the PPI team members who participated:

Robert Halligan, FIE Aust, CPEng IntPE (Aus)

PPI Managing Director, Principal Consultant & Training Presenter

René King, BSc (Engineering) MScEng

PPI Business Development Manager & Senior Engineer

CTI Managing Director and Training Presenter

Randall Iliff, BSc (Engineering), MSc (Systems Management)

Training Presenter & Principal Consultant

George Sousa, BEng, MSc, PhD

Training Presenter

John Fitch, BS EE and Physics, ESEP

Training Presenter & Principal Consultant

CONFERENCES, MEETINGS & WEBINARS

Upcoming events of relevance to systems engineering

INCOSE Western States Regional Conference (WSRC)

September 17-19, 2021 (In-person + virtual)
*** Early-bird registration ends August 17th ***

Location: Courtyard by Marriott, San Diego Airport / Liberty Station

The Western States Chapters of INCOSE will be presenting their Western States Regional Conference (WSRC-2021), themed "Sailing the Digital Wave", includes:

- 40 presentations
- 2 tutorials
- 2 keynotes
- Lunch and lite breakfast included

Optional events include:

- Saturday-evening banquet
- Special Sunday-afternoon tour to the USS Midway Museum in downtown San Diego. Includes bus and special tour
- INCOSE Systems Engineering Professional (SEP) paper tests

PPI will be a sponsor/exhibitor at WSRC-2021.

Find more information and registration here.

WEBINAR: Challenges of Needs and Requirements Definition and Management for Complex Systems (INCOSE Webinar 152)

August 18 @ 11:00 am - 12:00 pm EDT

Speaker: Raymond Wolfgang,
Systems Engineer, Sandia National Labs

This presentation will provide an update on the three major new documents from the INCOSE Requirements Working Group that can help to develop, manage, and verify requirements for technical projects:

- Guide to Needs and Requirements
- Guide to Verification and Validation
- Needs, Requirements, Verification and Validation Lifecycle Manual

This talk will share the evolution of these documents, describe some of the paradigm-shifts that they invite us to consider, and conclude with introducing the Outline of the Manual. After this presentation you will know where to get the answers to your needs and requirements questions: needs identification and elicitation, requirements authorship, development, V&V, and requirements management questions.

Find more information and registration here.

WEBINAR: What Does Test & Evaluation Mean in a Digital Engineering Enabled World? (SERC Talks)

August 18 @ 1:00 pm - 2:00 pm EDT

Speaker: Dr. Darryl K. Ahner, P.E., Director, Scientific Test and Analysis Techniques Center of Excellence (STAT COE), Air Force Institute of Technology (AFIT)

Moderator: Dr. Laura Freeman, SERC Research Council member; Director, Intelligent Systems Lab, Hume Center, Virginia Tech

Testing has often been looked at as a (un)necessary evil. In this talk, we will discuss the demand for testing events, the Scientific Test and Analysis Techniques process (since STAT is mandated in DoD policy anyway), and what test planning may look like in a digital engineering environment. Examples of efficient and effective test planning will also be discussed, both those that were conducted during development and those developed post deployment.

Find more information and registration here.

VIRTUAL PRESENTATION: Systems Engineers: Where Do We Fit In An Agile Environment? (INCOSE Chesapeake)

August 18, 2021, 6:00-8:30 PM EDT

Speaker: Peter Luckey, Senior Solutions Consultant at 321 Gang, Certified Scrum Master and Certified SAFe Program Consultant (SPC)

It's only within the last five years that the Scaled Agile Framework (SAFe) has accommodated cyber-physical systems engineering. This presentation focuses on how Model Based System Engineering (MBSE), aligned with some of the DoD's Digital Engineering Strategy objectives, can effectively be used in the 'agile at scale' frameworks that are becoming more common in our hardware-inclusive engineering environments.

Find more information and registration here.

VIRTUAL TUTORIAL: Verification and Validation (V&V) of Complex Systems: A Holistic, Model-Based Approach (INCOSE Enchantment)

August 27, 2021, 8:00 a.m. – 4:00 p.m. MDT

Presenter: William Miller, Executive Principal Analyst with Innovative Decisions, Adjunct Professor at Stevens Institute of Technology; Editor-in-Chief of INCOSE INSIGHT systems-engineering practitioners magazine, Future of Systems Engineering (FuSE) lead, and past INCOSE Technical Director (2013-2014).

V&V is inherently integral to risk and opportunity management, and therefore key to the technical systems engineering process areas identified in ISO 15288 (e.g., requirements engineering, architecture, implementation, integration). This tutorial presents an overview of V&V, its history, goals, and challenges. V&V of models will also be presented. Evaluation of V&V adequacy and effectiveness will be covered. Case studies, example models, and exercises illuminate the tutorial material.

Find more information and registration here.

Business Analysis Summit 2021

October 4-5, 2021 (virtual)

Produced by the South Africa chapter of the International Institute of Business Analysis™ (IIBA®), Business Analysis Summit 2021 aims to provide a practical approach to create, connect, iterate, and transform businesses, through a global community of thought-leaders and practitioners.

Just as the world will continue to change into the foreseeable future, businesses will need to re-invent and re-engineer approaches to deliver value to customers and the business.

Attend this year's summit for a new experience, with speakers full of bright ideas to inspire, and with everyone listening, learning, and engaging.

Find more information and registration here.

PDMA Innovators Conference & Research Forum

November 13-16, 2021 (In-person)

Location: Hilton Baltimore Inner Harbor

The Product Development Management Association (PDMA) will showcase the latest practices in product management, product research and innovation at its in-person Innovators Conference & Research Forum in Baltimore, Maryland over November 13-16, 2021.

The conference combines two events, the PDMA Innovators Conference and the Journal of Product Innovation Management (JPIM) Research Forum, in a single location. A virtual attendance option will also be available.

There will also be an opportunity on Saturday, November 13 to participate in ProductCamp DC, an opportunity to learn from, share with, and network with professionals from around the world involved in product management, marketing, entrepreneurship, and development.

Find more information and registration here.

Implementing Virtual Systems Engineering During a Global Pandemic

A study of the reinvention of value propositions and delivery models of services in the wake of COVID-19

by Rebecca Reed, Ian Presland, and John Greene

Abstract: The sudden onset of the COVID-19 pandemic in March 2020 required immediate transformation of the way most organizations do business. For companies providing systems-engineering support services, the transition to fully virtual meetings, team collaboration, product updates, and sales/marketing efforts introduced a wide array of new challenges, unexpected risks, and some new opportunities. This article explores the reality of the COVID-19 pandemic from the perspective of two small business providing systems-engineering support and training programs.

Introduction

In early March of 2020, the world had to shut down essentially overnight due to the shocking news that a new, deadly virus was rapidly spreading around the globe. For small businesses in the technical consulting industry, the dramatic shift in daily operations caused turmoil, fear, financial impact, and unexpected opportunity.

The initial reactions by small business teams and clients were focused on safety: safety for employees, safety for integrated operations, and safety for critical customer tasking. There was an almost immediate transformation from moving forward with regular daily in-person, on-site work to "all virtual everything". Suddenly, new constraints were placed on the systems small businesses rely on for day-to-day operations, and several new systems were immediately integrated into established business processes. Suddenly, people could no longer physically be within 6 or 12 or 20 feet of each other or be without facemasks in any situation outside the home. Home-based internet connections suddenly had to be consistent, reliable, with sufficient bandwidth and speed to support work-related tasks, and completely secure.

Projects were all converted to management by telecommuters, live training programs were transitioned immediately to virtual programs, and the systems approach to everything instantly took on new constraints. As systems engineers, we work hard to study the big picture, capture the needs, concepts, and risks associated with our projects. However, the pandemic created an entirely new set of needs, concepts, risks, and processes that had never been considered for most efforts before. The following examples of pandemic adjustment to systems engineering are actual scenarios that were experienced by two small businesses in the technical consulting and training arenas.

Adjustment to Service Offerings

Pre-pandemic, for a large-scale information technology (IT) system in the early stages of planning, requirements, and architectural concepts, the systems engineering effort was focused on generating an acquisition strategy with enough information for potential bidders to respond with cost-effective, innovative solutions without defining those solutions. Initial work included in-person collaboration to establish a high-level operational concept that integrated stakeholder needs and preferred elements derived from previous market research efforts. This collaboration made use of whiteboards and various colorful sticky notes as the thought processes evolved across the team members.

After COVID-related measures eliminated in-person development and melding of ideas, the final versions of the operational concepts had to be completed through virtual meetings and online collaboration tools. The integration of these toolsets, such as Microsoft Teams, Zoom, and Microsoft Office 365 document collaboration tools (including SharePoint) took time to complete, which initially caused delays. The end product was still very valuable to the acquisition process, but the effort took longer than originally planned, due to the sudden shift in how the work was able to be performed. The risk that was realized was a schedule impact, but the opportunity identified was in the team learning quickly to apply the same concept development approaches to a virtual interaction which would be required for the longer-term deliverables of the project.

Impacts to Training Offerings

For a small business focused on a face-to-face learning and development delivery model, the pandemic brought an immediate realization that our standard offering required a complete re-think, not just in terms of adapting core content and to an online delivery model, but also of the overall business proposition for our customers. Our primary unique selling proposition (USP) had always been to promote the benefits of face-to-face delivery when establishing new business – a focus on the individual, the ability to adapt course content in real-time response to delegate questions or concerns, real-time linkage to client organizational process-definition systems or processes and ongoing client projects – so that a believable relationship could be established between the theoretical content contained in our courses and the day-to-day, real-life experiences of our delegates.

For one of our existing clients, their go-to solution was initially to delay the delivery of courses, meaning that the income stream from the rescheduled deliveries was itself delayed with inevitable cash-flow implications. When this initial delay turned out to be unrealistic, courses were rescheduled for a second time, before a final realization that rescheduling was not going to be a viable solution. Our key stakeholder's strong desire was to keep everything unchanged in an effort to desperately hold on to previously approved financial budgets associated with the project. This viewpoint was perhaps understandable, as the client (a supplier to the Oil and Gas industry) was at the time suffering huge losses due to the rapid fall in oil prices and was trying to find "quick-win", radical cost-cutting solutions right across the business.

The commercial arm of our client was understanding and happy to try to get a signature on our request for formal changes to be made to the agreed contract (e.g., delivery methods, travel, sites, content, numbers), but internal communications in that business were suffering greatly, possibly due to staff working from home. Even more importantly, our key stakeholder themselves became a victim of their radical cost-cutting solution, having their own employment terminated. The individual concerned was very supportive in that they did hand on their notes to their successor, but as is often the case with systems-engineering initiatives, their successor was perhaps less driven by the initiative, and in the end, we chose to end the contract by mutual consent.

Adjustments in Training Offerings

In-person, instructor-led training programs are specifically designed to offer a real-time connection between participants and instructors that results in more effective learning and application of skills. Once the pandemic hit, all live instructor-led training was immediately eliminated. This required a rapid transition of materials, instructors, course segment timing, exercises, and instructional methods required extensive innovation to ensure the same successful outcome, which was satisfying client requirements for learning specific subject matter. Courses that excel by providing an instructor working hands-on with course participants to solve project scheduling issues at a live workstation were transformed into a distance version that had to achieve the same solutions. The entire training system from business-case analysis and stakeholder analysis to implementation had to be re-engineered with the new operational constraints incorporated.

The conversion of in-person training to live virtual training required the integration of several new systems into the overall process for developing, planning, managing, and delivering a course. Teleconferencing software like Microsoft Teams has become a daily part of many of our lives over the last year, but in early 2020, it was a relatively new tool that did not have widespread adoption. As such, several interface considerations emerged, both technical and human. For example, the integration of Microsoft Teams for training presented interface challenges, due to the differences in software capability and interface between different versions of the tool, whether the user was utilizing a web-based version or a native desktop application, whether they accessed the meeting from a PC or a Mac, and whether they had IT security constraints associated with their account or machine. Additionally, human factors had to be considered, including conducting pre-class training with students to ensure they understood how to use and navigate new tools to which they may not have had exposure in the past.

In addition to the changes in course delivery processes, the COVID-19 pandemic and the associated distancing requirements created system constraints on the instructional-design and course-development processes used to support the training delivery team. For example, instructional design teams accustomed to agile development processes relying heavily on daily meetings and in-person collaboration suddenly had to rely on toolsets designed to replicate the collaboration process. Each of these toolsets introduced new constraints, challenges, and opportunities. The initial impact of the pandemic was an increased timeline for course-development. However, when virtual systems were fully integrated into the development process, the time required to develop a new course was actually faster than the development timeline pre-pandemic. The improved efficiency resulted from a combination of new tools that allowed for the development of interactive eBooks (as opposed to print files for hard-copy materials) and a flexible work schedule that allowed the instructional design team to work more efficiently around normal distractions.

Stakeholder Needs and Requirements Definition

One of the most commonly asked questions from our customers once they had recovered from the original pandemic "hit" and after we as a business had worked out a possible way forward was, "*Why do you need to "rework" the material anyway? Can't you just deliver the same material online, after all, we have Zoom…*?". This mindset, when coupled with, *"We cannot pay towards your rework costs…*" and "*if you rework content, we cannot afford any schedule delay – the dates are fixed!*" caused several challenges for training providers, both logistically and financially.

To be fair, our clients had a point. The decision to rewrite any course is predicated on the well-established value-proposition that course content can be reused, often without much change from client to client. Many training providers have done this for years with classroom-based training. For us, while our core technical messaging was standardized (and therefore reusable), our primary learning and engagement mechanisms required small team-based exercises, flip charts, small group discussions, presentations, exercise handouts with answers to be worked out and then prepared individually or in teams to the other delegates.

However, remote and onsite delivery are not interchangeable. The idea of running the same set of slides and exercises online is optimistic at best. Slides can work to a point, but exercises and other learning devices (e.g., facilitated discussions) usually require a substantial adjustment to be delivered effectively in a virtual format. The dynamic of an onsite classroom is totally different from that of an online classroom group, and it is unique even from course to course within the same organization. This dynamic seems to be driven primarily by the personalities and commitment of a small number of delegates on the course and not by the course content. An experienced trainer will normally quickly recognize delegates on any course who will require extra attention to make the course successful. These are not just the outspoken types; they could be quiet individuals who are happier to chat one-on-one at coffee breaks.

Furthermore, the "coffee-break" aspect of course delivery is hard to replicate online. Of course, a "break" can be scheduled and an informal chat embarked upon, but this cannot easily replicate face-to-face interactions and ad-hoc conversations. Even a one-on-one break-out room within an online context is far more stilted and can feel more like an interrogation than an informal chat, even if asking about things like sports or television!

System Requirements

In systems-engineering terms, our core system requirements remained reasonably unchanged: promoting the learning and understanding of specific systems-engineering ideas in its participants, coupled with an expectation that these ideas could be applied immediately after the course to improve the development or effectiveness of systems within that organization. Changes were really at implementation level. This one change resulted in new and revised constraints on implementation of the requirements.

Course delivery had to be achieved without face-to-face contact. This required a delivery mechanism to operate wholly online, to allow for real-time collaboration, and to support slideware, handouts, documents, individual and group exercises, instructor and delegate responses, facilitated discussions, group sessions, and feedback.

The class numbers could now be far more flexible (constraint relaxed). Because many individuals were now in isolation at home, the opportunity arose to open up new or revised delivery mechanisms, such as working in isolation on set tasks, individual learning tasks to be done in isolation from others and getting groups to self-organize collaborative tasks outside the training courses. The delivery schedule was generally expected to be maintained (constraint broadly unchanged), but in a virtual format, courses could be split into shorter pieces and delivered over a longer period of time, such as offering an 8-hour course over two 4-hour sessions rather than as a full day. This delivery schedule would be more challenging in a classroom environment, when instructors may have to travel, but is relatively easy to implement in a virtual format. Additionally, offer pricing would need to be maintained, although there was an unspoken expectation that a reduction might result due to reduced travel and changed course numbers.

Architecture

Course structure, format, and timing (architecture) would need to reflect a new online model. Key architecture decisions revolved around:

- Estimating how long any individual would be content to sit in front of a computer as part of a class and for how many consecutive days.
- Determining optimum size of an online class. Online delivery offers a theoretical capability to deliver mass participation global events/courses, not just site/local or regional courses with limited participation.

However, the larger the group, the less time available for individual attention.

- Determining the revised delivery structure, such as the length of course, length of each session, number and duration of exercises, group vs individual exercises, placement of coffee breaks, etc.
- Understanding and maximizing reuse of existing materials to reduce development and rework costs.
- Investigating the technology available for online delivery and what was compatible with customer platforms. In 2020, a rapidly emerging "COVID" marketplace developed with new, but often unproven, technology and suppliers.
- Determining the supportability of any solution long-term, with the most likely upgrade request being hybrid (onsite + remote) delivery requests.
- Understanding changed customer expectations in pricing.
- Understanding if any of the above changed customer expectations of their return on investment and of effectiveness of training.
- Understanding our own return on investment (ROI) as training providers.

Design and Implementation

Several design and implementation decisions had to be made for each program, including:

- Selecting the best delivery approach and architecture.
- Determining development and delivery technology, including any required investment in these updated tools.
- Re-estimating the cost of developing the updated solution (development / non-recurring / recurring costs), bearing in mind that a well-established model in place for classroom delivery set expectations of course costs.

Validation and Verification

Of course, the *real* test is whether the new-format courses and exercises "work", both in the sense of providing a good learning experience for delegates and of delivering against the needs of the customer(s). As with any good learning and development class, short-term ("hot") and longer-term ("cold") feedback both need to be gathered from delegates and key stakeholders to make this judgement.

"Hot" feedback is useful but can often be driven by the quality of an instructor alone – through their ability to deliver an engaging and interesting experience *despite* the circumstances in which they are operating. So whilst positive feedback received to date is always very much appreciated, in this case it should perhaps be taken with a pinch of salt with judgement reserved.

More interestingly and arguably more importantly, true content-validation comes from confirmatory evidence downstream that the longer-term technical aims of courses were achieved, and that the knowledge delivered online was indeed successfully retained by delegates over time. Indeed, only when COVID restrictions have eased and customers start requesting follow-on courses using the newly designed delivery approaches (over traditional classroom methods), will we be able to conclude that the investments we made in course reworking have been successful.

Conclusion

Overall, a cautious strategy would be advisable for delivery to enable the new course structure/timings and any new or revised exercises to be piloted in a smaller group forum (using delegates chosen to be representative of the wider whole) and then allowing time for final "updates" before the first "real" delivery.

Does this approach sound familiar? The development of a training course can be modeled in the same way as development of any other system. This system's purpose is to promote learning and understanding of specific systems engineering ideas within its participants, with an expectation that these learned ideas can be successfully applied immediately after the course to improve the development or effectiveness of systems within that organization.

In the end, as mentioned earlier, we chose to cancel our contract with our Oil and Gas customer rather than try to rework the courses in a timeframe that we believed was not realistic. Our client recognized their part in delays beyond those from the basic COVID-19 hiatus but continued to insist that their delivery timeframe could not now be delayed further. Indeed, due to the "online" situation, they were keen for us to expand to substantially more delegates overall, believing that the online model permitted that more easily. We did not wish to compromise our delivery standard to meet their timeframe, and whilst the additional delegates would have resulted in increased revenue for us, we decided that the revised contract was not for us. We parted on good client-supplier terms.

We were ultimately helped by the fact that we were able to absorb this loss financially and the contract cancellation provided us with a period where a more orderly rethink of the courses in question could be performed before delivery to our next client.

Looking Forward

Overall, despite the introduction of severe challenges to existing operations, the pandemic did create new areas for opportunity. Many engineers, project managers, consultants, and instructors had to innovate real-time to maintain progress for their systems, contracts, and clients. Enhanced collaboration tools, new approaches to team communications, and new methods for interacting across multiple user platforms required the immediate improvement (or learning!) of technology in many forms.

We believe that face-to-face training will continue to play key part in the delivery of learning and development. However, the forced development of online components of delivery due to COVID now provides an opportunity to deliver using the hybrid approach. The areas best suited to an online approach remain core technical ideas and learning (e.g., preparation for SEP-certification examinations, awareness of technology, or ideas within specific competency areas) where a more didactic approach can still impact ideas and extract learning. The hybrid model can also support an initial preparatory session where theoretical ideas are learned wholly online (potentially using pre-recorded material and/or online tests), followed by on-site application session. This offers an opportunity for the face-to-face application sessions to focus on tailoring within a project or organization: working through a real / current problem or issue on-site (which will help with information security / distribution concerns) with direct access to ongoing project work products or tools to help reinforce or adapt "standard" pre-learned information to the real world.

About the authors

Becky Reed, ESEP is President and CEO of Reed Integration, Inc. With a degree in Aerospace Engineering from the University of Alabama, Ms. Reed is an internationally recognized authority on life-cycle systems engineering and risk management and their applications in government and commercial markets. She has more than 30 years of experience in leadership and engineering roles for aerospace, defense, nuclear, and environmental science programs. A member of the International Council on Systems Engineering (INCOSE), Ms. Reed obtained her Certified Systems Engineering Professional (CSEP) certification in 2004 and her Expert Systems Engineering Professional (ESEP) certification in 2010.

Ian Presland, CEng, FIET, ESEP is a retired independent systems-engineering consultant, with almost 40 years' experience developing complex systems for diverse domains ranging from satellite engineering to automated ticketing. He is a member of the INCOSE Certification Advisory Group and editor / co-author of the INCOSE Systems Engineering Competency Framework. In 2021, his contribution to this area was rewarded with the INCOSE Outstanding Achievement Award.

John Greene is the Operations Manager for the Reed Learning Institute, a strategic business unit within Reed Integration, Inc. With a BA in Communications and Media Studies from Christopher Newport University, Mr. Greene provides complete life-cycle training services to government, commercial, and academic clients in industries ranging from shipbuilding to space systems.

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"A pessimist sees the difficulty in every opportunity;

an optimist sees the opportunity in every difficulty"

Winston Churchill

Applying Heuristics to Model the System Physical Architecture

How can systems engineering better incorporate nonfunctional requirements into their design and development activities?

By José L. Fernández and Juan A. Martínez

Abstract: One of the challenges that systems engineers must face is how to meet nonfunctional requirements when they develop the model of the system physical architecture. Unfortunately, some of the most common MBSE (Model-Based Systems Engineering) methodologies do not provide specific guidance to implement nonfunctional requirements. In this article, we apply the MBSE methodology, ISE&PPOOA (Integrated Systems Engineering & Pipelines of Processes in Object Oriented Architectures) [1] to model the physical architecture of an intravascular medical device, where quality attributes such as safety, resilience, and other "-ilities" (reliability and maintainability) are important.

Introduction

ISE&PPOOA MBSE methodology promotes three best practices to deal with requirements that are complementary and can be applied iteratively during the system-architecture modeling process. The first best practice is allocation, where "functional + performance" requirements are allocated to the system components, taking into consideration maximum-cohesion and minimum-coupling principles. The application of this produces what is called the modular architecture in ISE&PPOOA (Figure 1).

But functional allocation does not address nonfunctional requirements, for which two additional best practices are proposed: trade-off assessment, and the use of heuristics. We use trade-off to select the best technology for implementing the system core components, based upon attributes that include the ability of those components to accommodate relevant nonfunctional requirements [2]. However, some of those requirements affect not just the selection of components but also their connections that form the architecture of the system. Therefore, heuristics are the proposed best practice to implement those nonfunctional requirements that are driven by connectivity and architecture. Accordingly, heuristics and trade-off are complementary best practices promoted by ISE&PPOOA methodology [1].

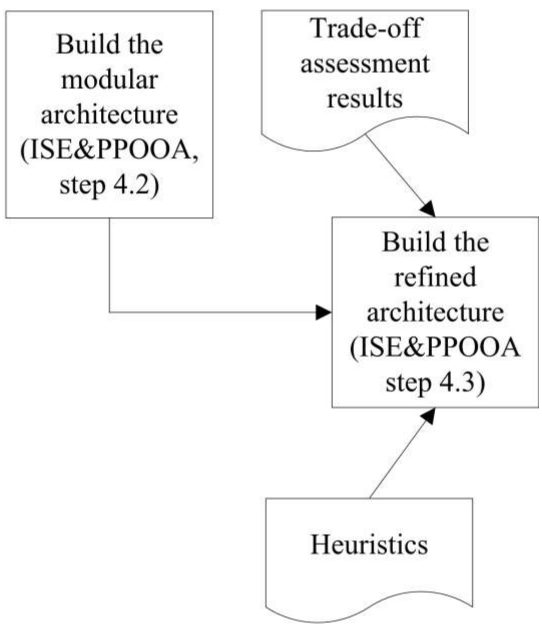

Figure 1. From modular to refined architecture using ISE&PPOOA

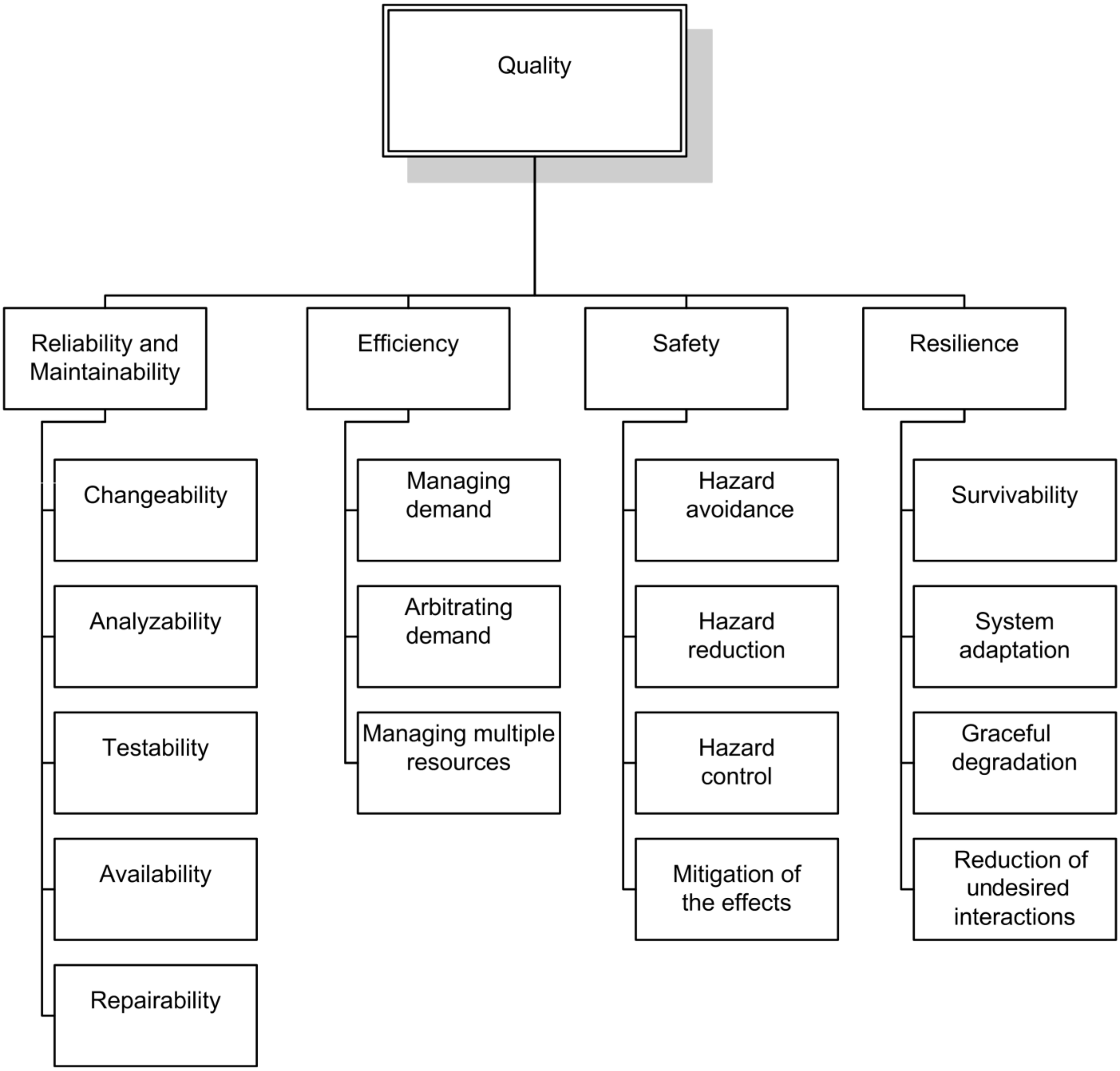

Figure 2. Quality model proposed for ISE&PPOOA, to be tailored for a particular system

Quality Model and Heuristics

Heuristics use knowledge from various quality-reasoning frameworks, such as maintainability, efficiency, safety, or resilience engineering. We propose the quality model shown in Figure 2 for the classification of the heuristics that we collected from diverse sources, to be applied for refining the solution architecture when using ISE&PPOOA methodology [1]. This model identifies quality characteristics & sub-characteristics that we consider most useful for applications where ISE&PPOOA is used.

The collection of safety heuristics proposed by ISE&PPOOA methodology is summarized in Table 1 and described elsewhere [1]. When the engineering team selects a specific heuristic to be applied, it is important to realize that it may have impact upon architectural decisions, requiring either the addition of new functionalities to the system or the addition of new components or the addition of new connectors to the architecture. In the last case, the application of architectural patterns is advised.

Quality	Category	Heuristic
Safety	Hazard avoidance	SF_Heu_1. Concentrate on dysfunctional system behavior
		SF_Heu_2. Minimize the number of components & interactions
		SF_Heu_3. Avoid non-deterministic behavior
	Hazard reduction	SF_Heu_4. Enforce time requirements
		SF_Heu_5. Sanity check.
		SF_Heu_6. Redundancy
		SF_Heu_7.Recovery
	Hazard control	SF_Heu_8. Use partitions.
		SF_Heu_9. Select the most appropriate output
		SF_Heu_10. Promote system degraded states when possible
	Mitigation of the effects	SF_Heu_11. Implement alerting capabilities
		SF_Heu_12_Implement operational data recording functions

Table 1. Safety heuristics

A more general quality model is proposed by ISO/IEC 25010 [3], where they describe quality characteristics such as functional suitability, performance efficiency, compatibility, usability, reliability, security, maintainability, and portability.

A more recent collection of heuristics is proposed by the INCOSE Heuristics Working Group, where they consider a wider application scope than physical architecture for their heuristics and principles [4], some of which is related what is called "elegant design" [5].

Example of application of safety heuristics

As an example, we apply a safety heuristic to develop the refined physical architecture of an intravascular medical device. This device must operate inside the patient, powered wirelessly and limited in size. (Approaches for micro energy-harvesting are found in the literature [6].) This places important constraints on system development.

The main subsystems of the intravascular medical device are presented in Figure 3 as a SysML BDD.

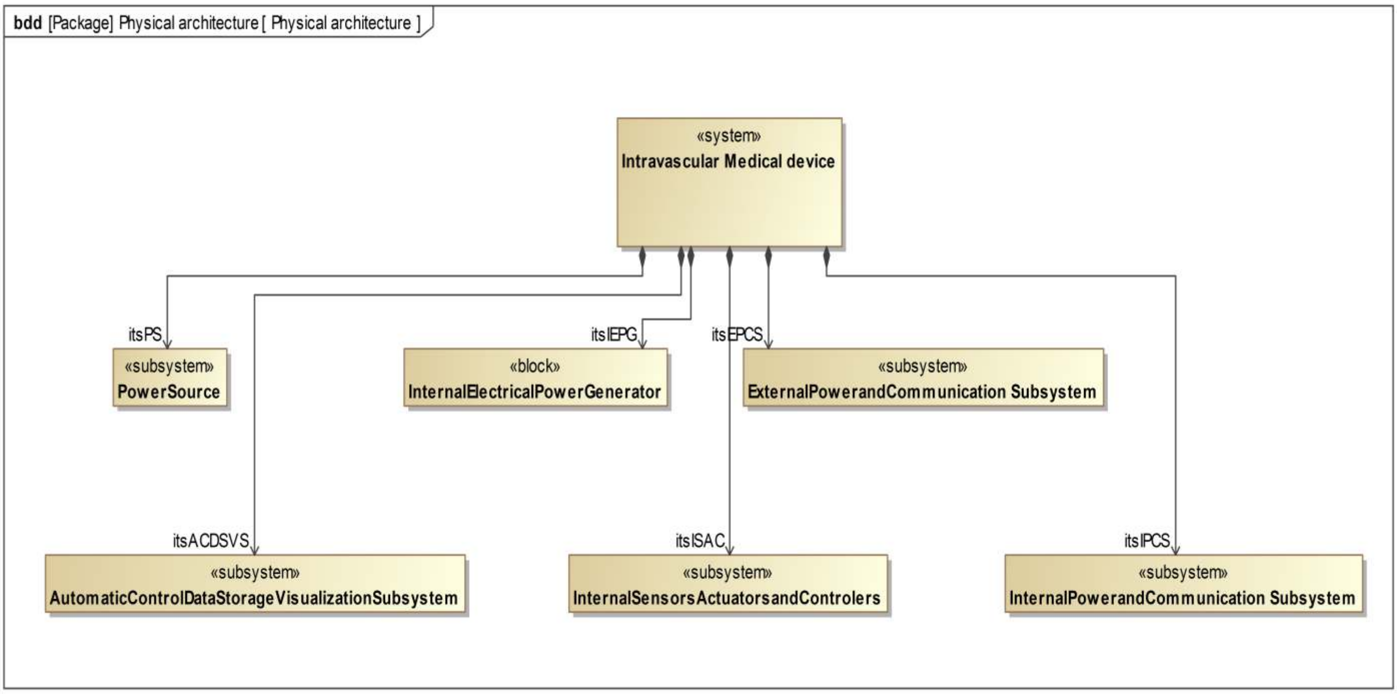

Figure 3. Subsystems of the intravascular medical device

Here, for brevity, we focus on the modeling of the Internal Power and Communication subsystem, whose main functions are:

- F3.1 Receive remote power signal inside the patient's body
- F3.2 Generate internal power
- F3.3 Regulate internal system power consumption and distribution
- F3.4 Dissipate heat produced by internal electronics and electrical devices
- F3.5 Minimize direct transfer of energy to other internal subsystems
- F3.6 Store energy inside the internal system
- F5.1 Regulate power source voltage
- F5.2 Monitor power radiation output level
- F5.3 Control power level
- F5.4 Manage power radiation level

The modular architecture of this subsystem is shown in Figure 4, as a SysML IBD presenting the main parts and connectors of this subsystem. These parts perform the functions identified previously as noted below:

- Voltage converter. It performs F3.2 and F5.1
- Battery. It performs F3.2 and F3.6
- Microwave modulator demodulator. It performs F3.1
- Power controller. It performs F3.3, F3.6, F5.1, F5.2, F5.3, and F5.4
- Isolation encapsulation. It performs F3.4, F3.5, and F3.6
- Thermal manager. It performs F3.5, F5.3 and F5.4
- Electrical ground plates. It performs F3.5 and F3.6
- Faraday cages. It performs F3.5

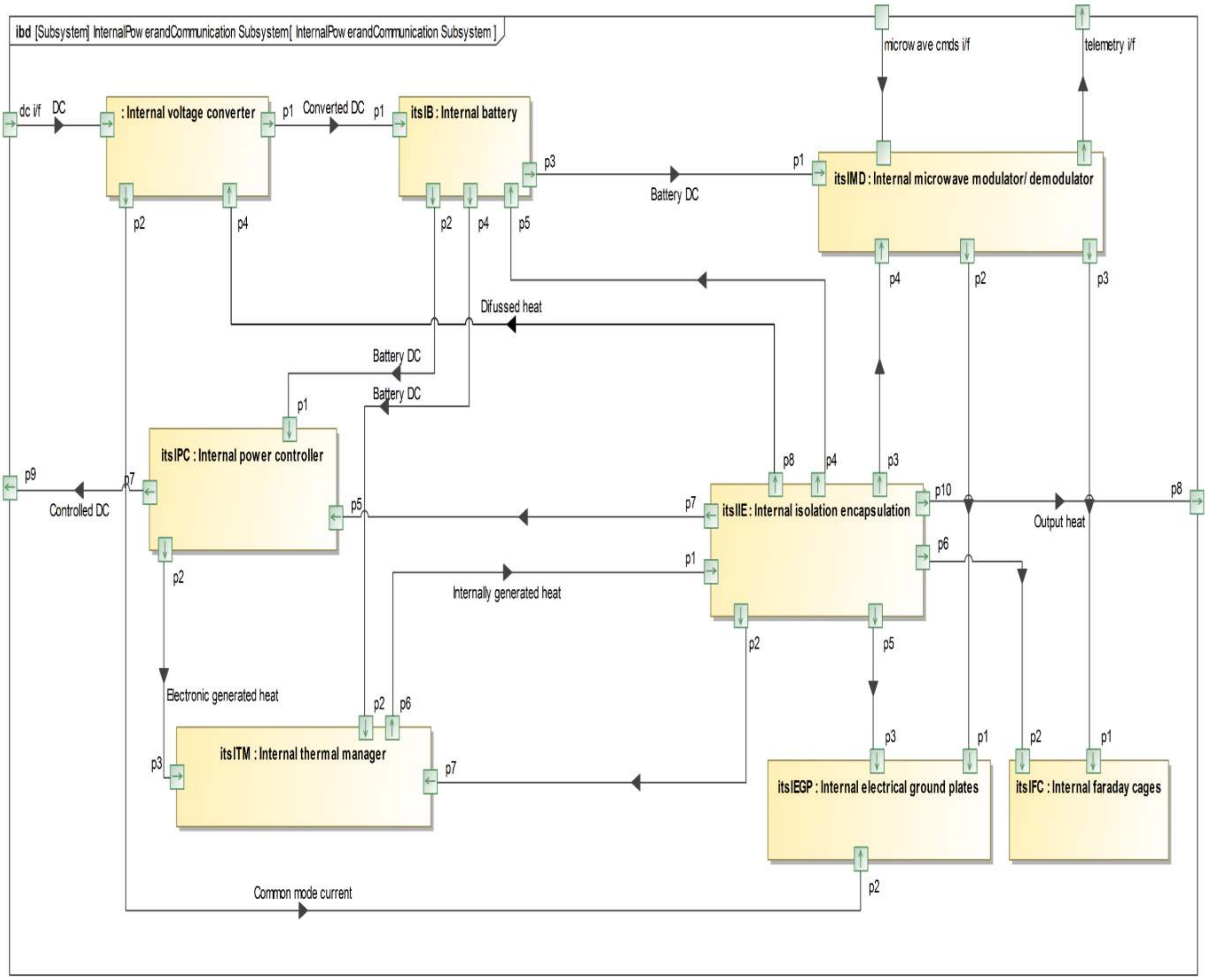

Figure 4. Internal Block Diagram of the Internal Power and Communication (IPC) subsystem

Req. ID	Requirement text
Req 41_NFR_SF	The internal subsystem shall be biocompatible with the patient's tissues
Req 44_NFR_SF	The system shall limit the energy transfer on the rise of 1 degree Celsius of temperature per kg of the local irradiated tissue
Req 45_NFR_SF	The system shall limit the energy transfer based on the rise of 1 degree Celsius of temperature per kg of the skin

Table 2. Selection of safety requirements

Req. ID	Heuristic ID	Heuristic short description
Req 41_NFR_SF	**Not applicable**	It is implemented as a physical property
Req 44__NFR_SF	**SF_HEU_5**	Sanity-check is a hazard-reduction heuristic that aims to enforce the validity or integrity of the output of a specific system component
Req 45_NFR_SF	**SF_HEU_5**	Sanity-check is a hazard-reduction heuristic that aims to enforce the validity or integrity of the output of a specific system component

Table 3. Heuristics selected

Table 2 represents some of the safety-system requirements specified for the intravascular medical device, primarily to ensure that the device is harmless both to its users and to the patient. So, avoidance, reduction, control, and mitigation of hazards and their effects are the safety sub-characteristics considered.

Based on the requirements specified on table 2, we select the heuristics to be applied to refine the system architecture, using an iterative process of refinement by the application of each heuristic selected. Table 3 relates the safety requirements of Table 2 to the safety heuristics selected to implement them from the collection of safety heuristics presented in Table 1.

Figure 5 shows the refined architecture of the Internal Power and Communication subsystem after application of the sanity-check safety heuristic. Three new components and additional connectors have been added to the subsystem, to reduce or eliminate the heat produced by the wireless-power radiation and the internal electronics.

The produced heat is monitored by means of two temperature sensors. The first one is internal and measures the temperature fluctuations inside the device isolation capsule. The second one is external to the isolation capsule and measures the temperature increments of the surrounding tissues. The healthy human body generally has an almost constant temperature, so we can safely assume that any local temperature raise is due to the medical device.

These sensors are connected to an emergency control switch that activates an immediate power-reduction signal until a safe operating temperature is achieved. Thus, two new connectors are added relating the internal power controller with both temperature sensors and the emergency switch.

Conclusion

The application of heuristics is recommended as a best practice to implement nonfunctional requirements that cannot be allocated directly to the system components. Today, allocation is the best practice used by systems engineers for the functional requirements, and it is well supported by current MBSE methods, notation, and tools. However, the use of principles and heuristics applied to implement nonfunctional requirements is still an open issue, not well supported by tools [7] and requiring important and sometimes conflicting decisions by system engineers. It is remains to organizations and development teams to create their own collections of heuristics that are based upon the quality model and quality factors that are applicable to their projects.

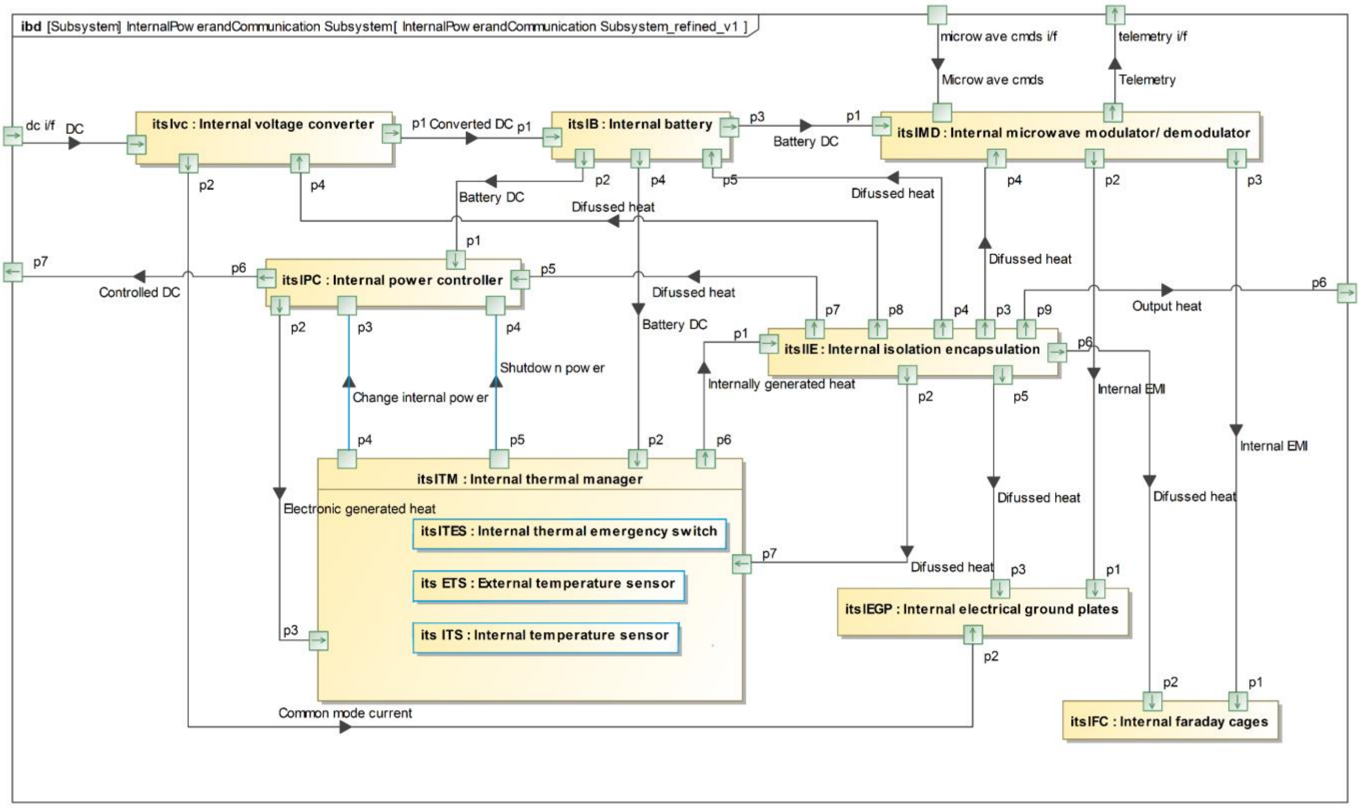

Figure 5. Refined Internal Block Diagram of the IPC subsystem after application of sanity-check heuristic

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About the authors

José L. Fernández has a PhD in Computer Science and an Engineering Degree in Aeronautical Engineering, both by the Universidad Politecnica de Madrid (Spain).

He has over 30 years of experience in industry as system engineer, project leader, researcher, department manager and consultant. He was involved in projects dealing with software development and maintenance of large systems, specifically real-time systems for air traffic control, power plants Supervisory Control and Data Acquisition (SCADA), avionics and cellular phone applications. He was associate professor at the E.T.S. Ingenieros Industriales, Universidad Politecnica de Madrid. He is the author of the ISE&PPOOA MBSE methodology, a senior member of the IEEE, and a member of INCOSE and of PMI.

Juan A. Martínez has a PhD in Physics and a degree in Psychology.

He has been an Associate Professor at the Department of Signal Theory and Communications of the University of Alcalá (Madrid, Spain) since 2012.

His main research interests are the study of complex systems, system of systems, biophysics, and biomimetic engineering.

“Creativity prospers best under particular conditions, especially where there is a flow of ideas between people who have different sorts of expertise.”

Sir Ken Robinson

PPI SyEN SPOTLIGHT: INCOSE IS-2021

Overviews and analyses from the recent INCOSE International Symposium by the PPI Training & Consulting Team

Observations and implications from IS-2021

By Robert Halligan, FIE Aust CPEng IntPE (Aus); Editor-in-Chief, PPI SyEN; Managing Director, Project Performance International

An interesting panel "To Vee or not to Vee", involved a debate on the usefulness of the Vee model. Unfortunately, however, the debate took place without defining which Vee model. The original Vee model as invented by NASA in the 1960s, repeated by Rook in 1979, then adapted to the double Vee by Fosberg and Mooz was subsequently subjected to some elaborations (for example, the German Vee model) and many mutations. The actual Vee model is not a process model at all except for its verification content, and it certainly isn't a lifecycle model, nor was it ever intended to be. Unfortunately, the attempts to morph the Vee into a process model, producing what I have described as mutations, were behind the points of debate without the debaters acknowledging so. Iteration, stakeholder interaction, and timing relationships were concerns with the Vee expressed in the debate. These concerns are all dealt with in my Wedge Model, which applies to any development process, including agile, whilst maintaining the purity of purpose of the Vee.

The official theme of the conference was "Accelerating through Adversity". A more general theme that was evident throughout was recognition of the exponential increase in the complexity of systems, including socio-technical and social systems incorporating widespread interconnection to form even bigger systems, and the need to accommodate this increase in complexity in our approaches to engineering. Whilst sharing this view, I left the INCOSE IS frustrated that the bigger problem remains that we continue to graduate engineers without even the most basic of engineering understandings, for example - that design creates requirements on solution elements, how to write a decent requirement, how to carry out a trade-off study, the difference between control flow and item flow in functional modeling, and why they all matter.

I would describe today's engineering as pinnacles of excellence in a sea of mediocrity. Those pinnacles of excellence are the organizations and projects that are practicing systems engineering well, not as a mindless rule book, a one-size-fits-all process, but as a set of mainly heuristic principles and a set of process tools that are used selectively, driven by value.

The sea of mediocrity to which I refer is populated by graduate engineers with education and work experience devoid of systems engineering principles and tools. That malaise is changing, but at nowhere near the needed rate.

Preaching systems engineering at an INCOSE conference is preaching to the choir. But beyond the choir are 15 million other engineers who would deliver much better results by using systems engineering principles, heuristics, and process tools in their work. It is not that we don't produce valuable products, we do, but the difference between "what is" and "what could be" is huge. Compelling evidence of my assertion lies in the landmark 2012 SEI study (Elm) on the value of systems engineering, and in many other studies. Look out for some papers in PPI SyEN on this topic soon.

Another frustration of the IS was the ongoing preoccupation with “systems engineers” rather than “systems engineering". I rarely use the term “systems engineer”, not because there is anything inherently wrong with the term, but because I see little reason to do so. To me, systems engineering is an integral part of the discipline of engineering, to be practiced by all engineers. Supporting this view is a study I carried out, looking at the set of SE principles defined by the INCOSE Principles Action Team, which have a scientific orientation, and my own set of SE principles having a heuristic orientation. For both sets of principles there was clear, consistent application to the engineering of large socio-technical systems such as the country of Singapore, complex technology items such as aircraft, simple technology items such as an electric jug, software of any size, and even to non-systems, unitary engineered products such as most coins. Regarding non-systems, only logical design did not apply.

I see the greatest opportunity for improvement in engineering outcomes arises not from system science or complexity theory or digital engineering information exchange, but from engineers, junior and senior, understanding and applying the foundation principles of systems engineering. Of course, we would like to have all these simultaneously, but if we must prioritize, competencies must come first. It is not that we don’t produce valuable products, we do, but the difference between “what is” and “what could and should be” is huge.

I also concluded that the battle to distinguish between System of Systems (literal interpretation) and System of Systems (system of autonomously managed systems) has been lost. The victim of an incredibly unwise use of language in the first place. About 95% of references to System of Systems at the IS had the literal intent, not the intent of a system comprising subsystems, each of which possesses the additional properties:

(a) Operational Independence of the subsystems: If the system-of-systems is disassembled into its component subsystems the component subsystems must be able to usefully operate independently. That is, the subsystems serve user purposes on their own.

(b) Managerial Independence of the subsystems: The component systems not only can operate independently, they do operate and are used independently. The component subsystems are separately acquired and managed and maintain a continuing operational existence independent of the system-of-systems. (after Maier 1998)

Look for additional news and views from IS-2021 in the September and October editions.

Product Line Engineering (PLE)

By John Fitch, BS EE and Physics, ESEP, PPI Consultant and Trainer

The topic of Product Line Engineering (PLE) was center stage at the INCOSE 2021 International Symposium (IS2021). Three presentations directly addressed this strategic capability. The advocates for PLE highlight its ability to:

- Improve engineering efficiencies by the elimination of low-value, replicative work
- Improve product quality
- Decrease technical debt
- Free up engineers for creative, high-value efforts; e.g. creating differentiation.

The broadest view of PLE was shared by Charles Krueger of BigLever Software in his talk, “Ushering in a New Era for Feature-based Product Line Engineering with the ISO/IEC 26580 International Standard.” Krueger provided a 20-year history of the evolution of PLE, the convergence of software product line engineering and hardware Product Lifecycle Management (PLM) that has led to the adoption of the combined software and systems standard.

The ISO/IEC 26580 standard focuses on featured-based PLE and addresses both methods and tools for delivering this enterprise capability. Five elements comprise the feature-based PLE factory:

- Feature Catalog: All options and variants of available capabilities across all products in the portfolio, including terms of variations
- Bill-of-Features Portfolio: Specific instantiations of the features for each product in the portfolio
- Shared Assets Supersets: Requirements, design, and lifecycle information; common across all products, plus product-specific variants
- PLE Factor Configurator: Automated generator of the relevant engineering information for each product instance.
- Product Asset Instances: Subset of portfolio-level information that is relevant to a specific product instance

The standard includes a UML model of the feature-based PLE factory that can serve as the basis for defining engineering databases and software tooling that meet the intent of the standard.

Krueger restated the fundamental business case for PLE: Product lines are ubiquitous, but traditional SE methods and tools focus on building a single point solution; a mismatch with huge risk and economic implications. He also highlighted ongoing efforts to create consistency between the ISO/IEC 26580 standard and other industry practices, e.g. SysML 2.0, Systems Engineering Body of Knowledge (SEBoK) and the INCOSE SE Handbook and Vision.

Rowland Darbin and David Hartley of General Dynamics Mission Systems reinforced the proven value of feature-based PLE by highlighting the level of PLE adoption and resulting cost avoidance benefits among large U.S. defense contractors. Their presentation, "Feature-based Product Line Engineering: An Essential Ingredient in Agile Acquisition" shared in detail how feature-based PLE supports each of the six acquisition pathways in the U.S. DoD's Adaptive Acquisition Framework:

- Urgent Capability Acquisition – less than 2 years from need to deployment
- Middle Tier of Acquisition – Rapid prototyping and rapid fielding
- Major Capability Acquisition: Traditional milestone-driven process for new systems
- Software Acquisition: Iterative development model
- Defense Business Systems
- Acquisition of Services

In addition to the pathway-specific benefits of feature-based PLE, they described how the journey toward a more disciplined portfolio-level view of features, engineering models and product configuration rules leads to the capture of tribal knowledge. Once made explicit, this knowledge helps to build a virtual trade space that enables better characterization, simulation, and feasibility assessment of solution prototypes.

Guillermo Chale, Juan Navas, and Stephane Bonnet of Thales Corporation dove deeper into PLE implementation in their presentation, "A value-driven, integrated approach to Model-Based Product Line Engineering." The Thales team sought to answer some essential questions on how to integrate Product Line Engineering (PLE) and Model-Based Systems Engineering (MBSE) to connect and align market and business analysis, architecting, design, and engineering. These questions include:

- What methods can be applied to architect, design and build the contents of a product line?
- How to align the architecture and design of the product to market and business analyses?
- How to verify the consistency of alternatives and options at different system levels?
- Is a feature model enough to understand what each product option or alternative consists of, or should tacit knowledge be made explicit to make informed design choices?
- How to guarantee that each defined configuration results in a feasible and valid architecture?

Their hypothesis was that modern MBSE methods and tools can provide the necessary rigor to create a consistent set of product representations, the shared models of a product portfolio required in PLE. The bulk of their presentation explored how Thales used the Arcadia method and Capella MBSE tool to capture product line engineering knowledge and how variability was handled in each class of data, e.g., stakeholder needs, capabilities & features, functions, and the product physical architecture.

Complementing these PLE-focused presentations, Arne Sundet of the University of Southeastern Norway presented the results of a research project on product variability titled "Product portfolio mapping used to structure a mature sub-system with large variation - A case study." The university team investigated a mature product that has been produced in over 1000 variants in the past two decades, with resulting challenges in predicting product development and manufacturing cost. From this example, they sought to learn the factors driving uncertainty and to discern:

- The needs in the company for a solution that handles product variance.
- How a product structure that follows architectural principles (i.e., systems engineering thinking/methods) can improve operational processes (workflow).
- How product portfolio analysis can help organizations increase efficiency in managing product variability.

Rather than focus on variability among end-user features, the team focused on four areas of potential commonality in creating a product data structure that worked across all the variants:

- Function-to-component mapping (understand decision factors that drive allocation)
- Interface mapping (grouping interacting parts that change together)
- Manufacturing process mapping (groups based on shared processes and tools)
- Procurement/Logistics needs (groups based on shared logistical data).

From this analysis, the team was able to create a dynamic cost calculator based on the design decision factors that they had isolated and demonstrated improvements in both product configuration time and cost prediction accuracy.

Viewing these four presentations as a whole, a clear takeaway from IS2021 is that Product Line Engineering (PLE) has matured into a disciplined practice supported by standards, methods and tools that make it high-value (and perhaps essential) enterprise capability for organizations that engineer solutions in a product line context. A solid conceptual framework is in place and organizations are reaping the benefits today. While "your mileage may vary", PLE is certainly an investment to consider.

INCOSE members may access the IS2021 presentations (once posted) through the Wiley Online Library link available in the INCOSE Connect portal.

Requirement Patterns

By John Fitch, BS EE and Physics, ESEP, PPI Consultant and Trainer

The INCOSE 2021 International Symposium hosted no fewer than four papers that delved into pattern-based approaches toward populating system models from natural language requirements, writing good requirements or aligning textual requirements with system models.

Annika Becker of Aachen University presented a paper, "Application of Natural Language Processing for Systematic Requirement Management in Model-based Systems Engineering" that described a method that converts unstructured and heterogeneous text-based requirements into model-based structures using Natural Language Processing (NLP). The method includes three steps:

- Cleaning of requirements: Breaking up requirement statements into individual words, mapping these words to parts of

speech, isolating nouns/phrases, using semantic and syntactical rules to understand the dependencies between the elements, replacing pronouns to reduce ambiguity and generating machine-readable requirement statements.
- Extraction of relevant requirements information and mapping this information to SysML model elements (entities, relationships, and attributes). Presentation of the mapping to the user in table form.
- Validation (Verification?) by the user of the requirement-to-model mapping and refinement of dictionary entries.

Although there are significant issues to resolve (e.g., handling conditions, performance, and other qualifying phrases; generation of unique and meaningful requirement titles; the handling of formulas and domain-specific requirement properties), the NLP preprocessor showed promise in reducing the human effort in creating initial MBSE representations of the problem definition from a diverse set of textual inputs.

According to Ron Claghorn and Hussam Shubayli of the Saudi Arabia Bechtel Company, requirement patterns for construction projects have evolved significantly in recent years to adapt to the digital transformation of the industry. The current “streamlined” pattern for specifications resembles System Modeling Language (SysML) blocks in that it provides a concise set of model-ready properties and operations relevant to construction processes. The streamlined requirements format includes no “shalls”, i.e. “The installer shall spread the adhesive with a notched trowel” becomes “Adhesive: Spread with notched trowel”.

Their presentation, “Requirement Patterns in the Construction Industry”, compared the characteristics of modern construction requirements to those listed in the INCOSE Guide for Writing Requirements. As a case study, they shared the methods and data required to convert a set of 262 legacy specification sections written in “natural language” into requirements that conform to the current streamlined pattern for construction specifications.

The largest effort in their project was setting up a database that included a dictionary of relevant construction-domain terms, mapping those terms to parts of speech and developing standard terms that eliminated duplicates. After this human intensive and interactive process, construction specification input files were individually prepared, automatically parsed at the sentence level and auto-written in the streamlined format. A feedback loop followed, in which the effectiveness of the automated parsing and rewrite were assessed and lessons learned were incorporated back into the database. The results of this effort indicate ~70% effectiveness in the automated generation of streamlined requirements relative to the final human-created edits. The Bechtel team also investigated a second methodology that used NLP to create UML models from the source specifications, with similar levels of effectiveness.

John Brtis of the MITRE Corporation focused his presentation, “Resilience Requirements Patterns”, on efforts at MITRE to improve the quality of system resilience requirements. The MITRE team sought to identify the critical content and structure of resilience requirements. They developed a resilience requirement pattern that was represented in three forms, each which contain the same information:

- Natural language,
- Entity-relationship diagram,
- An extension to SysML.

The goals of this effort were to produce a pattern that:

- Could be easily understood and validated by stakeholders who are not modeling experts.
- Is formal and rigorous, consistent with proven SE methodologies.
- Produces requirements that are computationally consumable and support MBSE and Digital Engineering (DE) environments.

The MITRE team identified the need for a new construct, the Resilience Scenario, that specifies the conditions under which resilience was needed and summarized the elements within each scenario as 4 **classes** connected by three *relationships*:

> **Adversity** -> *stresses* -> **System** -> *delivers* -> **System Capability** -> *gauged against* -> **Required Capability**

They also deduced the need for time-oriented attributes to be defined for each scenario and scenario element to fully describe the adversity and to characterize the system's resilient response.

The full natural language pattern was also mapped to an Entity Relationship Diagram (ERD) that elaborated each class of information, the attributes associated with each class and the relationships among them. Each element was then mapped to SysML elements and DoDAF viewpoints.

This research appears to hold great promise in improving the quality of resilience requirements. The authors believe that this work may be extended to other loss-driven engineering specialty areas, (e.g., security, safety) and that INCOSE should develop a curated repository of requirement patterns (consisting of natural language, ERD and SysML representations) for other domains.

The fourth requirements-focused paper, "Formulas and Guidelines for Deriving Functional System Requirements from a Systems Engineering Model", presented by John Shelton of Johns Hopkins University, shifted the focus of requirement patterns to the generation of natural language functional requirements from a system model. The Johns Hopkins team believed the model-based representation of system requirements should have primacy over its text-based equivalent. They produced SysML activity diagrams and then attempted to formulaically produce text requirements for each allocated action on the diagram. This effort uncovered multiple challenges including:

- The customer definition of functional requirements as independent from associated performance.
- Limited available guidance on how to create system requirements from a model.
- How to define what constitutes an overly prescriptive, under-prescribed or testable requirement.
- Use (or non-use) of SysML parameter and requirement objects.
- Customer-mandated deliverables that gave primacy back to text-based specification over the system model.

The Johns Hopkins team refined and expanded their approach to address these challenges. These expansions included an extended set of rules to model the problem domain more completely in SysML to improve the coverage and quality of auto-generated requirements.

The authors believe that:

- The project improved the overall requirements quality and the collective understanding of the behavior of the system of interest.
- The process used is extensible to other requirement types.
- The approach doesn't resolve the "What is truth?" question when multiple artifacts describe the same phenomena.
- Another iteration of methods refinements will yield better results.

All the requirements pattern techniques presented at IS20201 point to common foundational principle: that both the semantics implicit in natural language and explicit system models represent forms of structured thinking that can clarify intent, reduce ambiguity, and improve the problem definition that guides the development of any system or solution. When aligned together, natural language specifications and system models can yield improved communication of intent between stakeholders and the engineers who develop solutions on their behalf.

There were significant similarities between the dependency analysis used by the Aachen University team to model sentence structure and PPI's Parsing Analysis template. However, there was no indication in the presentation that the current NLP logic specifically addressed either the Conditions for Action or Exceptions to Action elements that are part of PPI's template. In contrast, the elaboration of the Resilience Scenario by the MITRE team provides a more rigorous method to express the Conditions for Action associated with such requirements. Future research on the use of NLP algorithms to populate system models or to generate allocated requirements from models should explicitly include handling of Conditions for Actions and Exceptions to Action. Such conditions may include system states, modes of behavior, completion of state or mode transitions or other events or newer constructs such as Resilience Scenarios.

Less clearly stated, but implied, is the principle that the design process (and specifically the decisions, therein) create the next layer of requirements that are allocated to the subsystems that flow from that design. Indeed, the subsystem requirements are created by the system design, but their documentation in specification form (whether as text, structured text, or models) is a critical handoff to reduce the risk of missed or misunderstood requirements on the subsystems.

None of the papers addressed side-by-side evaluation of the proposed automated analysis techniques with the quality and efficiency of skilled engineers using proven techniques such as Functional Analysis (control flow and item flow modeling), States & Modes Analysis or Parsing Analysis. Future research should be conducted such that the meaningful comparisons can be made between purely human analysis and differing levels of augmented intelligence by the partial use of AI. It is likely that the use of augmented intelligence will require significant extensions of requirement patterns and associated MBSE language elements to provide anything near complete coverage of the diverse types of requirements that may be faced when engineering solutions to complex problems.

INCOSE members may access the IS2021 presentations (once posted) through the Wiley Online Library link available in the INCOSE Connect portal.

Systems-Engineering Heuristics and Principles at INCOSE IS2021

By John Fitch, BS EE and Physics, ESEP, PPI Consultant and Trainer

INCOSE has undertaken the development and publication of heuristics for systems engineering as a valuable service to members. This emphasis was highlighted at the INCOSE 2021 International Symposium (IS2021) which included two panel sessions and a third presentation devoted to this topic.

In 2020, a team of INCOSE Fellows was asked to identify a set of heuristics useful in systems engineering today. The Heuristics project, led by Dorothy McKinney (Advanced Systems Thinking), discussed the subject and reported on their progress in a panel session titled, "Heuristics for Systems Engineering: Useful or Dangerous? Outdated or Enduring?" The Heuristics team has collected more than 500 heuristics and processed some of them so far to produce a set of 165 unique statements that have been published as an Online Heuristics Resource prototype in Stacker. INCOSE members may contact Dorothy McKinney to gain access to the prototype as a reviewer.

The panel discussion was triggered by the finding that the use of heuristics can be dangerous or helpful, depending on the context of their use. Panel members then shared their unique insights on this topic, with examples of both useful and potentially dangerous heuristics.

Robert Halligan (Project Performance International) made the case for the power of heuristics to improve engineering outcomes: "I see the greatest opportunity for improvement in engineering outcomes arises not from system science or complexity theory or digital engineering information exchange, important as these are, but from engineers, junior and senior, understanding and applying the foundation principles of systems engineering." He elaborated on the team's challenge of defining a heuristic (vs principle, lessons learned or rule) that led to the following consensus definition, previously formulated by Rechtin and Maier:

> SE Heuristic: A lesson learned, expressed as a guideline for the conduct of systems engineering

Peter Brook (Dashwood Systems Engineering) reviewed the history of heuristics, i.e., how they evolved to help engineers pass on their knowledge of how to build things, how science improved their precision by explaining the cause-effect behind the heuristic and how science and heuristics have co-evolved thereafter. Noting that practice often leads science, he emphasized the need to collect (from multiple knowledge sources), curate and maintain a library of heuristics and to use that structured set of heuristics to guide the search for scientific explanations behind them, especially in the more dynamic and uncertain 21st-century systems environment.

Sarah Sheard (Carnegie Mellon University, retired) placed heuristics in the context of human thinking patterns by summarizing findings from Daniel Kahneman's book, Thinking Fast and Slow. Kahneman identified two thinking systems within the human brain:

- System 1: automatic, intuitive, fast, easy; maintains mental model of personal "normal"
- System 2: effortful, controlled, requires focus, can deal with multiple variables

Sheard explained some common errors made by System 1 thinking and how SE heuristics are an attempt to move engineers into System 2 thinking patterns to avoid these errors. She also elaborated on a personal heuristic, "Systems are the way they are because they got that way" and explained why any change to a system first calls for root cause analysis to understand how the system evolved to its current state, and how the mechanisms that evolved will resist changes to the current system structure.

Scott Jackson (Burnham Systems Research) focused on heuristics that have been developed to assist in the definition of resilient systems, i.e., systems that can maintain required capability in the face of adversity.

Three heuristics have demonstrated success in enabling resilience:

- Functional Redundancy Heuristic: Employ an architecture with two or more unequal branches (in terms of capability).
- Restructuring Heuristic: Employ an architecture that can be restructured on the fly.
- Human Participation Heuristic: Employ an architecture that employs human elements when there is a need for human cognition.

Jackson contrasted the effectiveness of these heuristics with a potentially dangerous heuristic: "The customer (or management) is always right" and elaborated the potential consequences of following this oft-quoted guideline.

Chandru Mirchandani (Leidos) continued the theme of dangerous heuristics and explained in more detail how different parties in a design process may use well-intentioned heuristics to produce a "good enough" or "satisficing" solution from their perspective. However, the use of each such heuristic could lead to a far from optimum overall system solution that is deemed a failure. He concluded that it is often dangerous to follow the letter of the heuristic over the intent or the objective.

Gan Wang (BAE Systems) took a cultural perspective on heuristics and shared a set of Chinese proverbs that map to modern-day SE heuristics. He emphasized the benefits of seeking heuristics across a broad set of historical and cultural perspectives.

The Bridge Team, a spin-off from the Heuristics team and INCOSE's Principles Action Team, composed of Peter Brook, Michael Pennotti (Stevens Institute of Technology), and David Rousseau (Centre for Systems Philosophy) conducted a panel session titled, "A Framework for Understanding Systems Engineering Principles and Heuristics."

Kerry Lunney, INCOSE President, kicked off this panel session by making the case for the need for a better set of SE principles and heuristics to face the challenges of the 21st century. The panel members then shared their journey as a Bridge Team that sought to clarify the relationship between SE principles and SE heuristics and to create a framework (bridge) that linked these two concepts.

This team arrived at a definition of a SE principle:

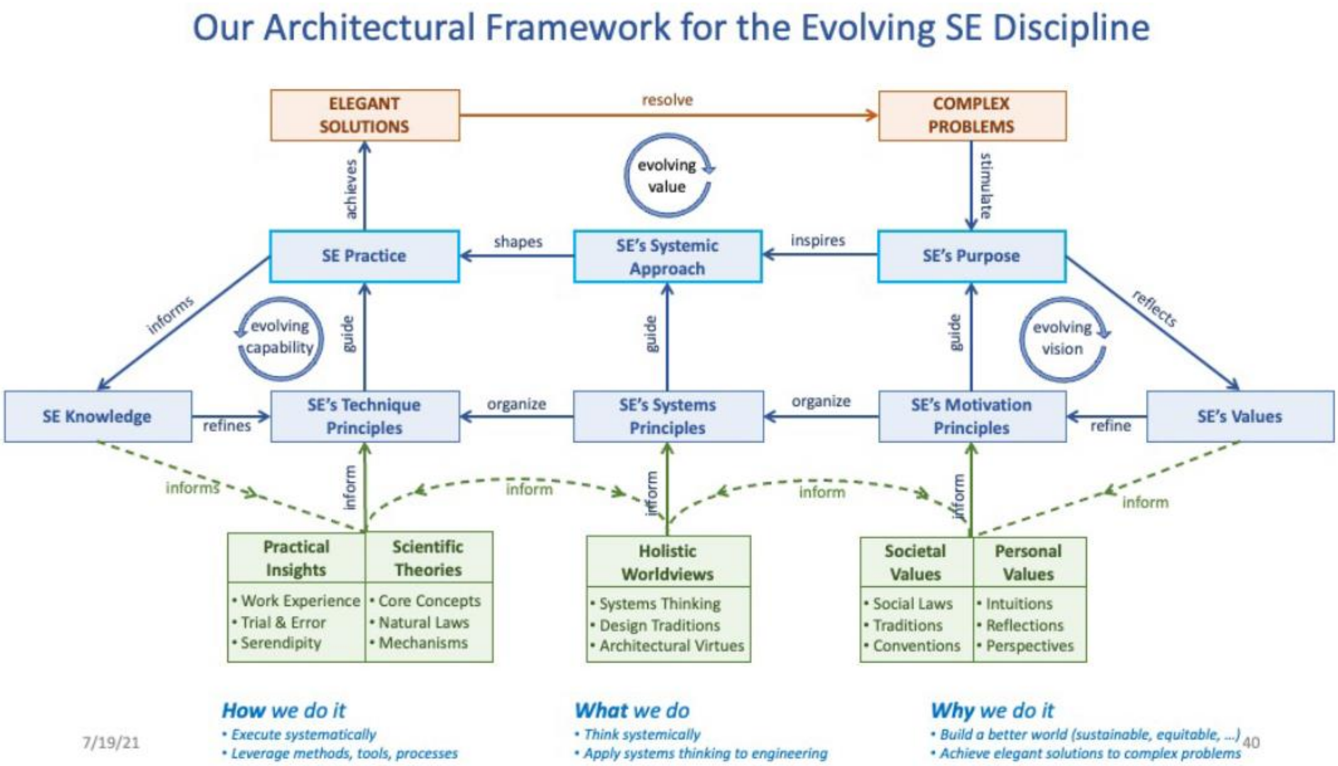
> Principle: A fundamental idea or rule that can provide guidance for making a judgment or taking an action to achieve a specified purpose in a given context.

The team further sub-classified principles as:

- Motivational Principles (that articulate WHY we do what we do, i.e., the purpose of SE), based on societal and personal values.
- Systems Principles (that guide WHAT we do, i.e., use a systemic approach to find solutions), based on holistic perspectives such as systems thinking and various design and architectural traditions.
- Technique Principles (that guide HOW we engineer systems, i.e., the SE practice), based on practical insights and scientific theories.

Using the definitions stated earlier, the team asserted that a heuristic is a type of principle, specifically a technique (HOW) principle based on practical experience. The term "heuristic principle" has been adopted, where it has been important to differentiate from "scientific principle".

The Bridge Team developed and promoted an architectural framework (below) that illustrates how these principles interact and can evolve to improve our effectiveness in developing elegant solutions to complex problems. They believe that the framework will create value within the discipline, especially as INCOSE works with other engineering and problem-solving communities that are looking for more holistic approaches to addressing the increasing complexity of the challenges that they face.



The third heuristic-related presentation, "Using Heuristics to Refine the System Physical Architecture" was delivered by Jose Fernandez. A medical-device case study was used to discuss the application of a MBSE methodology, the Integrated Systems Engineering & Pipelines of Processes in Object Oriented Architectures (ISE&PPOOA), to a product where non-functional requirements such as safety, resilience, reliability, and maintainability were important architectural design drivers.

The highlights of ISE&PPOOA include:

- A system has parts that may be either simple or composite parts. A system interacts with the environment. These interactions are described by an operational context that models the interactions as a set of scenarios
- Based on the operational context and scenarios, the engineer translates the set of specific needs into a set of system capabilities that should be solution independent. Each capability is a container of system properties that may be either system quality attributes, physical properties, states, or functions.
- In contrast to functional requirements that are allocated to system parts, non-functional requirements implementation is essentially different. Nonfunctional requirements may be met by the application of design heuristics.

As such, heuristics bridge the quality attribute model related to the problem definition and the physical architecture of the system. A heuristic describes how a quality attribute requirement, also known as nonfunctional requirement, can be controlled through design decisions to meet it. A heuristic uses knowledge from various quality reasoning frameworks such as performance, maintainability, safety, or resilience engineering.

The collection of heuristics used in ISE&PPOOA is broken into these categories:

- System architecting
- Reliability and maintainability
- Efficiency
- Safety
- Software architecting

The use of heuristics complements two other common practices:

- Allocation of functions to the system physical architecture.
- Trade-offs used to select the best technology for implementing system components.

After providing an overview of the methodology, Fernandez walked through a detailed case study of an intravascular medical device, illustrating the ISE&PPOOA method with context diagrams, use case diagrams, operational needs, safety requirements and associated safety-related heuristics and before-after architectural diagrams. The application of two safety heuristics to three non-functional safety requirements resulted in the addition of new components and interfaces in the design.

Challenges in implementing heuristics on non-functional requirements include:

- Lack of tool support for heuristic-driven implementation of non-functional requirements.
- Decisions in which two or more heuristics lead to conflicting designs.
- The initial effort to develop an appropriate collection of heuristics based on the quality attributes that are relevant to their programs.

A common theme that runs through all these presentations is the importance of teaching engineers to think, with heuristics providing a pattern for thinking creatively, effectively, and efficiently using lessons learned from prior engineering experience.

INCOSE members may access the IS2021 presentations (once posted) through the Wiley Online Library link available in the INCOSE Connect portal.

Systems Engineering at the Hello: Frameworks for Applying Systems Engineering in Early Stage R&D

By John Fitch, BS EE and Physics, ESEP, PPI Consultant and Trainer

The INCOSE International Symposium (IS2021) hosted an informative panel discussion that addressed the challenges of applying Systems Engineering disciplines and practices to Early Stage Research & Development (ESR&D). The panel included the following contributors:

- Heidi Hahn (New Mexico Tech; formerly Los Alamos National Laboratory): Moderator
- Frédéric Autran (Airbus Defense & Space)
- Michael DiMario (Astrum Systems)
- Nick Lombardo (Pacific Northwest National Laboratory – PNNL)
- Ann Hodges (Sandia National Laboratories)

While providing varied perspectives for better application of SE to early stage projects, the panel voiced a high degree of consensus on:

- The common challenges faced by ESR&D projects
- The value proposition for use of right-sized Systems Engineering on these project,
- Use of a risk-based approach toward tailoring SE practices to meet the needs of various types of projects

ESR&D projects identify, evaluate and mature technologies that may provide enhanced capabilities and performance to future systems and products. The scope of ESR&D projects includes:

- Basic Research
- Applied Research
- Exploratory Development
- Advanced Development

Each type of ESR&D project advances technology maturity, which is typically expressed in terms of Technology Readiness Levels (TRLs) from 1 to 9. TRL 1-5 are the focus of ESR&D efforts and TRL 6-9 are accomplished through traditional Product Development processes.

The panel believed that ESR&D projects suffer from high failure rates, low Return-on-Investment (ROI) and longer-than-necessary schedules because of ad hoc, limited or mechanistic application of SE practices. Limited or ineffective application of SE was caused by:

- Genuine differences in the types of thinking needed to excel in R&D when compared with later-stage product development (expansionist, divergent discovery vs reductionist convergent analysis);
- Mismatch between the R&D/Innovation and product development language and cultures;
- Belief among researchers and R&D managers that SE practices are ponderous and creativity-crushing.

There was consensus on the need to tailor and right-size SE disciplines to address the wide variety of ESR&D use cases and to reduce cultural pushback. Proposed approaches included:

- Risk-graded tailoring of SE discipline.
- Project type-driven tailoring of SE discipline.
- Use of a core (non-tailorable) set of minimum SE practices.

These tailoring approaches were not theoretical; the speakers shared their experience in deploying enterprise-level frameworks for the application of SE to ESR&D projects. Beyond the appropriate level of SE process tailoring, the frameworks also had to address the broader issues that also affect SE practice success on ESR&D projects:

- Supporting an experimentation mindset among researchers.
- Reframing language to fit the research culture, i.e. requirements become “research goals”.
- Designing organizations to facilitation effective teamwork between functional areas.
- Use of a shared SE knowledge repository to improve asynchronous communication between R&D and product development teams.

- Use of a System Readiness Level (SRL) model that combines TRLs with Integration Readiness Level (IRL) metrics.

Researchers speak of a "Valley of Death" problem at TRL 5 in which a technology, despite best efforts at maturation, gets stuck and fails to transition into use within real-world products. The panel's belief was that the application of right-sized SE can significantly reduce this risk.

Although the frameworks generally focus on risk-graded application of SE practices, the speakers' recognized that to improve R&D ROI they must also accelerate technology maturation and find new applications (derivatives) for technologies.

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Book of Abstracts

The International Council on Systems Engineering (INCOSE) has published a Book of Abstracts of Plenaries, Papers, Key Reserve Papers, Presentations, Panels, Tutorials and Invited Content associated with its 30th International Symposium, conducted online over 17-22 July, 2021. Just the list of titles, reproduced below, provides a snapshot of the scope of systems engineering as perceived by the INCOSE community, as well as a path to topics of individual interest. The full Book of Abstracts is downloadable here.

Keynote - Plenaries

K1: Countering Digital Authoritarianism

K2: The role of architecture in achieving Society

K3: How systems engineering made solar cars a reality

Presidents Panel: Accelerating through Adversity – Back to the Future!

Papers

002: Assessing a supplier to the offshore oil and gas industry following a worldwide pandemic

004: Developing domain-specific AI-based tools to boost cross-enterprise knowledge reuse and improve ...

006: Enterprise Architecture Process Guide for the Unified Architecture Framework (UAF)

007: Aspect-Oriented Architecting Using Architecture Frameworks

008: You Don't Save Money by Doing Less Testing – You Save Money by Doing More of the Right Testing

009: Why Systems Engineers May Have an Edge When It Comes to Personal Resilience

011: Innovative Approaches to Superset Asset Templates using Feature-Based Product Line Engineering

013: A Guide for Systems Engineers to Finding Your Role in 21st-Century Software-Dominant Organization

016: Evaluation of Requirements Management Processes Utilizing System Modeling Language (SysML)

018: Experience in Designing for Cyber Resiliency in Embedded DoD Systems

020: Formulas and Guidelines for Deriving Functional System Requirements from a Systems Engineering ...

021: How Missile Engineering is Taking Product Line Engineering to the Extreme at Raytheon

024: Employing a Model Based Conceptual Design Approach to Design for Resilience

027: Putting the Social in Systems Engineering: An Overview and Conceptual Development

028: The value of trade-off studies for student projects

029: Analyzing Standard Operating Procedures Using Model-based System Engineering Diagrams

030: The risk maturity model: a new tool for improved risk management and feedback

031: Feature-based Product Line Engineering: An Essential Ingredient in Agile Acquisition

032: Social Science Solutions for the Systems Engineer: What's Needed

034: Challenges in Detecting Emergent Behavior in System Testing

037: Unlocking the power of big data within the early design phase of the new product development …

038: Product portfolio mapping used to structure a mature sub-system with large variation - A case study

040: Conceptual modeling of energy storage systems

041: Predicting failure events from crowd-derived inputs: schedule slips and missed requirements

042: From UAF to SysML: Transitioning from System of Systems to Systems Architecture

043: Agility in the Future of Systems Engineering (FuSE) - A Roadmap of Foundational Concepts

045: Security as a Functional Requirement in the Future of Systems Engineering

046: Network Rails Systems Integration for Delivery (SI4D) Framework

047: Insights for Systems Security Engineering from Multilayer Network Models

049: Security in the Future of Systems Engineering (FuSE), a Roadmap of Foundation Concepts

051: Developing a Model Based Systems Engineering Architecture for Defense Wearable Technology

052: Applying Systems Engineering framework for architecting a Smart Parking System within a Smart …

053: Integrating Safety Analysis into Model-Based Systems Engineering for Aircraft Systems: A Literature …

054: A value-driven, integrated approach to Model-Based Product Line Engineering

055: Dealing with COVID-19 Pandemic in Complex Societal System for Resilience Study: A Systems Approach

056: From Brownfield to Greenfield Development – Understanding and Managing the Transition

057: Application of natural language processing for systematic requirement management in model-based systems engineering

058: Conceptual Modelling of Seasonal Energy Storage Technologies for Residential Heating in a Dutch …

062: A Framework for Identifying and Managing New Operational Requirements during Naval Vessel B

064: How can simplified requirements affect project efficiency – A case study in oil and gas

065: Application of T-shaped engineering skills in complex multidisciplinary projects

067: Idea Development Method, Applying Systems Design Thinking in a Very Small Entity

074: Enhancing Enterprise Architecture with Resilience Perspective

075: Application of A3 Architecture Overviews in Subsea Front-End Engineering Studies: A Case Study

076: Developing a Topic Network of Published Systems Engineering Research

078: A Method to Visualize the Relationship between Regulations and Architectural Constraints

079: Opportunities and Challenges of Sociotechnical Systems Engineering

080: A Metrics Framework to Facilitate Integration of Disaggregated Software Development

081: A Concept for a Digital Thread based on the Connection of System Models and Specific Models

085: Using Models and Simulation for Concept Analysis of Electric Roads

088: Requirement Patterns in the Construction Industry

089: Solar Energy Investment Framework for Real Estate in Norway – a Case Study in Systems Engineering

094: The Systems Engineering Conundrum: Where is the Engineering?

095: Demonstrating the Value of Systems Engineering as the Professional Standard of Care

098: STPA-Sec Analysis for the DevSecOps Reference Design

099: Verification and Validation of SysML Models

101: Ontology-Based search engine for simulation models from their related system function

102: Resilience Requirements Patterns

103: The Benefits of Enhanced Contact Tracing and Quarantine to Resume and Maintain College-Ca …

105: Systems Thinking in Socially Engaged Design Settings: What Can We Learn?

106: Systems Thinking: A Critical Skill for Systems Engineers

109: Implementation of tailored requirements engineering and management principles in a supplier to …

110: Framework for Formal Verification of Machine Learning Based Complex System-of-System …

112: Integrated Security Views in UAF

114: Investigation of Remote Work for Aerospace Systems Engineers

115: An Elaboration of Service Views within the UAF

116: Model-Based Systems Product Line Engineering of Physical Protection Systems

117: The Evolution of HELIX: A Competency Model for Complex Problem Solving

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124: Measuring performance and identifying metrics of machine protection systems for particle accele ..

128: An Assessment of the Adequacy of Common Definitions of the Concept of System

130: Is CAD A Good Paradigm for MBSE?

131: Towards a Software Defined Truck

132: A Systems Engineering Approach to the Design and Education of a Robotic Baby

137: UAF (Unified Architecture Framework) Based MBSE (UBM) Method to build a System of Systems …

Key Reserve Papers

KRP005: Overview of the Revised Standard on Architecture Description – ISO/IEC 42010

KRP010: Organizational Redesign Through Digital Transformation: A Case Study in the Life

KRP017: Architecture Literacy

KRP025: An Agile Systems Engineering Analysis of a University CubeSat Project Organization

KRP048: OMG RAAML standard for model-based Fault Tree Analysis

KRP063: Architecture Analysis Methods

KRP083: Broadening the Definition of Breadth in Systems Engineering

KRP091: MBSE Enabled Trade-Off Analyses

KRP096: Using Digital Viewpoint Concept Model for Defining Digital Engineering Information

KRP104: A State-of-Practice Survey of the Automotive and Space Industry Product Develop …

KRP108: Automated trade study analysis based on dynamic requirements verification in the …

KRP121: Workforce and Evaluation and Training for Digital Engineering in the US Department of …

KRP125: Conceptualizing the Lessons Learned Process in Delivery Projects: Detecting …

KRP136: Model of Models Methodology: Reuse Your Architectural Data

Presentations

Pr01: Using Heuristics to Refine the System Physical Architecture

Pr02: Utilizing a Human Readiness Level (HRL) Scale to Promote Effective System Integration

Pr03: How do we know that we know? - A Model-Based-Knowledge-Management Concept Support …

Pr07: Systems Engineering Professional Certification Standard

Pr08: How to get the most out of your Systems Engineering consultants

Pr09: Delighting your client as a Systems Engineering consultant

Pr11: Safety Engineering of Semi-Autonomous Cars

Pr12: Towards an Integrated Approach of Systems Behavior Modeling and Specification

Pr13: 6 Vs and 3 Ts of Systems Engineering

Pr14: Conflict is your friend- Managing healthy conflict in the systems engineering workplace

Pr15: Making Your Case- Negotiation and persuasion for the systems engineer

Pr16: Providing truth, trust and traceability to MBSE

Pr17: Economic Analysis of Unmanned Aerial Vehicle (UAV) Platform Options

Pr18: Am I doing the right job and am I doing the job right?

Pr20: System Holarchy Structures for Sustainable Development Goals

Pr21: Integrating MBSE and Product Lifecycle Management

Pr22: System of Systems Modeling to empower decision makers in drone based services

Pr23: A Systems Theory Approach to Building Management

Pr24: Designing Systems by Drawing Pictures and Telling Stories

Pr25: Systems Engineering – A Matter of Perspectives

Pr26: Practical demonstration of a highly functional system-centric digital thread

Pr28: MBSE Components in the Supply Chain, Spring 2021 Student Capstone Project

Pr29: Ushering in a New Era for Feature-based Product Line Engineering with the ISO/IEC 26580

Pr30: Defining a Measurement Framework for Digital Engineering

Pr31: From Systems to Silicon: MBSE-Enabled Digital Electronics Verification

Panels

P1: The MBSE Futurist’s Dilemma: Diffusing systems engineering practices in an AI dominated era

P2: Systems Engineering at the Hello – Frameworks for Applying Systems Engineering in Early Stage

P3: A Framework for Understanding Systems Engineering Principles and Heuristics

P4: Human-AI Teaming: A Human Systems Integration Perspective

P7: Solving the Digital Engineering Information Exchange Challenge

P8: Heuristics for Systems Engineering: Useful or Dangerous? Outdated or Enduring

P9: Investigating transdisciplinary systems approaches for health care access

Tutorials

T07: Overview of the INCOSE SE Handbook Version 4.0

T15: Systems Security Engineering: A Loss-Driven Focus

T19: Applied Systems Theory to Enhance Systems Engineering Practice for Complex Systems

T20: Handling Organizational Complexity

T21: From Operational Concept Development to Systems Architecture Definition with SysML and MBSE

T23: Leadership Skills for Systems Engineers

T24: Modeling and Analysis of Standard Operating Procedures

T25: Introduction to Model Simulation and Engineering Analysis with SysML

T26: Artificial Intelligence for Systems Engineers: Going Deep With Machine Learning and Deep Neur …

Invited Content

IC01: Viewing Grand Challenges as a System

IC03: Using Systems Thinking to Add Value in these Uncertain Times

IC04: Spectacular Views of the City

IC04: The next Systems Challenge: Developing resilient, effective, inclusive, sustainable so...

ICT01: Panel: To "Vee" or not to "Vee"

ICT02: DE meets SE: Building a Joint Culture

ICT03: S.O.S. for FSS: The need for Systems of Systems (SoS) Thinking per Financial ..p. 147

ICT04: Leading the Way to Diversity, Equity, and Inclusion in Systems Engineering

ICT05: Panel: The Journey from SysML 1.7 to 2.0

“

“I have one major rule: everybody is right.

More specifically, everyone has some important pieces of the truth, and all of those pieces need to be honored and included.”

Ken Wilbur

PPI SyEN SPOTLIGHT: INTERVIEW WITH KERRY LUNNEY

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

René King, Managing Editor of PPI SyEN, sat down with Kerry Lunney to discuss INCOSE and the systems engineering profession in general. The following excerpts from that interview are edited for clarity and for conciseness. [This is Part 2 of 2; part 1 appeared in PPI SyEN #102, June/July 2021]

Perhaps the most critical skillset required to achieve success in any endeavor is leadership. As someone who has been a successful leader, what is your advice concerning effective leadership?

I get asked this all the time! Any advice I would give would be tailored to the specific recipient of the advice, but I can share a few lessons that I've learned. Firstly, life happens – learn to adapt, adopt, and master the unexpected. If you thought you could plan your career to a "T" – forget it! Secondly, find inspiration from leaders with whom you resonate and emulate those traits that you admire. For me, examples would include Barack Obama and his ability to captivate an audience with his speeches, or Albert Einstein for his curious mind.

Thirdly, it's important to be accountable. Make it happen: take ownership of your life and your career; you are the leader, so lead by example. Power through those tough times.

Furthermore, I recommend embracing tactical empathy. A very good book, "Never split the difference," speaks about tactical empathy. Be empathetic, but at the same time, think about how you can embrace someone's issue to get your desired outcome. I also recommend building on your strengths and the strengths of your teams! If you build on your strengths, the weaknesses will have a much less significant impact.

Lastly, never lose your "quirkiness" – it can be the source of a great adventure. Be confident. Be true to yourself, be your authentic self! (Any veneer will eventually be seen through.)

It is important to remember that, as SE leaders, you are uniquely positioned to understand and preserve the "strategic thread", linking the policy and strategy drivers with the operational needs to guide the design for a responsive and elegant solution. This is a powerful position to be in – to influence and persuade to achieve the desired outcome. You won't always be successful but treat everything as a positive learning experience… Always seek to serve.

INCOSE Empowering Women Leaders in Systems Engineering [EWLSE] is releasing a book through Springer titled, "Emerging Trends in Systems Engineering Leadership: Practical Research from Women Leaders" early next year. I am co-authoring a chapter with Anne O'Neil and Melissa Jovic on influence and persuasion, so that's something you may want to look out for.

What is your impression of the progress INCOSE is making to foster diversity, both within the organization and throughout systems-engineering practice worldwide?

Within INCOSE, our membership is growing every day across the world, with demographics becoming more varied. We are taking steps to improve our Diversity, Equity, and Inclusion (DEI), and I feel we are making good progress. INCOSE has created a new Board position this year: Associate Director (AscD) DEI, reporting to the President. We also have created a new DEI advisory committee, chaired by the AscD DEI, and there is now a new policy on DEI.

We also have reviewed our bylaws, policies, and website to remove gender or similar bias. We've provided guidance to working groups on DEI considerations in the development of products, and we have circulated several small write-ups for consideration to bear in mind regarding DEI. Our INSIGHT publication dedicated to Diversity has been quoted in several publications in the last few years, which is really promising. We're also creating a web page dedicated to DEI which will be accessible from the INCOSE website.

Lastly, we've undertaken a review and analysis of INCOSE using the UK Royal Academy of Engineering Diversity and Inclusion Progression Framework – the results of this framework will help to plan our next steps in terms of DEI.

Regarding diversity within systems-engineering practice, I wouldn't separate it from any other kind of engineering. A diverse team is critical to tackle any problem, to look for options, to conduct trade-offs, and to select the best solution. As engineering in general embraces greater diversity, we will see greater diversity in teams that appreciate and practice systems thinking and systems engineering.

My ultimate goal for DEI is a future where we stop talking about DEI, because there will be no need to talk about it, as DEI practices will be the norm and our work on DEI will be done.

What is the status of INCOSE collaboration with PMI? Will you comment on why we need to be concerned with the integration of engineering and project management? What are the biggest challenges to the proliferation of this integration?

The collaboration with PMI is very active. We renewed our MOU with PMI in February 2021. Following the 2017 release of the "Integrating Project Management and Systems Engineering" book authored by the PM-SE Working Group, we have embarked on other projects to foster this integration. For example, we held a joint webinar in April 2021 to discuss our present collaborative activities and to identify potential new opportunities, such as contributing jointly to the SE Handbook Edition 5, looking at possible STEM joint projects, contributing to SEBoK and PMBoK collaboratively, and considering mutual recognition of each other's certification programs. There are ongoing activities to garner wider involvement in these projects as it is a very broad area.

Regarding the importance of integrating engineering and project management, they go hand in hand – one cannot succeed without the other. There are common practices, such as risk management and scheduling, but there are also differences: SE emphasizes the technical elements of system delivery, while PM focuses on the programmatic elements. It's difficult to leverage the full benefits of specific system-engineering approaches, practices, and tools without the appropriate PM support. For example, an agile approach cannot succeed without PM changes to complement it. Continuous Systems Integration, which is essential in digital engineering, cannot succeed without changes to PM practices.

Some challenges include simple things, such as use of different terminology for essentially the same concepts. We need to coordinate and synthesize the two disciplines to provide the most effective delivery or implementation model. Aligning risk sharing would be a start.

Much of the systems-engineering discussion today centers around model-based systems engineering (MBSE) and digital engineering (DE). How would you frame these concepts and the corresponding benefits for practitioners, managers, and executives?

I see a stronger relationship between systems engineering (SE) and DE, than between MBSE and DE. SE and DE are more aligned. MBSE supports a DE approach, but a DE solution is more than just MBSE.

Digital engineering must engage all the stakeholders. Furthermore, DE must consider holistically the information-set required to engineer a system, not just representations, artefacts, or the current content of a specification. The underlying data-model is key, not the model itself! Digital engineering is only possible through applying a systems-engineering approach, and MBSE can be employed as a helpful means to getting there.

Benefits of MBSE have been reported for a long time: facilitating the conceptualization of a proposed system; identifying and managing its requirements; architecting and designing it; providing better information to all engineering disciplines/specialties to support their work, etc. MBSE can be used to identify anomalies in the concept design and to challenge and verify the activities throughout the design and development phase. MBSE can help to develop appropriate test scenarios, provide a common understanding of the solution, and create a digital twin. MBSE makes the relationships, dependencies, coupling, and cohesion of a system to be more visible, and changes or alternative options can be more readily carried out and assessed.

Benefits of DE are similar to MBSE in the creation, sharing, preservation, and utilization of data (and of metadata). Additionally, DE enhances the ease of interoperability and integration with other systems utilizing or sharing the same data. DE allows for security enhancements and improved resilience of the design – dependent on the system, operating environment, and adversity scenario. Mission-level simulations may be integrated with the system simulation using digital assets, and early system verification and validation can be done via the DE environment. Additionally, DE allows for quicker, more cost-effective analysis and support during the in-service phase when there are bugs or requested changes and improvements, through exploitation of the digital twin. We used models previously to do this but not to the extent that digital engineering proposes. MBSE – as it is in systems engineering – is just one of the approaches we need to employ when doing digital engineering. And we mustn't forget there is more to digital engineering than just the technical aspects. There is also the culture, structure, and management and contractual practices of the organization to consider.

If you were to share a cautionary note as we move forward with MBSE and digital engineering, what would it be?

Interesting question! Firstly, I think we ought to engage more in the practice of MBSE and DE overall. The uptake is not happening fast enough. On green-field projects, we should be doing this right from the beginning – yet there are still green-field projects coming up with no mention or plan of utilizing MBSE, which is concerning. On brown-field projects, it may be a little bit more challenging, particularly in identifying where one would start. For example, how far back into an existing system design does one undertake digitization to enable moving forward with a digital approach for the modifications?

As a cautionary note, I would advise engineers not to get so focused on the models or data that they lose sight of the information-set required to engineer a system! We still need to practice systems engineering under the umbrella of digital engineering. If you want to carry out DE, it means using a systems approach while creating digital artefacts under a digital supported environment (contracts, mindset, risk sharing, etc.). Digital engineering requires us to look at things holistically, over the life cycle, observing interactions and performance – that's all systems work! Hence the importance of the information-set required to engineer the system.

It is interesting to note that a digital approach often involves smaller deliveries, starting with a minimum viable product (MVP) and getting feedback from the end-users, to address in future deliveries. Use can be made of the actual system or that of a digital twin to try out new ideas and aid in verification. Either way, the terminology may be relatively new and the tools may be new, but the essence behind it is relatively the same – it's systems engineering, at least how I practiced it years ago in the gaming domain.

[End]

SYSTEMS ENGINEERING SAMPLER

Selected examples of systems engineering in theory and in practice

ARTICLE: 4 ways to boost enterprise resilience with systems thinking

Many a company was taken by surprise by the impact of the Covid-19 pandemic, and at least some of them that have not made it through the challenges. In an article on the MIT Sloan School of Management website, Beth Stackpole talks about how a systems-thinking approach can help to build such resilience.

Access the article here.

ARTICLE: Making the right resilience choices for future infrastructure

In this article in *Infrastructure Intelligence*, Seth Schultz and Juliet Mian of The Resilience Shift consider the issues with defining quantifiable metrics for infrastructure resilience and setting boundaries for those who need them.

These six aspects are difficult to measure but essential to create the needed shift:

- The need to overcome fragmented governance across a system, such that all stakeholders are part of the planning, response, recovery, and adaptation cycle.
- Considering infrastructure for the critical services it provides to the wider system it is a part of, i.e., focusing on outcomes (connectivity) not outputs (a bridge).
- Taking a broader view of the social, environmental, and physical elements of an infrastructure system, to understand how a change to one part of the system can impact other parts.
- Connecting stakeholders and guidance across different sectors, towards a joined-up approach across the infrastructure system-of-systems rather than multiple siloed approaches.
- Unlocking the finance through articulating the value of resilience through the whole infrastructure lifecycle, to governments and investors
- Leadership. Our future leaders need to both be resilient, in the face of deep uncertainty, and to lead for resilience, recognizing all the previous points.

Access the article here.

ARTICLE: New Design Approaches For Automotive

"The ultimate goal is to create an executable specification based on industry-accepted standards, with enough flexibility to be able to customize that spec for different customers. This is a difficult engineering challenge, and by most accounts, automotive is now at the top of the list for complex electronic design."

In this extended article, Ann Steffora Mutschler, executive editor of Semiconductor Engineering, discusses the growth in the use of Model Based Systems Engineering (MBSE) and Model Based Requirements Engineering (MBRE) in the automotive industry.

"Will we get ever to the point that you just put a specification in the black box and out comes the system and chip?" is the question asked by Kurt Shuler, vice president of marketing at Arteris IP. The answer is concluded to be: Probably not. It is clear that trying to define everything up front is not going to deliver the best solution, but finding the balance between the appropriate level of detail required at each level and the time spent on these models will deliver much better results.

Access the article here.

STANDARD: Interface Definition Language™

Interface Definition Language™ (IDL) is a specification from the Object Management Group (OMG®), with whose Unified Modeling Language (UML) and Systems Modeling Language (SysML) specifications many systems engineers are familiar.

The following extract from the scope paragraph of the IDL v4.2 specification provides a succinct description of its purpose:

IDL is a descriptive language used to define data types and interfaces in a way that is independent of the programming language or operating system/processor platform.

The IDL specifies only the syntax used to define the data types and interfaces. It is normally used in connection with other specifications that further define how these types/interfaces are utilized in specific contexts and platforms:

- Separate "language mapping" specifications define how the IDL-defined constructs map to specific programming languages, such as, C/C++, Java, C#, etc.
- Separate "serialization" specifications define how data objects and method invocations are serialized into a format suitable for network transmission.
- Separate "middleware" specifications, such as, DDS, or CORBA leverage the IDL to define data-types, services, and interfaces.

The description of IDL grammar uses a syntax notation that is similar to Extended Backus-Naur Format (EBNF)."

More information on IDL can be found here.

STANDARD: Requirements Interchange Format (ReqIF)

The Requirements Interchange Format (ReqIF) Standard is an Object Management Group (OMG) standard that originated in the automotive industry. The objectives for the ReqIF standard are summarized below from part 1.2 of the standard:

> The automotive industry introduced requirements management around 1999. Not surprisingly, with this established discipline in place, manufacturers and suppliers strive for collaborative requirements management where requirements management does not stop at company boundaries. However, two companies in the manufacturing industry can rarely work on the same requirements repository for technical and organizational reasons, and sometimes do not work with the same requirements authoring tools. Therefore, a generic, non-proprietary format for requirements information was needed to satisfy the urgent industry need for exchanging requirement information between different companies without losing the advantage of requirements management at the organizations' boundaries.

ReqIF defines such an open, non-proprietary exchange format. Companies can exchange requirement information by transferring XML documents that comply with the ReqIF format. This allows improved collaboration between partner companies (or departments within a company) without requiring that they use the same requirements-authoring tool.

The ReqIF standard essentially defines a standardized format for requirements documents with a hierarchical structure that uses formatted text (including references to binary files) to express uniquely identified requirements, together with their associated attributes, established relationships between requirements, groups of relations, and user access control. These also happen to be the underlying features of most requirements authoring tools.

More information on ReqIF can be found here.

STANDARD: Architecture Analysis and Design Language (AADL)

Architecture Analysis and Design Language (AADL) was originally published by the Society of Automotive Engineers (SAE) in 2004. The latest revision of the language is available as SAE standard AS5506 Rev C.

From a June 2015 CMU article: "AADL consists of a textual and graphical language with precise execution semantics for modeling the architecture of embedded software systems and their target platforms, an XML/XMI interchange format to support AADL model exchange between contractors and interoperability with commercial and in-house tools, and an error model annex as a standardized AADL extension to support fault/reliability modeling and hazard analysis.

"AADL can be used to model embedded systems as component-based system architecture; component interactions as flows, service calls, and shared access; task execution and communication with precise timing semantics; and execution platform and specify application binding; and operational modes and fault tolerant configurations."

Further reading on AADL can be found at:

- The Architecture Analysis & Design Language (AADL): An Introduction.
- An Overview of the SAE Architecture Analysis & Design Language (AADL) Standard: A Basis for Model-Based Architecture-Driven Embedded Systems Engineering
- Create and Analyze System Models Using Architecture Analysis and Design Language
- The Architecture Analysis and Design Language: an overview
- Architecture Analysis and Design Language (AADL) Tool
- Architecture Analysis and Design Language (This site also contains a podcast.)

ORGANIZATION: International Association for the Engineering Modelling, Analysis and Simulation Community (NAFEMS)

NAFEMS is an individual membership-based international society that aims to provide knowledge, international collaboration and educational opportunities for the use and validation of engineering simulation.

The specific goals of NAFEMS are to:

- Be the recognized independent authority and trusted source for communicating engineering simulation knowledge, and for sharing best engineering modeling, analysis, and overall simulation practices in developing reliable products and innovative solutions.
- Facilitate unbiased worldwide communication and collaboration between industries, academia, and government organizations for the advancement of best practice in multidisciplinary engineering simulation expertise.
- Develop and deliver training and personal educational opportunities that are aligned with the rapidly advancing engineering simulation technologies.
- Have a strong impact on product quality, development efficiency and safety.

NAFEMS working groups play a major role in the activities of the organization. Drawn from experienced international membership, the technical working groups identify areas of interest to the community, gaps in educational materials, requirements for further research, and opportunities for collaboration in engineering analysis and simulation. The groups draw together a blend of leading engineering practitioners, academic researchers, and software vendors, giving independent insight and perspective into every aspect of engineering analysis and simulation.

The Society engages with the analysis and simulation community with more than fifty events each year, including conferences, seminars, workshops, open forums, and webinars.

NAFEM's PSE (Professional Simulation Engineer) Certification allows engineers and analysts to demonstrate competencies acquired throughout their professional careers. Independently assessed by NAFEMS, the Certification enables individuals to gain recognition for their level of competency and experience, as well as enabling industry to identify suitable and qualified personnel.

The NAFEMS Resource Centre is a database that contains thousands of presentations, books, webinar recordings, magazine articles, journals, and more, which have been categorized and tagged in one central accessible location. There are currently over 1,500 resources available, with this number growing weekly. Members have access to numerous types of resource as part of their membership, including presentations from previous events, conference papers, webinar archives, and much more.

Over the past 35 years, NAFEMS has produced over 200 books covering the cutting-edge of engineering analysis and simulation. Many of the standards used today were tested against benchmarks produced by NAFEMS, whilst most of its publications have been written by industry experts, reviewed extensively by its working groups, and are available at significant discounts to its members. Each year, NAFEMS produces a plethora of how-to guides, industry surveys, technical textbooks, academic journals, best-practice guidelines and more.

NAFEMS and the International Council on Systems Engineering (INCOSE) have established a relationship for mutual participation and collaboration for the advancement of engineering simulation and model based systems engineering. This collaboration includes the implementation of a joint cross-organizational working group on Systems Modeling & Simulation. The mission of the SMSWG is to develop a vendor-neutral, end-user driven consortium that not only promotes the advancement of the technology and practices associated with integration of engineering simulation and systems engineering, but also acts as the advisory body to drive strategic direction for technology development and international standards in the space of complex engineering.

More information about this working group is available here.

See also the NAFEMS Systems Modeling & Simulation (SMS) Working Group home page.

More information on NAFEMS is here.

MITRE knowledge-sharing

As a not-for-profit organization, MITRE works in the public interest across federal, state, and local governments, as well as industry and academia. They collaborate widely with the community of practitioners – including academia, industry, and other non-profits – to advance the discipline and practice of systems engineering. Their staff also publish in the open literature, including conference proceedings, technical journals, and books.

Their many resources include their Systems Engineering Guide, their Systems Engineering Competency Model, Key Questions for Acquisition Success, Risk-management and technology-evaluation toolkits, and a white-paper series. Also, MITRE and scientific publisher CRC Press have collaborated on six books on enterprise systems:

- Engineering Mega-Systems: The Challenge of Systems Engineering in the Information Age
- Enterprise Systems Engineering: Advances in the Theory and Practice
- Model-Oriented Systems Engineering Science
- Probability Methods for Cost Uncertainty Analysis: A Systems Engineering Perspective
- Analytical Methods for Risk Management: A Systems Engineering Perspective
- Advanced Risk Analysis in Engineering Enterprise Systems

Learn more and access these materials here.

VIDEO: Six Myths of Systems Engineering

In this 13-minute video, Robert Halligan, Editor-in-Chief of PPI SyEN and Managing Director of Project Performance International, discusses six common misconceptions of systems engineering. These misconceptions include:

- Systems engineering is a process.
- Systems engineering is for systems engineers.
- Process standards are icons of virtue.
- MBSE is SysML.
- Functional design precedes physical design (synthesis).
- Work breakdown structure is a breakdown of work.

Watch this video here.

ACADEMIA: The University of North Carolina at Wilmington to Offer New Programs in Cybersecurity and Intelligent Systems Engineering

UNC Wilmington has received approval from its Board of Governors to begin two new bachelor-of-science programs: cybersecurity and intelligent systems engineering. UNCW is the first institution in the UNC System to offer undergraduate degrees in those disciplines. The programs are slated to start in fall 2022, pending approval by the Southern Association of Colleges and Schools Commission on Colleges.

The intelligent systems engineering degree brings together computing and engineering disciplines and liberal arts to prepare students to succeed in an area that is becoming increasingly important for industry, government, and society. Industrial sectors such as agriculture (precision farming), transportation (smart cars), medical devices (intelligent sensors) and government initiatives (smart cities) could benefit from the engineering skills and knowledge students graduating from this program would exhibit.

More information on the new UNCW programs can be found here.

ACADEMIA: New Graduate Certificate in Systems Engineering from Australian National University (ANU)

The ANU College of Engineering and Computer Science, based in the Australian capital city of Canberra, ACT, has introduced a Graduate Certificate of Systems Engineering. This Graduate Certificate can be completed as a standalone postgraduate qualification or used as a pathway to a Master of Engineering at ANU. The next intake for applications is Semester 1, 2022.

There are many other ways to study systems engineering in Australia (apart from PPI and CTI's training!). Existing Australian university providers of systems engineering education are:

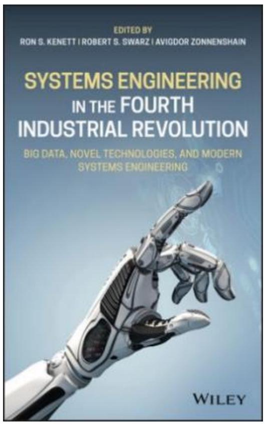
Undergraduate:

- Bond University – Systems Thinking & Management Modelling for Projects (single unit)
- Curtin University – Industrial and Systems Engineering (Major)
- James Cook University – Introduction to Systems Engineering and Project Management (single unit)
- University of Adelaide – Defense Systems (Major)
- University of South Australia – Principles of Systems Engineering (single unit)

Postgraduate:

- University of Melbourne – High Integrity Systems Engineering (single unit)
- University of New South Wales- Master of Systems Engineering
- University of South Australia – Graduate Certificate in Defense Systems Integration
- University of South Australia – Master of Defense Systems Integration

SYSTEMS ENGINEERING RESOURCES



Systems Engineering in the Fourth Industrial Revolution: Big Data, Novel Technologies, and Modern Systems Engineering

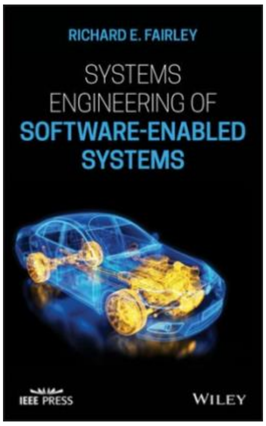
Ron S. Kenett (Editor), Robert S. Swarz (Editor), Avigdor Zonnenshain (Editor)

From the Wiley webpage:

Systems Engineering in the Fourth Industrial Revolution: Big Data, Novel Technologies, and Modern Systems Engineering offers a guide to the recent changes in systems engineering prompted by the current challenging and innovative industrial environment called the Fourth Industrial Revolution — INDUSTRY 4.0. This book contains advanced models, innovative practices, and state-of-the-art research findings on systems engineering. The contributors, an international panel of experts on the topic, explore the key elements in systems engineering that have shifted towards data collection and analytics, available and used in the design and development of systems and also in the later life-cycle stages of use and retirement.

Written for systems engineers, *Systems Engineering in the Fourth Industrial Revolution* offers an up-to-date resource that contains the best practices and most recent research on the topic of systems engineering. The book covers a wide range of topics including five systems engineering domains: systems engineering and systems thinking; systems software and process engineering; the digital factory; reliability and maintainability modeling and analytics; and organizational aspects of systems engineering.

See this book at Wiley Online Library.



Systems Engineering of Software-Enabled Systems

Richard E. Fairley

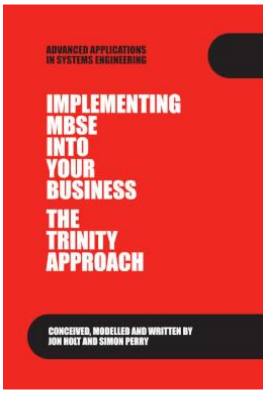
From the Wiley webpage:

Systems Engineering of Software-Enabled Systems offers an authoritative review of the most current methods and techniques that can improve the links between systems engineering and software engineering. The author offers an introduction to systems engineering and software engineering and presents the issues caused by the differences between the two during the development process. The book reviews the traditional approaches used by systems engineers and software engineers and explores how they differ.

The book presents an approach to developing software-enabled systems that integrates the incremental approach used by systems engineers and the iterative approach used by software engineers. This unique approach is based on developing system capabilities that will provide the features, behaviors, and quality attributes needed by stakeholders, based on model-based system architecture. In addition, the author covers the management activities that a systems engineer or software engineer must engage in to manage and lead the technical work to be done.

Written for advanced undergraduates, graduate students, and practitioners, *Systems Engineering of Software-Enabled Systems* offers a comprehensive resource to the traditional and current techniques that can improve the links between systems engineering and software engineering.

See this book at Wiley Online Library.



Implementing MBSE into Your Business - The Trinity Approach

Jon Holt and Simon Perry

ISBN: 978-0-9934857-5-6

Whilst the theory and practice of MBSE is becoming more mature, one of the biggest obstacles in realising the full benefits of an MBSE approach is how to develop a strategy in order to plan and, ultimately, realise its implementation in an organisation.

Many organisations rush into into buying MBSE tools and training courses, without any forethought. It is essential that an organisation understands the reasons why it is adopting MBSE, what its current MBSE capabilities are, what future MBSE capabilities it requires and how to plan to evolve in terms of its people, processes and tools in order to achieve its future goals.

This book is aimed at practitioner-level Systems Engineers and draws on the authors' decades of experience applying and deploying MBSE in companies of all sizes. It introduces the Trinity Approach to MBSE implementation, which provides a toolkit to help organisations determine their reasons, capabilities and planned evolution for an effective MBSE implementation.

See this book at the INCOSE UK online store.

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.

Websites of note

https://sw-eng.larc.nasa.gov/supporting-products/build-qual-product-reqs/

This webpage provides download access to a number of requirements-engineering documents:

- Product Requirements Development and Management Procedure (and associated Checklists)
- Product Requirements Review Procedure (For Low Control)
- Guide for Managing and Writing Requirements
- Example Review Item Disposition (RID)
- Requirements Metrics Collection Worksheet
- Example DOORSTM Work Instructions
- Sample Requirements Document Template
- Sample Requirements Document Template Instructions
- IEEE Std 1233,1998, IEEE Guide for Developing System Requirements Specifications (R 2002)
- IEEE Std 1362, 1998 Guide for Information Technology – System Definition – Concept of Operations (ConOps) Document (R 2007)
- MIL-STD-961E, 2003, Defense and Program-Unique Specifications Format and Content

https://resources.jamasoftware.com/ebook

This webpage provides access to downloads of the following SE-relevant eBooks:

- ASPICE 101: The Complete Guide For Automotive Development
- Best Practices Guide to Requirements & Requirements Management
- Best Practices Guide for Writing Requirements

- How to Overcome Three of the Biggest Challenges in Medical Device Development
- Optimize Engineering Team Collaboration to Streamline Product Development
- Project Management Best Practices
- The Complete Guide to ISO 13485 for Medical Devices
- and others …

https://ndiastorage.blob.core.usgovcloudapi.net/ndia/2016/systems/18854_MichaelGooden.pdf

This webpage overviews a thesis by Michael E. Gooden (Ph.D. Candidate), School of Engineering and Applied Science, George Washington University. The thesis, "Return on Investment for Complex Projects Utilizing Model Based Systems Engineering (MBSE)", provides scarce if limited data on that critically important question. From the overview, the scope considered to comprise MBSE is unclear. SysML is clearly within that scope, however.

https://www.ssse.ch/content/mbse

This page, the Model-based Systems Engineering (MBSE) knowledge exchange of the Swiss Chapter of INCOSE, offers a number of downloadable presentations on aspects of MBSE, from “where to start" to advocacy of Arcadia/Capella.

https://mersyse.com/index.php

This substantial website relates to what the authors call "Relativized System Engineering (RSE)”, and related concepts. The site records academic and industrial endeavours spanning the late1990s to date. The main contributors to the site are Messrs. Henri Boulouet, Vincent Brindejonc, Eric Campo, Fabrice Fleuchey, and Bruno Massy de la Chesneraye. The site is most likely to appeal to those with an interest in systems science who have the time and energy to search in French or a French version of English for potential nuggets.

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Course Title	Targeted Region	Local Starting Time	Dates
Systems Engineering Management	Europe	9:00 CEST (UTC +2:00)	Aug 23-27, 2021
Systems Engineering Management	United Kingdom	8:00 BST (UTC +1:00)	Aug 23-27, 2021
Systems Engineering Management	South Africa *[only]*	9:00 SAST (UTC +2:00)	Aug 23-27, 2021
Requirements Analysis and Specification Writing	North America	8:00 EDT (UTC -4:00)	Aug 30 – Sep 03, 2021
Requirements Analysis and Specification Writing	South America *[only]*	9:00 BRT (UTC -3:00)	Aug 30 – Sep 03, 2021
Requirements, OCD & CONOPS in Military Capability Development	North America	8:00 EDT (UTC -4:00)	Aug 30 – Sep 03, 2021
Requirements, OCD & CONOPS in Military Capability Development	South America *[only]*	9:00 BRT (UTC -3:00)	Aug 30 – Sep 03, 2021

FINAL THOUGHTS

Syenna's Corner

If you have read Syenna's Corner in previous editions, you may have a rough idea of my age. In fact, I am nearly as old as written forms of Systems Engineering (SE), but people have been SE-savvy for a lot longer than that, which is my theme this month.

I am grateful to Professor Stephen Halliwell for telling me that the ancient Greeks used the term *sustema* (σύστημα). It referred to many phenomena conceptualized as an organized structure of parts that interact to form a functional whole: for example, this included political constitutions, the human body, musical systems (of intervals, scales etc.), armies, and various other institutions.

I am convinced that ShakSEpeare (1564 – 1616) knew about SE. (William was not consistent in the spelling of his own name, so I feel at liberty to tweak it to my purposes.) He devoted much of his intellect to his own famous line: "*To SE, or not to SE? That is the question*." He could have saved himself a lot of trouble, if he had had access to the CMU/SEI report at https://resources.sei.cmu.edu/asset_files/SpecialReport/2012_003_001_34067.pdf.

I once asked a senior executive whether we should let the bad stuff happen or head it off with some risk management. ShakSEpeare's Hamlet puts this so eloquently: "*Whether 'tis nobler in the mind to suffer the slings and arrows of outrageous fortune, or to take arms against a sea of troubles, and by opposing, end them?*"

It is no accident that, in love, Hamlet is OPHELIA'S, which is an anagram of SHOPAILE, which we all know is an acronym of Systems Have Organization, Purpose, Architecture, Interfaces, Life cycles, and Elements.

Have you ever worked on a doomed project, for which half the requirements are missing, the ones present are mostly rubbish, and the CEO cut out requirements-analysis activities to save cash? If so, ShakSEpeare has the verse for the moment: "*Once more unto the breach, dear friends, once more.*"

I am sure that ShakSEpeare belonged to an SE society that had to be kept SEcret because it was seen as SEditious by the authorities. Instead of doing what they were told, these people asked dangerous questions such as, "are you sure you understand the problem?" and "how about if we did it a different way?" Further adding to their suspiciousness, they couldn't explain to mere mortals what they were about, and they talked in a language understood only by themselves, which is ironic given that SE is meant to be a silo-buster. Think, dear reader, how much things have changed in the last 400 years!

As part of their induction, members had to learn a list of ShakSEpeare plays and swear never to reveal it; in a Dan-Brown-esque way, this would allow the knowledge to be passed on through the generations. Sadly, an exquisite modern form of torture (a multiple-choice exam) has forced several members to crack, and we now know the list to be as follows:

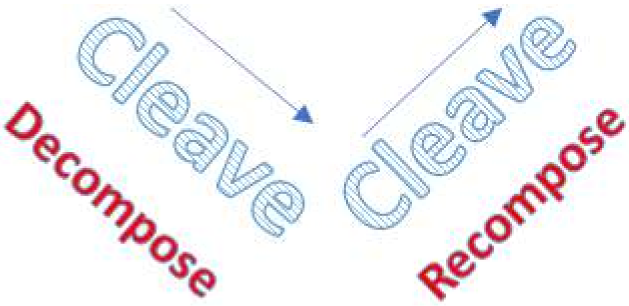
> Merchant of Venice, King John, Lear, Othello, Venus and Adonis, Measure for Measure, Macbeth, Much Ado About Nothing, Henry V, Dionysys, Diana.

I can now reveal the last part of this puzzle in an SyEN exclusive. I recently came across a 16th-century decoding device, formed as follows. An inner ivory disc is divided into 26 sectors, marked up with the letters of the alphabet. An outer ivory ring, inscribed with the numbers 0 to 25, can be rotated around the inner ring. If the number 1 is positioned against E for Effectiveness (the nirvana of SE), the initial letters of the "playlist" convert to the number 9781118999400. This, of course, is the ISBN number of a well-studied SE handbook.

Answer to last edition's SE Riddle

In the previous edition of PPI SyEN, I asked, "What was Syenna thinking in this diagram?"

Unfortunately, no correct answers were submitted, but I hope you find the answer interesting:



Syenna was thinking of the familiar "V"-diagram of systems engineering.

The word, "cleave", can mean "to cut apart" or "to bind together", depending upon its context. (It's an example of an auto-antonym: a word with multiple meanings, one of which is the opposite of another.

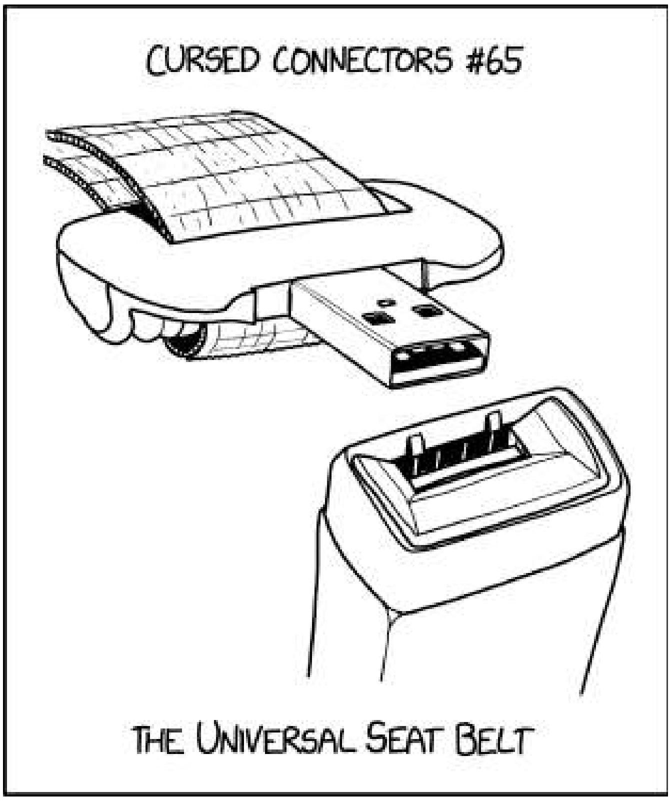
Why not submit a riddle of your own, to be published in a future edition of PPI SyEN?

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

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.

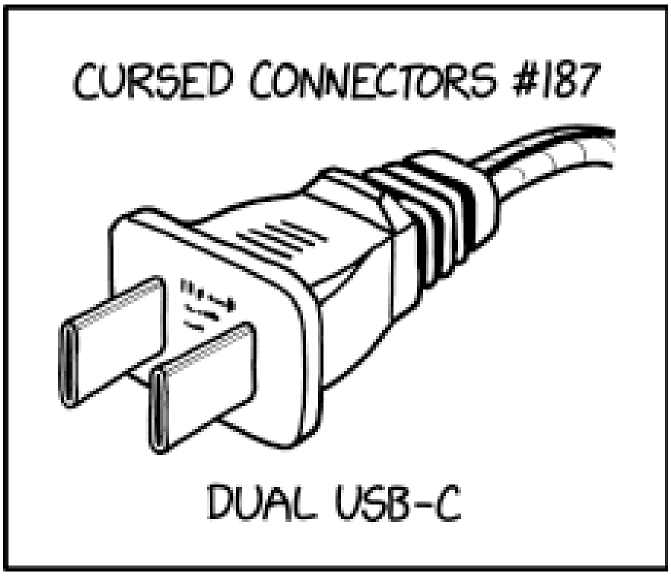


https://xkcd.com/2495/

The last wish of a Product Manager:
"When I die, I want the developers I have worked with, to lower me into my grave so that they can LET ME DOWN one last time."

The response from the developers:
"At least the requirement is clear."

(origin unknown; found on LinkedIn)



https://xkcd.com/2493/