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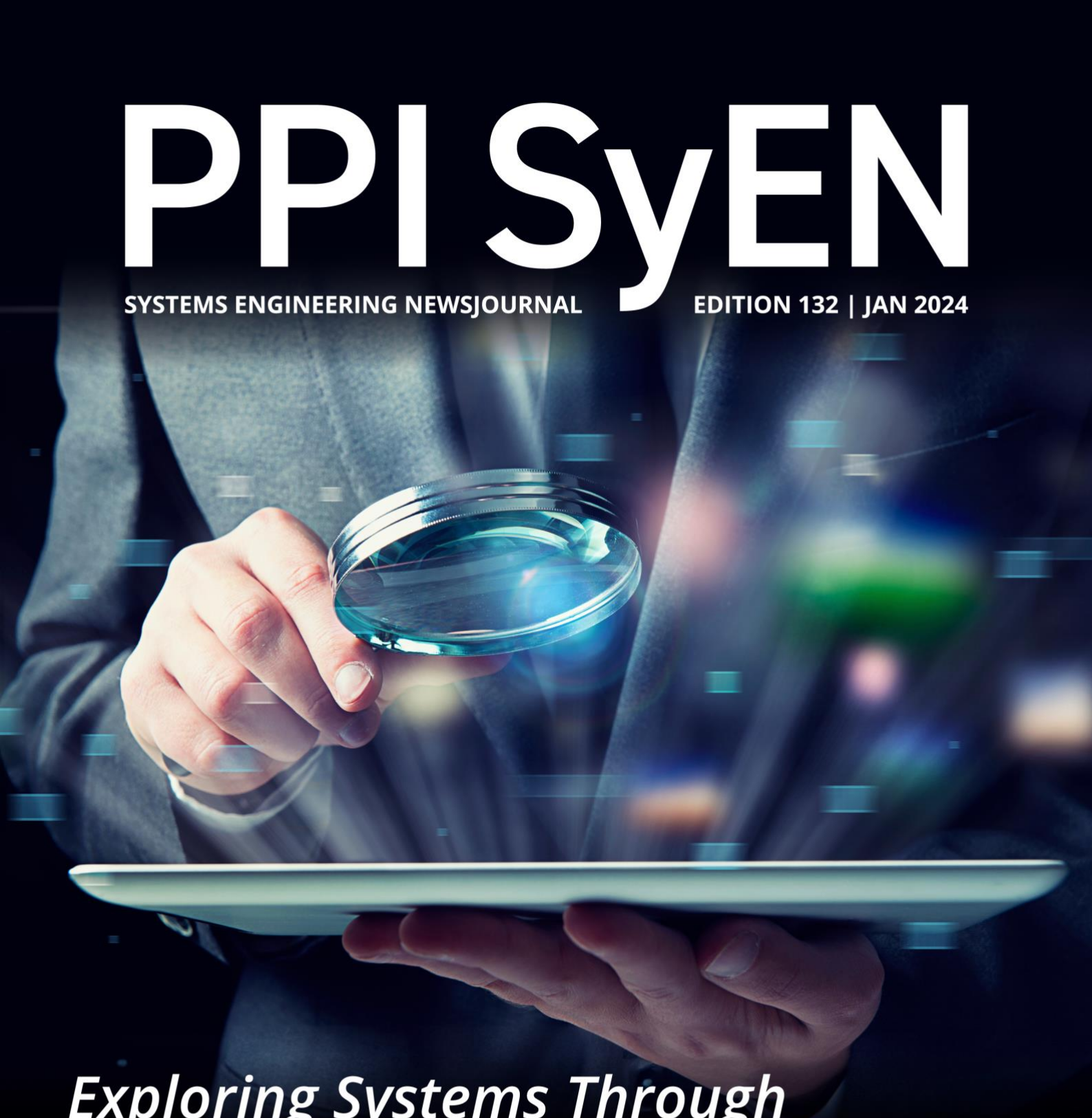

Exploring Systems Through Various Lenses

CONSIDERING DIFFERENT PERSPECTIVES
A Rapid Immersion into Systems Thinking: Part 2

A PROJECT PERFORMANCE INTERNATIONAL PUBLICATION | PPI-INT.COM

PPI SyEN

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WELCOME

Dear Readers,

As we usher in 2024, I am thrilled to present to you the fresh edition of PPI SyEN. It is with anticipation that we step into this new year, ready to embrace a year filled with learning and innovation.

This month, our 2024 PPI SyEN journey begins with the theme 'Converging Concepts: Exploring Systems Through Various Lenses,' where we cover a range of insights and perspectives on systems-related topics.

In this issue, learn about updates from the Resilience Engineering Association, along with highlights from INCOSE in Q4 of 2023. Immerse yourself in the recent strides of the Systems Engineering Society of Australia (SESA) and take a look at the notable Q4 accomplishments of the Systems Engineering Research Center (SERC).

Moreover, uncover the details of NIST's easyEXPRESS tool for Product Manufacturing Modeling, and read about INCOSE's Academic Equivalency Agreement with Drexel University.

It is also with excitement that we bring further updates about growing PPI-INCOSE's Systems Engineering Tools Database (SETDB), an indispensable resource for SE practitioners.

In the sphere of SE events, we offer you a preview of the 2024 Systems Thinking and Modeling Symposium by SDS Oceania, alongside knowledge-packed webinars from IIBA and PDMA that are sure to be highly informative.

Anticipate what lies ahead for Smart Cities Events in 2024 and revisit the highlights from Capella Days 2023 with their curated video and presentation collection.

Our feature article, written by John Fitch and René King, is the second installment reflecting upon the Waters Courses on Systems Thinking - a compelling read following the series debut in December 2023.

To augment your professional development journey, we have highlighted upcoming NAFEMS e-Learning courses, listed resources primed for Product Development and Innovation, and spotlighted essential publications, including the enlightening "Don't Panic: The Absolute Beginner's Guide to SysML 2.0."

As we navigate through the evolving landscape of SE, it is our hope to inform, inspire and share valuable knowledge with our esteemed readers.

Happy reading! See you in February ☺

Warm regards,

René

Managing Editor (on behalf of the Editorial Team)

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.

Resilience Engineering Association (REA) News

Issue #15 (December 2023) of the Resilience Engineering Association (REA) Newsletter includes a 243-page summary of the Proceedings of the 10th Resilience Engineering (RE) Symposium that took place in Sophia Antipolis, France in June 2023. The symposium theme, *Resilience at frontiers, frontiers of resilience*, was reflected in the desire to clarify the boundaries of RE and study how RE can help address increasing system complexity. To that end, the symposium sought to answer questions such as:

- What is the nature of boundaries to be considered by Resilience Engineering studies?
- How do their nature and dynamic affect adaptive capacities?
- How do other boundaries (organizational, national, or geographical) affect systems adaptive capacities?
- How does the RE perspective adapt to support organizations coping with this new complexity?
- What is the actual and future nature of complex threats and opportunities?
- What are the limits of the RE perspective towards their complexity?
- Are there principles, concepts and practices that can be scaled-up (or not) from resilient systems to resilient organizations towards resilient societies?

The diverse nature of the RE discipline is reflected in the breadth of symposium content, summarized as thirty articles in the Proceedings:

- A graph with a thousand edges: rummaging in complex work varieties
- A Joint Activity and Coordination Approach to Graceful Extensibility in Emergency Events
- Bound by Tradition? Functional Resonance Analysis Method (FRAM) as an Instrument for Organisational Diagnosis in Literature and Practice
- Command-and-Control Policy Implications for the TRUSTS Resilience Framework
- Conceptualizing resilience through a temporal lens: the role of interaction dynamics
- Deep down and up high resilience in systems recovery - studying the San José Mine (2010) and Apollo 13 (1970) accidents
- Design for resilient performance: a study of toolbox talks in construction
- Exploring the links between leadership and resilience – a middle managers' perspective
- Facilitated Debriefs in Trauma Health Care Simulations Enable Resilience
- Flightdeck Observation for Learning from Successful Daily Operations: Development of Japan Airlines (JAL) Resilience Operation Monitoring
- From academia to society: How to empower citizens in times of crisis
- Handling the Multi-Party Dilemma
- How Richard Cook Prepared Me to See the Impact of a New Technology on Complex Cognitive Nursing Work
- Joint Performance Graphs (JPG): Visualizing Resilient Performance?
- Learning and Improvement team

- Learning from Hassles, Big and Small
- Meaningful Learning: What can we learn from what actually happened and how can we become safer? The experience of one technical breakdown from a complex domain
- New Tricks for New Dogs: Using Systemic Contributors and Adaptations Diagramming (SCAD) for Blunt End Work Insights
- Perturbation Training: Insights for Training Design in the Resilience Engineering Approach
- Post Incident Learning
- Proactive Organizational Learning Toward Adaptive Capacity Building, Leveraging Data Analytics and Machine Learning
- Resilience and initiative: actions of informal actors in disasters
- Re-thinking a system's spatial and temporal boundaries through art
- RE-working rules: supporting resilience through collaborative rule-making
- Safety culture specialists as resilience professionals – insights from Nuclear Power Plant (NPP) construction
- Seeking Advantage in Video Games
- Side-Effects of Resilience Engineering Interventions: A Review
- Surviving in *The Martian*: resilience and imaginaries in extreme situation
- The Resilience of Resilience Engineering: Extending resilient design methodologies with a regenerative design approach
- Work-as-Imagined vs. Work-as-Done during a Hospital Response to a Disaster

PPI SyEN readers are encouraged to select a few of these articles as "quick reads" to gain an insight into the RE discipline and then dive deeper into topics of interest. These brief topical summaries are well-written and provide sufficient reference works to support further investigation.

The 2023 Young Talents Workshop

The REA welcomes and annually recognizes high-potential Master's and PhD students whose research aligns with the interests of the REA community. The 2023 Young Talents Workshop took place before the commencement of the REA symposium, having been preceded by a virtual gathering of selected candidates. The virtual workshop provided an opportunity for brief candidate presentations, followed by constructive feedback in preparation for the in-person workshop.

2023 candidates and their areas of interest included:

- Francesco Simone - Methods to quantitatively assess resilience in cyber-socio-technical systems.
- Antonio Nakhal - How safety reporting systems are exploited in the complex socio-technical systems to improve their interaction and the capacity to manage changes.
- Birte Fagerdal - Adaptive capacity in different types of hospital teams.
- Helene Degerman - Adaptive capacity of public management during the "European refugee crisis of 2015".
- Mirela Schramm Tonetto - How to promote resilient performance (productivity, quality, and reliability) in construction projects.
- Steven Foster - How physicians adapt their workflows during patient handoffs to balance tradeoffs between stress and workload and patient safety.
- Christine Jefferies - Analyze stories of adaptation that might enhance organizational learning both vertically and horizontally in the domains of healthcare and defense acquisition.
- Peng He - How resilience engineering can affect the civil aviation industry compared to

traditional safety management
- Ivenio Teixeira de Souza - Extending the applicability of FRAM in quantitative terms.
- Maria Calero Gonzales - English railway system resilience performance, i.e., dealing with with disturbances, uncertainties, and pressures.

Thanks to REA Contributors

The REA offers its thanks to two leaders of the association for their significant contributions. Ivonne Herrera was recognized for her four year leadership terms as the REA President, particularly for her efforts to maintain forward momentum during the global pandemic. Eric Rigaud was lauded for his efforts in coordinating the flow of an engaging and effective 2023 symposium.

Upcoming Events

The REA highlights that 2024 will include multiple events that may be of interest to the RE (and broader systems engineering) communities:

- 27th Annual Applied Ergonomics Conference (25-28 March in Kentucky, USA)
- Human Factors and Ergonomics Society Europe Chapter Meeting (17-19 April in Lübeck, Germany)
- 33rd European Safety and Reliability Conference - ESREL 2024 (23-27 June in Cracow, Poland)
- 15th International Conference on Applied Human Factors and Ergonomics - AHFE 2024 (24-27 July in Nice, France)

See prior REA Newsletters here.
Learn more about the REA.

INCOSE Q4 Highlights

The 4Q2023 edition of the INCOSE Members Newsletter was organized to highlight different aspects of the INCOSE catchphrase, "*Connect, Learn, Lead, Prosper*."

- Connect – meet new leaders.
- Learn – insights from the Member Survey.
- Lead – explore progress from working groups and initiatives.
- Prosper – through the latest products and publications.

Leadership Notes

Marilee Wheaton penned her final article as INCOSE President, emphasizing the significant organizational changes that have occurred during her two-year term. Some of these include:

- Progress against the SE Vision 2035 and the Future of Systems Engineering (FuSE) initiative
- Record participation at the International Symposium (IS2023)
- The rollout of the Professional Development Portal (PDP)
- Continued growth in Individual and Corporate memberships
- Expansion of Diversity, Equity and Inclusion (DEI) initiatives

The 4Q2023 newsletter also recognized the contribution of recent leaders and provided an

opportunity for them to share their reflections. These individuals include:

- Michael Vinarcik, Treasurer
- Barclay Brown, CIO
- Kirk Michaelson, Director of Outreach

New and renewing members of the Corporate Advisory Board (CAB) include:

- Ball Aerospace
- Embraer
- Mitsubishi Electric
- Northrop Grumman
- University of Maryland, Baltimore County (UMBC)

Member Survey Results

In July, INCOSE launched a survey to inform a new strategic plan with the voice of its members. Nearly 2000 members and CAB associates responded with consistent participation across the three sectors (Americas, EMEA, Asia-Oceania). Takeaways from the survey include:

- 72% of respondents are "engaged" in the organization with 85% planning to renew their membership.
- 63% of respondents believe that the value of membership is consistent with its cost.
- Members' level of engagement tracks with their perception of value.
- INCOSE publications, technical products, and online resources are perceived as the services that create the most value.
- Less than 1/3 of members have attended an International Symposium (IS) or International Workshop (IW) in person, with cost being a primary deterrent.

Two challenge areas have been identified from this data:

- How to engage and retain early career members.
- How to provide more value to our member organizations (including better communicating the value currently provided).

A Town Hall is planned on 28 January during IW2024 to review a draft version of the INCOSE strategic plan that incorporates the findings from the member survey.

Calling All Systems Series

In March 2023, INCOSE launched "*Calling All Systems*," a series of online panel discussions that brought together 22 industry leaders and experts from the global systems engineering community. Over 1300 attendees participated in the five-event series, with video replays available on the INCOSE YouTube channel:

- The Future of MBSE
- Product Line Engineering: Are You Missing a Piece in Your Digital Engineering Puzzle?
- Sustainability
- Models in Space: From Theory to Practice: Applying Modeling to Space Venture
- The Future of Systems Engineering: Navigating Tomorrow's Challenges: Building the
- Future of Systems Engineering

Learn more here.

Sector and Chapter Updates

A sample of the second quarter highlights from INCOSE sectors and chapters include:

- The Asia Oceania Systems Engineering Conference 2023 (AOSEC 2023) was held on 11-14 October in Bangalore, India with over 300 attendees.
- The 2023 International Conference on Complex Systems Design and Management (CSD&M2023) and INCOSE Beijing Summit 2023 were held in Beijing, China on 30-31 October. Conference proceedings are available through Springer.
- The Korean Society of Systems Engineering (KOSSE) held the 2023 Fall Academic Conference in Seoul from 10-11 November with the theme "*Acceleration of System Engineering Using AI*".
- The Emerald Coast (Florida, USA) chapter is being resurrected, beginning with a set of virtual meetings to support its geographically dispersed membership.
- The INCOSE UK team announced the publication of three new resources, including *Adventures in Systems Engineering Manual and Workbook, Don't Panic! The Absolute Beginner's Guide to SysML v2, and Don't Panic! The Absolute Beginner's Guide to Integration and Test*. The last of these is authored by PPI's Paul Davies.

INCOSE chapters continue hosting national and regional conferences. Planned events in 2024 include:

- France: AFIS 2024 on 16-18 January.
- Nordic Systems Engineering Tours on 27-29 May and 16-18 September.
- Korea: INCOSE Human Systems Integration Conference on 27-29 August.
- Australia: Systems Engineering Test and Evaluation (SETE) Conference on 22-25 September.

Working Group and Initiative Updates

Various working groups and initiatives reported their progress, including:

- Integration Verification & Validation (IVV) Working Group: Plans to meet at the IW2024 to identify content for a Systems Integration Guidebook and additional V&V guidance that is not included in the current V&V Guidebook.
- Future of Systems Engineering (FuSE): Will focus on synthesizing a wealth of insights gathered from multiple workshops during 2023 to create a Global Systems Engineering Story to be shared and refined at the IW2024.
- Mentoring Service: Based on the 2023 pilot project, INCOSE has launched a full mentoring program to foster knowledge sharing and professional growth within the INCOSE community.
- SE Quality Management Working Group: Infused the INCOSE Handbook, version 5, with significant new content on quality management, namely the consideration of human values.
- Requirements Working Group (RWG): Continues promoting the effective use of the Guide to Writing Requirements (GtWR) v4.0 and providing inputs to the Systems Engineering Body of Knowledge (SEBoK) and SE Handbook v5.
- Professional Development Portal (PDP): Phase 2 rollout of the PDP is underway, with enhanced search and filter capability across the growing library of over 1000 online resources.

- Technical Leadership Institute (TLI): Cohort 8, 20 strong, has completed projects and submitted papers detailing their learnings. Cohort 9 consisting of 24 members will commence their two-year efforts in early 2024. TLI has also launched a quarterly virtual workshop series to explore emerging topics.

New Product Releases
Recently published INCOSE products include:

- Systems Engineering Handbook Fifth Edition: Vital reference for systems engineering practitioners.
- Guide to SysML Model of a "Smart Parking Lot" Reference Architecture: Model that provides a reference architecture for developers or independent contractors to build Smart Parking Lots that would work effectively with the other elements of the smart city.

For details on these items and more topics of interest, download the full (58-page) INCOSE Q4 2023 Member Newsletter.

SESA News Highlights

In its latest newsletter (December 2023), the Systems Engineering Society of Australia (SESA) shared multiple highlights from their 2023 activities and how past progress has paved the way for continued growth in 2024.

Membership history and milestone
The first meeting of what would become SESA was held in Canberra in December 1994. In 1995, SESA become a technical society within Engineers Australia and one of the first international chapters of the newly expanded INCOSE. By the end of its first official year, SESA had 206 members. During 2023, SESA passed the 1000 member milestone, making SESA one of the largest chapters of INCOSE. Accommodating this growth has led to the formation of three state branches of SESA in New South Wales, Victoria and Queensland.

Wider professional engagement
During 2023, SESA partnered with the Simulation Australasia (SimAust) and the southern cross chapter of the International Test & Evaluation Association (ITEA) in conducting the Australasian Simulation Congress (ASC) 2023 with the theme of "*Life between reality and simulation*". Responding to the need to integrate data and practices across engineering disciplines, the SimAust and ITEA partnerships will continue to expand in 2024 as SESA leads the integrated and transdisciplinary Systems Engineering Test and Evaluation (SETE) 2024 event in Melbourne in September.

SESA leadership
Paul Pearce has joined the SESA committee as Treasurer, bringing nearly two decades of systems engineering experience to that task.

In August 2023, Marco Meloni took the role as SESA's new Defence and Aerospace Domain Lead, bringing two decades of engineering leadership to this influential position.

In February 2023, Mikaela Stewart became SESA's new Communications and Engagement Lead,

building on her experience in establishing SESA mentoring programs and supporting the 2020-21 Australian Systems Engineering Workshops (ASEW).

SESA Healthcare Working Group

The SESA Healthcare Working Group (HWG) conducted a two-part event during 2023: a Special Interest Panel, and a Workshop. The Special Interest Panel, titled "*Systems Modelling and Simulation Approaches in Healthcare – Breaking down Complexity*" heard from a diverse cadre of speakers including Marc Lyell, Nathan Moore, Grace Kennedy and Jawahar Bhalla. The Workshop, titled "*Using Systems Thinking to Explore the Challenges in Healthcare Systems*" was facilitated by Grace Kennedy and addressed two challenges:

- Pathology Standardization
- Chronic Illness Care.

Workshop results reinforced the necessity of using transdisciplinary forums with diverse perspectives to uncover and resolve bureaucratic and siloed approaches that limit healthcare system effectiveness.

Interested parties may engage with the SESA HWG through their LinkedIn group.

Follow SESA on LinkedIn.

SERC 4Q Highlights

The December update from Systems Engineering Research Center (SERC) highlighted a diverse set of achievements by the organization during 2023.

SERC Research Review

The 2023 SERC Research Review (SRR) showcased the latest year of innovation from the SERC and provided a fitting celebration of 15 years of impact since the SERC was founded in 2008. The SERC community of researchers met on 14-15 November; speakers highlighted the collaborative nature of the SERC as a network of universities. Technical presentations addressed high-value systems engineering topics such as:

- Transforming systems engineering to model-based systems engineering
- Digital engineering for test and evaluation
- Digital engineering simulation
- Measurable requirements for operational resilience
- Workforce development in AI and data analytics

SERC Chief Scientist

At the 2023 SRR, the SERC's current Chief Scientist, Dr. Dan DeLaurentis, announced Dr. Zoe Szajnfarber as the successor in this role. As chief scientist, Szajnfarber will lead the SERC Research Council, which plays a formative role in shaping the SERC research portfolio. Szajnfarber will be the SERC's third chief scientist, following DeLaurentis and the late Dr. Barry Boehm.

Boehm Award

During the 2023 SERC Doctoral Student Forum (SDSF), Ms. Sonali Sinha Roy of Purdue University

presented on risk assessment frameworks and earned the Dr. Barry Boehm Award for Doctoral Student Research Excellence. Roy's presentation, "*A State-Based Probabilistic Risk Assessment Framework for System-of-Systems Operations*" addressed the complexity of predicting failure modes in a systems-of-systems (SoS) based on the dependencies and failure mode coupling between the constituent systems.

Systems Engineering for the Digital Age - Practitioner Perspectives
This noteworthy publication, a 41-chapter book, translates some of the mature research inspired by the SERC into a compendium of topically clustered chapters for the benefit of practicing engineers in industry and government. Contents include:

- Transforming Engineering Through Digital and Model-Based Methods (Chapters 1-5)
- Executing Digital Engineering (Chapters 6-12)
- Tradespace Analysis in a Digital Engineering Ecosystem – Context and Implications (Chapters 13-17)
- Evaluating and Improving System Risk (Chapters 18-21)
- Model-Based Design of Safety, Security, and Resilience Systems (Chapters 22-27)
- Analytic Methods for Design and Analysis of Missions and Systems-of-Systems (Chapters 28-33)
- Applying Systems Engineering to Enterprise Systems and Portfolio Management (Chapters 34-37)
- Systems Education and Competencies in the Age of Digital Engineering, Convergence, and AI (Chapters 38-41)

An electronic abstract and online bibliography are available for each of the 41 chapters. The entire document may be purchased on Wiley.

Access the latest SERC news here.
Follow SERC on LinkedIn.

INCOSE Foundation Celebrates Twenty Years

The INCOSE Foundation is celebrating 20 years of service to the global engineering community. In addition to its history of providing grants to students and teachers, underwriting special projects, and the assisting the efforts of INCOSE working groups and chapters, current Foundation initiatives include:

- Global Collaboration: Provide a platform, through the SE Global Member Project, for like-minded professionals to connect, exchange ideas, and collectively drive innovation in systems engineering on a global scale.
- Outreach and Advocacy: Raise awareness about the vital role of systems engineering in addressing complex societal and technological issues.
- Professional Development: Invest in professional growth, equipping students and practitioners with the resources, skills and tools needed to tackle today's complex challenges.

Donate to the INCOSE foundation here.

NIST Previews easyEXPRESS tool for Product Manufacturing Modeling

The U.S. National Institute for Standards and Technology (NIST) has developed and demonstrated a preliminary version of a new tool to simplify the process of capturing the flow of product information from design through manufacturing to support. Product information can include 3D geometric models of part designs, assemblies, and information about how that part must be manufactured, This information flow is enabled by a family of ISO standards called STEP (STandard for the Exchange of Product model data).

STEP standards are written using an information modeling language EXPRESS that describes information elements and their relationships. The process of writing the EXPRESS models for a product is complex and subject to error, particularly when performed using simple text editors that do not support the EXPRESS language features.

To address these concerns, NIST researchers developed "easyEXPRESS" to help with EXPRESS model authoring. easyEXPRESS provides modern development features to improve users' focus on information modeling, including:

- Syntax validation and highlighting
- Intelligent code completion
- Semantic validation and error reporting
- Automated code fixes
- Quick file and symbol navigation
- Reference management

Final release testing of easyExpress is underway.

easyEXPRESS can be found in the Visual Studio Code Marketplace as an easyEXPRESS extension. Interested parties are invited to track of progress, report bugs, and discuss new features on the NIST easyEXPRESS public page.

Learn more here.

INCOSE Renews Academic Equivalency Agreement with Drexel University

INCOSE has announced that an Academic Equivalency Agreeement has been renewed with Drexel University. Drexel was first recognized with Academic Equivalency in 2019 and has recently renewed with a streamlined course requirement for its students. Students who do well in university courses which have been assessed to have Academic Equivalence (AcEq) are allowed to bypass the certification knowledge exam when applying for ASEP and CSEP Certification. The assessments they complete through their coursework have been recognized by the INCOSE Certification Program's volunteer reviewers as an equivalent alternative to the standardized test developed by INCOSE.

Learn more about the Academic Equivalency process here and in the Certification Blog.

Updates to SE Tools Database (SETDB)

The Systems Engineering Tools Database (SETDB), developed by PPI in partnership with INCOSE, provides a virtual platform for engineering tool vendors to communicate their latest offerings. Recent SETDB updates, including both new tools and updates to existing tools, include:

Vendor: Ansys Inc.

- Ansys Twin Builder: An analytics-driven, simulation-based digital twin is a connected, virtual replica of an in-service physical asset - in the form of an integrated multidomain system simulation - that mirrors the life and experience of the asset.

Vendor: Autodesk Inc.

- Autocad: Power your teams' creativity with automation, collaboration, and machine-learning features of AutoCAD® software. Architects, engineers, and construction professionals use AutoCAD to design and annotate 2D geometry and 3D models with solids, surfaces, and mesh objects plus compare drawings and more.
- Architecture Toolset: Gives you all the tools you need to complete your projects faster and scale your project pipeline. Boost architectural design and drafting productivity by up to up to 61%* with time-saving features and task automation.
- Revit: Revit® Building Information Modeling (BIM) software helps architecture, engineering, and construction (AEC) teams create high-quality building and infrastructure designs in 3D with parametric accuracy and precision in a unified project environment.

Vendor: Eclipse Foundation AISBL

- Capella: Comprehensive, extensible, and field-proven open source MBSE tool and method to successfully design systems architecture. Capella relies on Arcadia a field-proven model-based methodology that covers each engineering phase.
- Eclipse Papyrus™: Open-source model-based engineering solution intended for industrial and academic applications to enable techniques like model-based simulation, model-based formal testing, safety analysis, performance/trade-offs analysis, architecture exploration, etc.

Vendor: Frontline Systems, Inc.

- Analytic Solver®: The built-in Solver Engines included with Analytic Solver can handle problems with thousands of variables and constraints, and offer great performance at no extra cost.

Vendor: National Instruments Corp.

- Test Workflow: A bundle of LabVIEW, TestStand, DIAdem, and more NI software that
- test professionals use to accomplish everything from their day-to-day work to
- overcoming their most challenging obstacles.
- HIL and Real Time Test Software Suite: A collection of software for validating embedded software and running model-based physical tests. It is a combination of LabVIEW and application software modules to create real-time test applications.

- DIAdem: Application software to process, visualize, and streamline root-cause determinationto find the answers to the most complex test problems - all in one place. DIAdem helps engineers accelerate post-processing of measurement data.
- LabVIEW: Systems engineering software for applications that require test, measurement, and control with rapid access to hardware and data insights. Its graphical programming environment enables engineers to develop automated production test systems.
- LabView Statechart Module: Provides a high level of abstraction for designing applications using states, transitions, and events.
- LabVIEW Real-Time Module: Software add-on for LabVIEW that you can use to create and deploy real-time, distributed system applications for test, monitoring, and control.
- LabView FPGA Module: Enables engineers and scientists to develop, debug, and deploy custom FPGA code for NI hardware with user-programmable FPGAs.

TestStand: Test executive software that accelerates system development and deployment for engineers in validation and production. TestStand automates, accelerates, and standardizes the overall test process across all of your testers.

- FlexLogger: No-code data acquisition software engineers use to build validation and verification test applications. Provides visualization tools to monitor testing, saves data as directed, provides alarms for unexpected behavior and an monitor over 2000 mixed-signal measurements.
- VeriStand: Helps reduce the time test engineers need to test their products with a wide range of functionality including configurable data acquisition, simulation model integration, test sequencing, and logging.
- SystemLink: An intelligent Systems and Data Management environment that can be used from concept to manufacturing. Designed for engineering use cases, SystemLink software combines focused applications and data services to leverage comprehensive real-time information.

Vendor: Visure Solutions Inc.

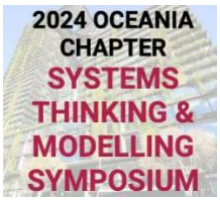
- Visure Open ALM Platform: Intended for software teams to enable their software development lifecycle in a single ALM integrated solution.

PPI SyEN readers are encouraged to check out these new and updated systems engineering tool offerings.

Access the SETDB website.

CONFERENCES, MEETINGS & WEBINARS

SDS Oceania: 2024 Systems Thinking and Modeling Symposium



The Oceania Chapter of the System Dynamics Society (SDS) is hosting a hybrid 2024 Systems Thinking & Modelling Symposium on 9 February 2024. The in-person portion of this event will take place at the University of Sydney, New South Wales, Australia. The objective of the symposium is to gather as a community and discuss current systems thinking and system dynamics modeling work at any stage of maturity across industry, government, or academia.

Learn more and register for this free event here.

IIBA Webinar: Top 10 Mistakes to Avoid as a Business Analyst

The International Institute of Business Analysis (IIBA) is hosting a free open-access business analysis webinar on 22 February titled *Top 10 Mistakes to Avoid as a Business Analyst*. L.N. Mishra (Adaptive US, Inc.) will lead the exploration of this topic.

Overview
While the role of a business analyst is crucial in any organization, it's not without its pitfalls. Whether you're new to the game or have years of experience under your belt, it's important to identify and rectify these common missteps. So, buckle up as we explore the top 10 business analyst mistakes that you can avoid to ensure you're on the road to becoming a stellar Business Analyst.

In this live expert webinar, we will delve into the top 10 blunders and provide practical solutions to help you avoid them like a seasoned pro. This webinar tries to achieve the following objectives/outcomes:

- Expert Insights: Gain wisdom from a seasoned BA who've navigated the industry's challenges.
- Error Prevention: Discover the most common pitfalls and how to sidestep them.
- Career Growth: Learn how avoiding these blunders can fast-track your professional journey.

Register here.
View prior IIBA public webinars here.

Learn more about the IIBA.

PDMA Webinar: The Interviewer's Edge

The Product Development Management Association (PDMA) will host a webinar on 27 February 2024 titled "*The Interviewer's Edge: Unlocking Customer Insights Through Conversation*". Andrea Ruttenberg of Applied Marketing Science will share her insights on how to get closer to customers and deliver winning innovations using in-depth customer interviews.

Designed for those seeking to develop or further improve their qualitative research skills, this interactive course will demonstrate the importance of Voice of the Customer (VOC) research and share tried-and-true techniques to add to your toolkit. While Andrea will provide you with a solid foundation of interviewing best practices and VOC theory, this will be a very hands-on course. Ample time will be dedicated to practicing your interviewing technique through role-playing activities, and you will have the opportunity to gain feedback from Andrea directly. You should expect to leave this session ready to conduct customer interviews that uncover actionable insights.

Register here.

Program Details: NAFEMS ASSESS Summit 2024

Program details are now available for the NAFEMS ASSESS Summit 2024 that will take place on 4-6 March 2024 in Atlanta, Georgia, USA. The Summit will be organized around the following NAFEMS themes:

- Align: Alignment of Commercial, Research and Government Efforts
- Autonomy: Supporting Autonomy with Engineering Simulation
- Business: Business Challenges
- Credibility: Engineering Simulation Confidence & Governance
- Democratization: Democratization of Engineering Simulation
- Generative: Generative Design
- Integration: Integration of Systems and Detailed Sub-System Simulations
- Twins: Engineering Simulation Digital Twin(s)

Recently announced presentations include:

- *Crossing the Chasm: System Qualification and Certification by Analysis* (Scott Shaw: MBDA Systems)
- *Digital Twin, building block of Industrial Metaverse* (Virginie Maillard: Siemens Corporate Research)
- *Physiological Digital Twins* (Robert Hester: University of Mississippi)
- *RIED: Bioinspired generative design* (Trevor Robinson: Queen's University of Belfast)
- *Scaling metadata extraction with large language models* (Olivia Pinon-Fischer: ASDL)
- *Simulation-based Methods for Enabling Collaborative Multidisciplinary Design for Smart Cities* (Michael Balchanos: ASDL)
- *The future for the modeling and simulation expert* (Bob Tickel: Cummins)
- *The Ongoing Simulation Revolution* (Petra Gartzen: Cambashi)
- *Verification, Validation and Uncertainty Quantification for Engineering Simulations*

to establish Credibility for Decision Makers (Alexander Karl: Rolls Royce)
- *You can simulate what?* (Alan Rose: Corrdesa)

These talks complement the previously announced keynotes:

- *Modeling: Mastery, Marketing & Making Decisions!* (Alison Main: Procter & Gamble)
- *Reduced-Order Models as Enablers for Design, Control and Predictive Digital Twins (*Karen E. Willcox: Oden Institute for Computational Engineering and Sciences, The University of Texas at Austin):

Learn more about ASSESS Summit 2024 and register here.

OMG Q1 2024 Technical Committee Meeting - Companion Events

The Object Management Group (OMG) is offering three companion events to be held in conjunction with the OMG's First Quarter 2024 Technical Committee Meeting planned for Reston, Virginia, USA on 18-22 March. PPI is an Influencing Member of the OMG. The following learning, networking and engagement opportunities may be of relevance to PPI SyEN readers and systems engineering practitioners.

Business Architecture Innovation Summit™
The Business Architecture Guild® and OMG® are hosting the 12th annual Business Architecture Innovation Summit™, a hybrid event, on 19-21 March. The Summit will deliver global success stories, industry advancements and key learnings associated with business architecture. The event will include presentations, open discussion, panels, and other interactions with business architecture enthusiasts. Sample topics include:

- A Business Architect's Journey to Making an Impact
- A Framework for Startups Using a Business Architecture Reference Model
- Architecting Success: The Dynamic Duo of Business Architecture and Formal Product Management Framework
- Business Architecture: A First Year Journey
- Business Architecture Tool Vendor Panel: Updates and Insights
- Embedding Strategic Insight into Initiative Portfolio Planning
- Leverage Business Architecture to Envision Data and AI Use Cases
- Organizational Change Management Using Business Architecture
- Scaling an Enterprise-wide Business Architecture Practice
- Successful Business Architecture: Demonstrating Value from Strategy to Technology Investment Realization
- Superpower of Service Designer and Business Architect Co-creation

Attendees will have the option to attend a pre-Summit, Business Architecture Primer™ free of charge.

See the full Business Architecture Innovation Summit™ agenda.
Register here.

Q1 Digital Twin Consortium Member (DTC) Meeting

Employees of Digital Twin Consortium member organizations may attend the Q1 Member Meeting to be held in Reston. This face-to-face event will run from 19-21 March. Check back here for more information on the evolving DTC agenda.

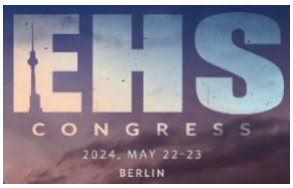
Register here.

2024 UAF® Summit
The Unified Architecture Framework (UAF®) Summit will be a hybrid event on 20 March with the theme of *Actionable Architecture in the 21st Century*. The Summit will feature the latest thinking around enterprise and system of systems architecture with examples of how UAF can be developed and used to provide timely and accurate information to decision makers.
The keynote address for the Summit will be delivered by Jeffrey W. Eggers, U.S. Air Force ISR Chief Architect, on the topic, *The Dawn of Enterprise Architecture in the Air Force*.

Check back here for more information on the evolving Summit agenda.

Register for this free event.

Environmental, Health and Safety (EHS) Congress 2024



The 2024 Environmental, Health and Safety (EHS) Congress will take place on 22-23 May in Berlin, Germany. Over 300 delegates are expected to attend this in-person event with opportunities to hear from 50+ industry leaders and to participate in 20 breakout workshops.

Featured workshops include:

- Moving from blaming to learning by seeing what lies beneath (Diane Chadwick-Jones, former Director of Human Performance at bp)
- Breaking the Incident Cycle (Claus Rose, Vice President EHS Renewable, GE)
- Could we bring innovation into our safety learning processes (Juliana Bley, TEDxSpeaker, Author of “Safe Behavior”, Creator of SafetyLab)

A sample of the diverse range of presentation topics includes:

- AI’s Role in Helping to Reduce Workplace Incidents
- Bringing HOP (Human & Organizational Performance) To Life
- From Incidents to Insights: Empowering a Learning Organization
- How new is the “new view” in safety?
- How to effectively implement agile methodologies in HSE?
- Human Factors and Trust
- Invisible Factors
- Mastering Risk: Navigating the Challenges of a Smart World with Intuition and Adaptability
- Orchestrating Excellence through Digitalization
- Realm of Safety Measurement and Benchmarking
- Revitalizing Safety Science: Paradigm Shift in Safety Research
- Safety in Design

- Symbiosis of Ergonomics, AI and Health
- Viral Safety

Download the detailed conference agenda.

Learn more about the 2024 EHS Congress. Register here.

Smart Cities Events in 2024

The Smart Cities Council (SCC) hosts, supports, or recommends a variety of global events that address the challenges of urban development. Here are some of the events on the SCC calendar for 2024. Systems engineering practitioners with interest in smart city concepts and technologies, or broad socio-technical systems may find these events of interest:

3rd Annual Digital Built World Summit (DBW24)
This hybrid event will take place in Sydney, NSW, Australia on 27-28 February with the theme "*Leveraging AI Digital Twins to unlock value and efficiencies across the entire infrastructure lifecycle*". The Summit is dedicated to digital value creation related to the design, build, management, and operation of large-scale assets. It focuses on the needs of asset managers and digital service teams in public-private asset-intensive industries including power networks, building portfolios, energy, mining, and smart city infrastructure.

Download program brochure. Register here.

Smart Cities Council Cybersecurity Summit
The Cybersecurity Summit will take place in Sydney, NSW, Australia on 14 March. This gathering of executives from both public and private sectors aims to foster a comprehensive understanding of the intricate facets of cybersecurity and its significance in the contemporary smart cities landscape.

Register here.

Smart Cities Expo LATAM Congress (SCELC24)
The Congress will be held in Mérida, Yucatan, Mexico on 9-11 July. It seeks, through *leadership* and community *commitment*, that our cities in Latin America are transformed into more inclusive, equitable and sustainable environments. Focus areas include:

- Urban Spaces
- Digital Transformation
- Smart Destinations
- Connected Society
- Cities that care
- Climate change and sustainable territories

The Congress will be co-located with the Tomorrow-Mobility event that will present cutting-edge ideas, conferences, and exhibitions in the fields of mobility and transport.

Register for SCELC24 here.

Additional events

Other events on the SCC horizon, with details being developed, include:

- Power and Utilities 2024 on 7-8 May in Melbourne, Victoria, Australia.
- Smart Cities Week New Zealand on 21-22 May in Auckland, New Zealand.
- Smart Cities World Expo on 22-23 May in New York, NY, USA.

Check back for upcoming events.

Capella Days 2023 Videos and Presentations

Capella Days 2023 took place on 14-16 November 2023. Over 950 registrations for this online event are evidence of the breadth and depth of the community of Arcadia (method) and Capella (tool) community. Videos and slides have been posted for the following ten presentations:

Capella for Modelling CubeSat: Tailored SE Process for Leveraging Model-Based Systems Engineering

- Suvigya Gupta, Dhirendra Singh and Stueti Gupta (BlueKei Solutions)
- Video and slides

Capella MBSE Integration for Robotic Arm Development

- Vinayak Vadlamani (Redwire Space Europe)
- Video and slides

Collaborative Model-Based Engineering and Large Systems Development

- Catherine Morlet and Alberto González Fernández (European Space Agency)
- Video and slides

Efficient and Comprehensive FMECAs: Harnessing the Power of MBSE Models in Capella

- Sushim Koshti and Neela Ayalasomayajula (Applied Materials)
- Video and slides

Enhance the Efficiency of Systems Engineering with a Tailoring of SE processes and ARCADIA Method

- Bruno Vuillemin (Capgemini Engineering)
- Video and slides

Enterprise Modelling for Lifecycle Engineering on the Example of Sustainability

- Chantal Sinnwell and Michael Bitzer (Siemens Digital Industries Software)
- Video and slides

In Pursuit of Robust Failure Mode Effects Analysis in the Design Phase

- Steven Huang (ManTech) and Alice Cellamare (p2m berlin)
- Video and slides

Introducing MBSE in an Organization Successfully

- Erik Visser (Thales Communications)
- Video and slides

CONFERENCES, MEETINGS & WEBINARS

Lean Startup with Capella MBSE

- Brent Bailey (StarFish Medical)
- Video and slides

Model-driven Design and Development of an Electromechanical Actuation System

- Elena García Llorente (CESA - Heroux Devtek) and Luis Cárdenas González (Anzen Engineering)
- Video and slides

Practice in COMAC to Conduct MBSA in Avionics System Based on Capella

- Wang Ran (COMAC) and Yan Weizhen (PGM)
- Video and slides

Upcoming PPI Live-Online ™ Systems Engineering Five Day Courses

Click here to view the full schedule or register for an upcoming course.

P006-933-1	Asia SGT 5:00 (UTC +8:00) PPI Live-Online™	05 Feb - 09 Feb 2024
P006-933-2	Oceania AEDT 8:00 (UTC +11:00) PPI Live-Online™	05 Feb - 09 Feb 2024
P006-934	London, United Kingdom GMT 8:30 (UTC +0:00) In-Person	26 Feb - 01 Mar 2024
P006-935	Las Vegas, USA PST 8:00 (UTC -8:00) In-Person	04 Mar - 08 Mar 2024
P006-936-1	Asia SGT 5:00 (UTC +8:00) PPI Live-Online™	18 Mar - 22 Mar 2024
P006-936-2	Oceania AEDT 8:00 (UTC +11:00) PPI Live-Online™	18 Mar - 22 Mar 2024
P006-937-1	North America EDT 8:00 (UTC -4:00) PPI Live-Online™	18 Mar - 22 Mar 2024
P006-937-2	South America BRT 9:00 (UTC -3:00) PPI Live-Online™ *(Exclusive to South America)*	18 Mar - 22 Mar 2024
P006-938-1	Europe CEST 9:00 (UTC +2:00) PPI Live-Online™	08 Apr - 12 Apr 2024
P006-938-2	United Kingdom BST 8:00 (UTC +1:00) PPI Live-Online™	08 Apr - 12 Apr 2024
P006-938-3	South Africa SAST 9:00 (UTC +2:00) PPI Live-Online™ *(Exclusive to South Africa)*	08 Apr - 12 Apr 2024
P006-938-4	Turkey TRT 10:00 (UTC +3:00) PPI Live-Online™	08 Apr - 12 Apr 2024
P006-938-5	Saudi Arabia AST 10:00 (UTC +3:00) PPI Live-Online™	08 Apr - 12 Apr 2024

A Rapid Immersion in Systems Thinking - Part 2

by John Fitch and René King

Project Performance International

Authored for PPI SyEN

Introduction

In this article, we continue a walkthrough of the final 10 of 15 Systems Thinking "Habits" courses offered online by the Waters Center for Systems Thinking.
Part 1 of this series addressed Habits Courses 1-5 of which Course 1 provided an introduction and Courses 2-5 addressed these four habits of a successful Systems Thinker:

A Systems Thinker:

1. Makes meaningful connections within and between systems
2. Seeks to understand the big picture
3. Changes perspectives to increase understanding
4. Considers how mental models affect current reality and the future

In this month's article, we continue with the final 10 habits.

A Systems Thinker:

5. Observes how elements within a system change over time, generating patterns and trends
6. Surfaces and tests assumptions
7. Recognizes that a system's structure generates its behavior
8. Identifies the circular nature of complex cause and effect relationships
9. Recognizes the impact of time delays when exploring cause and effect relationships
10. Considers short-term, long-term and unintended consequences of actions
11. Considers an issue fully and resists the urge to come to a quick conclusion
12. Pays attention to accumulations and their rates of change
13. Uses understanding of system structure to identify possible leverage actions
14. Checks results and changes actions if needed: "successive approximation"

As in Part 1 of this series, we are looking at the Waters Center's perspective on systems thinking and design through the "lens" of experienced systems engineering practitioners and attempting to highlight differences between the mental models of the two communities. Our belief is that learning occurs by understanding the differences between such disciplines (systems thinking vs systems engineering) and their associated frameworks, processes, tools or viewpoints and using those differences to guide further exploration that will increase our understanding and capabilities. We

don't learn unless our current mental models are challenged.

Habits Course #6: Observes How Elements Within Systems Change Over Time, Generating Patterns and Trends [Habit 5]

Habits Course #6 emphasizes the importance of paying close attention to behavioral patterns and trends, while noting that such patterns and trends are often not obvious. Key skills for the systems thinker include:

- Observing change over time in systems.
- Recognizing change, patterns and trends in personal life and the system of interest.
- Making patterns and change visual by creating behavior-over-time-graphs (BOTGs).
- Explaining ("telling the story") of these graphs.

System changes may be measured in tangible, quantitative ways or as qualitative judgments from the perspective of particular stakeholders.
Even when change is measured quantitatively and visualized as a BOTG, different individuals may perceive and "tell the story" behind the graph using their own narrative and understanding of cause and effect, i.e., the variables that drive the shape of the graph. Systems thinkers take advantage of these differing perspectives to surface mental models that deepen their understanding of the system of interest.

The shape of the trend line in the BOTG, e.g., growing or declining, leveling off or oscillating, becomes the story of the change. BOTGs visually describe the nature of the change, but should also document the rationale for the shape of the pattern or trend over time.
Beyond visualizing past performance, BOTGs may be forecast (extrapolated) into the future to envision a wide range of anticipated system outcomes. Differences between such forecasts may also help to clarify the variables that are perceived by individuals as the most significant drivers of future performance.

Systems thinkers recognize a variety of generic patterns of system behavior in the BOTGs. Such patterns (trend shapes) include:

- Linear growth
- Linear decline
- Exponential growth
- S-shaped growth
- Oscillation
- Steady state
- Goal-seeking
- Decreasing growth

The Waters Center has a separate Behavior-Over-Time Graphs (BOTGs) course in their Tools series.

Course 6 Reflections
As noted in the Part 1 article, Course #1 asserted that "*most system thinkers focus their attention on living systems, especially human social systems*." Considering this focus on natural and human-intensive socio-technical systems highlights the relevance of this Habit #5 principle:

"Change over time is an inherent property of systems"

Engineered systems that are developed to be used by humans (e.g., typical hardware/software products or facilities) are generally designed to produce consistent, stable and predictable outcomes across the range of use cases they will encounter during their service life. However, it's important to recognize that engineered systems are part of larger socio-technical systems and also interface with natural systems. Both socio-technical and natural systems will evolve regardless of the use of the engineered system or in response to the use of the engineered system in the larger context.

A functional analysis of the mission scenarios for an engineered system should take into account the changes associated with the larger mission context, including human actors, intelligent adaptive systems, and the natural environment. For example, an engineered military system will encounter adversaries who will adapt their behavior to counter the military system and reduce its effectiveness. An educational system comprised of instructors, instructional information, delivery media and facilities will interact with adaptive students who may take shortcuts to pass a course without meeting learning objectives. A product that prevents the spread of a contagious disease, e.g. a vaccine, may reduce the future demand for its consumption, threatening business viability by achieving its intended disease-suppressing purpose.

The use of BOTGs to complement mission functional analysis may be an effective technique to anticipate system changes and incorporate methods of adapting that change within the system design.

Rooted in a human-centric and continuous improvement mindset on systems, this course emphasizes that value of human perspectives in understanding system behavior.

"Efforts to make perceptual change visible is a good first step to sharing honest opinions about the current state of the system and clarifying the evidence that people attach to important variables"

However, most systems engineering practitioners would prefer, where possible, to replace human opinions or rationale behind the shape of the BOTG curve with confirmed root cause or at least mathematical correlations backed by objective evidence derived from well-constructed research experiments. Although this objective is near impossible to achieve with a high degree of accuracy, feedback loops between systems thinking and systems engineering are facilitated through systems science.

Systems science establishes a rigorous theoretical framework based on empirical evidence from real-world application of systems thinking. There is an input to a process, the execution of that process, and an output of the process. Systems science aims to predict what that output would be based on a known set of inputs. Systems science is a major topic on its own and will not be covered extensively in this series of artices which is intended mainly to contrast systems thinking and sysems engineering based on the Waters Center courses. The purpose of mentioning systems science here is to recognize the role that science plays as the foundation of engineering. One could say systems thinking serves to understand the world, systems science serves to express that understanding through mathematically related terms and systems engineering uses these terms to adapt the world. There is an ongoing feedback system between these three elements; each advances through interaction with the others (see more about feedback loops in Habit #9).

Habits Course #7: Surfaces and Tests Assumptions [Habit 6]

This course delves deeper into how the assumptions of system participants and designers influence their understanding of the current system, its behavior and the causality behind this behavior.

Desired systems thinking skills include:

- Considering multiple viewpoints on an issue.
- Weighing each side of a controversial claim.
- Surfacing and testing assumptions.
- Using the Ladder of Inference to surface beliefs and recognize how they influence actions.
- Using BOTGs to test assumptions.

The course asserts that systems thinkers articulate their beliefs about observed system behavior (as visualized on BOTGs) and the rationale behind this behavior and then look for evidence to support or refute this belief.

Such research provides a method to make assumptions about behavior explicit so that these assumptions (each being a hypothesis) may be tested and confirmed or refined based on experimental results.

The course also addresses how to handle conflicting studies that provide different explanations for system behavior. It introduces a tool, the Ladder of Inference, to help identify how our existing beliefs influence the data we "see" and actions that we take. It highlights the perils of unexamined, highly-filtered beliefs that may lead to poorly-informed decisions and actions. Three practices are recommended when using the Ladder of Inference:

- Reflection: Suspend judgment and ensure that all relevant data is being considered.
- Inquiry: Ask questions to understand the thinking of others.
- Advocacy: Make your thinking visible by describing what influences your beliefs.

The Ladder of Inference is the subject on another Waters Center Tools Course.
The course also reinforces the benefits of using BOTGs to provide a visual method to surface and test personal assumptions.

Course 7 Reflections
The Ladder of Inference and BOTGs, tools recommended in this course to clarify and test assumptions, appear to be "tuned" to human-intensive socio-technical systems. Although there is mention of research via designed experiments, more emphasis is placed on human opinion in understanding system behaviors.

> *"Systems thinkers articulate their belief … and then look for evidence to support or refute this belief."*

The authors of this article respectfully disagree with the above statement. Although the search for evidence is commendable, this approach is closer to the common bad thinking habit of "jumping to cause" by introducing possible cause ideas prior to a full description of the problem. That is, there is no discussion of formal Problem (Root Cause) Analysis techniques [1] that describe a deviation from expected behavior and then rigorously capture:

- A statement of the problem/deviation for which cause must be determined
- A description of the IS-IS NOT behavior in terms of Identity, Location, Timing and Magnitude (What, When, When and Extent)
- Using the contrast between the deviation's IS-IS NOT specification to identify a range of possible causes

- Testing possible causes to rule out causes that are inconsistent with the problem specification
- Verifying/confirming root cause via experimentation.

Formal Problem Analysis techniques are certainly more efficient and less subject to personal bias than addressing "beliefs" one at a time and looking "for evidence to support or refute" these beliefs.
The course also doesn't address rigorous techniques that combine causal analysis with correlation data. [2]

"Unexamined, highly-filtered beliefs can lead to ill-informed actions"

The need to filter personal beliefs is much less significant in the design of most engineered systems. Traditional engineering disciplines depend on choosing the appropriate equations to match the system technology choice and resulting system structure, e.g., F = ma requires very limited reflection, inquiry and advocacy beyond defining boundary conditions. However, those techniques have clear value in product scoping decisions, particularly those in which defining a "winning" system value proposition in various use cases depends on the designers' understanding of end user/stakeholder priorities and constraints. See *Rethinking Requirements Derivation – Part 2 in* PPI SyEN Edition #130 (November 2023) for an example of product scoping decisions.

Overall, this Habit misses out establishing formal approaches to surface and test assumptions and seems to imply that finding evidence to support a notion is best way to remove bias. SE logic suggests the contrary.

Habits Course #8: Recognizes that a System's Structure Generates its Behavior [Habit 7]

This course teaches how the design of a system, i.e., its structure – the arrangement of and connection between its elements, produces its behavior. Systems thinking skills to be learned include:

- Understanding system structures.
- Recognizing structures in a system of interest and how changing structures influences outcomes (system performance).
- Thinking like a "system designer" of ways to implement structures that will create positive outcomes.

Systems thinkers understand that a system's structure generates its behavior. Armed with this belief, they are intentional about matching a system's design with its purpose. They think through the desired system behavior and then they structure (aka architect) a solution that will produce the desired outcomes. Structures can be physical elements arranged in some configuration (aka physical architecture) or laws, policies, regulations, business rules, processes or traditions (legal or social constructs).

Physical structures are tangible and easily recognized in a system. Less tangible structures such as process or cultural traditions are less obvious, but certainly influence system behaviors.
Reuse of proven system structures is valid, but must be done with caution by understanding how such structural patterns may be blended with the unique elements of the system of interest. Cookie-cutter designs added for improvement often backfire or produce temporary results.
The course recommends further study using Design Thinking resources to help systems thinkers improve their skills at thinking like a designer. [3,4,5]

Course 8 Reflections

The fact that system structure drives behavior is the nearly universal "big idea" that drives design processes. At the foundational level, this assertion is a restatement of a systems science principle know as *emergence*. [6] The *emergent properties* of a system are those characteristics or capabilities that are not observable in the parts, but created by the combination of these parts in some configuration. Readers may want to review two prior PPI SyEN articles for more background on emergence and how this reality impacts the engineering of systems:

- *IS2022 Thoughts on Emergence in* PPI SyEN Edition #114 (July 2022)
- *More Musings on Emergence in* PPI SyEN Edition #115 (August 2022)

The relationship between system structure and behavior is the basis for the existence of two models of any system, the physical architecture model and the logical architecture model. These models are independent representations of the system, but they must always be aligned. PPI training courses on Systems Engineering and Architectural Design spend significant time on teaching students how to construct these models, maintain consistency between them and use that consistency-assessment process to improve system designs. Much of the Model-Based Systems Engineering (MBSE) effort on any project revolves around building these models and successively decomposing them as a design progresses.

Many of our students have to "unlearn" faulty practices concerning functional decomposition. Solution-independent functional decomposition is a myth. Every decomposition of a parent function is based on the physical solution concept under consideration or chosen to implement that parent function. We state this principle as "*the logical design is the logic of the physical solution concept*."

When using decision patterns, this relationship is even more obvious. A decision must be made on *HOW* each system-level function will be accomplished. The physical solution concepts under consideration are evaluated as alternatives. After an alternative is selected, its structure, behavior, footprint, interfaces and lifecycle become the source of next-level derived requirements (functional, performance, interface, etc.). See *Rethinking Requirements Derivation – Part 1* in PPI SyEN Edition #129 (October 2023) for more details on this process.

Although the logical architecture of a system is most often represented by a system functional model (e.g. Functional Flow Block Diagram or Activity Diagram), other logical representations such as state models, math models and information models may supplement the functional view of system behavior.

Course #8 states that:

"Systems' structures can also focus on relational connections."

In PPI's recommended Systems Engineering process, the description of the physical interfaces between system elements is an essential part of physical architecture definition. The physical architecture must define how the elements connect through physical interfaces. Each interface is a full-fledged object of interest which may have its own requirements within the solution architecture. On the softer side of the systems thinking practice, the course highlights a side benefit of the focus on system structure as the source of system behavior.

"Recognizing that a system's structure generates its behavior … eliminates the need for blame"

This understanding frees us from jumping to the cause of a system failure by looking for human errors first and foremost. We can objectively analyze a failure and even if a human error (compared to a published process standard) was a contributor, repetitively ask "what caused the cause?" until we identify the ultimate process design flaw that made the human error possible. This mindset makes it possible to redesign the process (or its training or enabling tooling) such that repeat errors become improbable (with the aim of impossible.)

Habits Course #9: Identifies the Circular Nature of Complex Cause and Effect Relationships [Habit 8]

Habits Course #9 takes a deeper dive into the causal nature of systems introducing the role of feedback and the distinction between balancing and reinforcing scenarios. System thinking skills to master include:

- Understanding and identifying circular cause and effect relationships as feedback.
- Recognizing how and when feedback reinforces behavior.
- Using causal loop diagrams to show causal relationships that exist between system elements.
- Distinguishing between reinforcing and balancing causal relationships

In a systems thinking context, feedback is the information provided to inspire improvement that actually feeds back to the original input and causes reinforcement or change in system behaviors. Feedback may be captured in a Causal Loop Diagram (CLD) that visualizes circular stories of causal relationships that exist between system elements (more specifically between the variables that track changes in system elements). The Waters Center offers three separate Tools courses that expand on the use of CLDs:

- Tools Course #7: Causal Loop Diagrams Part 1: Reinforcing Feedback
- Tools Course #8: Causal Loop Diagrams Part 2: Balancing Feedback
- Tools Course #9: Causal Loop Diagrams Part 3: Bringing Reinforcing and Balancing Loops Together

CLDs illustrate causality with arrows drawn between elements or variables, with arrows pointing from cause to effect. The use of loops to explain relationships highlights the insight that there is no variable that begins or ends the causal story.

Feedback loops may be reinforcing, i.e., where the two variables trend in the same direction. Feedback loops illustrate balancing scenarios if two variables trend in opposite directions. Balancing loops tend to bring the system towards an equilibrium.

When telling the causal story of a system, a best practice is to talk through the causal links in the loop at least two times. Then describe the continuous impact of effects feeding back and initiating a change in the initial cause.

The ability to "sense circular causality" is asserted to be a critical systems thinking skill, learned through practice.

Course 9 Reflections

There is no explicit discussion in Course #9 of how a Causal Loop Diagram relates to the Causal Connection Circle introduced in Habits Course #2. The authors of this article work under the assumption that the two diagrams are different views of the same fundamental causal model based on a common (but not specified herein) language. The Causal Connection Circle is assumed to be the higher-level abstraction that hides complexity for the sake of teaching systems thinking from its simplest ideas to more complex constructs. The Causal Connection Circle may be an entry step into producing the more detailed Causal Loop Diagram with more specific interactions.

The course reinforces our belief that causal models, regardless of visualization, depict elements that can change over time, i.e., the parameters used to count or track certain quantities in system elements are variable with respect to time. However, the failure to name the parameters as variables is a bit unnerving to experienced systems engineers, increasing the risk that these parameters are misidentified as elements (physical things of which the system structure is built) and not ways to count and track changes in these elements. There also appears to be nothing in the nomenclature of a CLD that identifies the "direction of goodness" associated with each variable. That lack of specificity may be appropriate when modeling natural systems (is having more caribou better than having more grass?), but engineered systems typically need to clarify the direction of goodness of performance parameters to inform design tradeoffs that maximize the value delivered to stakeholders. Stakeholders will have a perception of the value of each measure as being better or worse when varied within a range. For example, a stakeholder objective could be that the cost is minimized. Thus incorporating this 'better' or 'worse' perspective into the CLD may provide another way for optimizing solutions based on preferred direction of measures.

"When people understand the circular nature of cause and effect, they are better able to recognize cause and effect relationships and anticipate the subsequent dynamics these relationships create."

This quote is a strong statement of a fundamental principle, but it fails to elaborate how circular causality adds value beyond discrete event causality.

Many causal system models used in the engineering of systems are discrete in nature, not made up of continuous variables that can be expressed as mathematical relationships between the variables. Examples of discrete models used to analyze system designs include:

- Risk assessments, in which each risk is a statement of a discrete potential problem with an estimated probability and severity.
- Failure modes and effects analysis (FMEA), in which each failure mode is also a potential problem that can be prioritized by probability and severity.
- State machines and associated state transition diagrams, in which each state is a discrete condition of the system with clear state-to-state transition events.
- Discrete event simulations which model the behavior of the system in response to discrete external stimuli.

It would have been helpful if the continuous causal models presented as central to systems thinking would have been compared/contrasted with other types of system models, to clarify their relative contributions to successful design. Some questions triggered by this course include:

- How might the various discrete event causal models used in engineering be enhanced and replaced by circular causal models?

- Where do *acausal* models fit, as explained in article, *Technology and trends in systems modeling and simulation,* in PPI SyEN Edition #110 (March 2022) and the Modeling of acausal connectors highlighted in *Modelica Business Simulation Library 2.0 Released* item in PPI SyEN Edition #112 (May 2022)?

Two widely-used engineering techniques, Axiomatic Design [7] and TRIZ [8], seek to limit the coupling (mathematical relationships, particularly value-destroying ones) between system performance parameters and quantitative constraints. This triggers an important question for further research:

- How can CLDs be used to visualize the decoupling of functional requirements in Axiomatic Design or the implementation of TRIZ inventive principles that resolve performance contradictions and tradeoffs?

Habits Course #10: Recognizes the Impact of Time Delays When Exploring Cause and Effect Relationships [Habit 9]

Habits Course #10 adds the ability to account for the impact of time delays when creating causal models of a system. New skills include the ability to:

- Recognize everyday and personal time delays.
- Identify time delays in causal loop scenarios.
- Understand the positive and negative impacts of time delays.
- Understand the effect of time delays through an Archetype (causal model pattern).

The basis of this course is the reality that the relationship between a cause and its effects is often separated in space-time. Systems thinkers depend on the ability to recognize the potential impact of time delays and anticipate the delayed effects of certain actions.

Time delays may be visualized in causal loops as symbols (two parallel lines or "hash" marks) on the arrows that represent cause and effect relationships.

The course uses a system archetype to illustrate how time delays impact system outcomes both positively and negatively. Systems archetypes use causal loops to tell stories that reoccur across multiple settings and time periods. As such archetypes represent useful behavioral patterns for systems thinkers to understand.

The pattern used as an example, the Tragedy of the Commons archetype, is the subject of a separate Waters Center course (one of nine Archetype courses).

Course 10 Reflections

Given that system behavior is derived from system structure/architecture, there must be a similar derivation relationship between system physical architecture (patterns of solution design) and system archetypes (behavioral patterns). And because solution design patterns (common solution architectures) are the result of decisions (which also follow patterns), further valuable research may illustrate the benefits of the causal relationships between these three types of patterns:

- System design decision pattern >
- Solution physical architecture pattern >
- System archetype (behavioral pattern).

PPI SyEN readers should look for this analysis in future articles.

Habits Course #11: Considers Short-term, Long-term and Unintended Consequences of Actions [Habit 10]

This course focuses on key questions that a systems thinker asks before making decisions intended to improve the performance of the system of interest. These questions are simple tools to help designers:

- Consider short and long-term consequences in various scenarios.
- Understand "fixes that backfire" and apply this understanding to casual loop diagrams.
- Weigh benefits and tradeoffs when making decisions.

Each of these techniques improves the likelihood that a change to the system will yield lasting, positive results.

Questions that may clarify short and long-term consequences include:

- Who will be impacted by this action/decision?
- What possible results, both desirable and undesirable, will we see from this decision?
- Will others view the consequences of this decision differently, especially compared to my view of the results?

The course recommends using the Fixes that Backfire archetype as a template to think through and identify problem symptoms, quick fixes, unintended consequences and associated time delays.
Two additional techniques are recommended to help systems thinkers consider multiple factors when making decisions:

- T-charts, 2-column tables that summarize the benefits vs trade-offs (negative consequences) of a course of action.
- Reflective questions that probe what-if scenarios that have downside potential.

Systems thinkers recognize the limitations of their individual perspectives. Any technique that is used to clarify the consequences of a decision depends on receiving an appropriate diversity of inputs from other stakeholders and knowledge sources. This process invokes other habits including:

- Seeks to Understand the Big Picture
- Changes Perspectives to Increase Understanding
- Considers an Issue Fully and Resists the Urge to Come to a Quick Conclusion

As an example, the course offers a set of questions that can help clarify short-term, long-term and unintended consequences when scaling up a business or system by thinking through broader market scenarios.

Course 11 Reflections

The decision analysis techniques advocated in this course, while valid, appear too simplistic to fully evaluate a course of action that represents a significant aspect of a complex system.

"We are constantly faced with the consequences of our day-to-day decisions. Staying one step ahead by asking reflective questions and imagining possible consequences is the practiced Habit of a Systems Thinker."

The T-Chart focuses attention on a single alternative rather than providing a mechanism to objectively evaluate a set of competing solution concepts (alternatives) in a comprehensive and consistent manner. There is no process recommended for:

- Defining a set of evaluation criteria and gaining consensus on these criteria prior to generating alternative solutions. This is a surefire way to introduce bias into the evaluation process and trigger second-guessing of decisions from stakeholders whose criteria are not adequately considered.
- Using the criteria to screen out (kill off) alternatives that can't deliver stakeholder "must have" levels of performance.
- Weighting criteria to communicate the relative value contributed to stakeholders.
- Generating alternative performance estimates to score alternatives against these criteria and roll up these scoring judgments to identify the solutions that offer the greatest relative value to stakeholders.
- Separating the assessment of risks (possible failure modes associated with alternatives across their lifecycle) from the screening and scoring process.
- Using probability and severity (negative impact) as a method to prioritize risks.
- Performing final scoring (overall effectiveness) vs risk tradeoffs.

The reflective questions posed in the course make sense in the context of such a decision analysis process, but done in an ad hoc manner even by skilled systems thinkers they are unlikely to provide a holistic picture of the best course of action. These reflective questions don't form a sufficient picture to ensure that important data isn't missing or that data that is generated during analysis is integrated into the decision-making process in a balanced and defensible way.

The unintended consequences questions are valid methods to identify risks, but are also not used consistently across all alternatives in a way that the overall risks associated with competing solutions may be compared.

The "scaling up" discussion uses "custom" questions, when a generalized decision analysis approach using criteria-driven evaluation and risk assessment would be more effective.

Habits Course #12: Considers an Issue Fully and Resists the Urge to Come to a Quick Conclusion [Habit 11]

This course continues with recommended practices to improve design decisions and their outcomes. It revisits the need to identify short and long-term consequences of proposed actions. It adds techniques to mitigate pressures to make a hasty and ill-fated decision. Decision-making patience and discipline is taught through four example scenarios.

The course workshops propose questions to counter time-pressures and increase the quality of data used to inform a decision. Examples of these questions include:

- What is the decision that needs to be made?
- What is the timeline for making the decision?
- How do you know when you have taken the right amount of time to make a decision?
- What are the different perspectives that need to be taken into account when making this decision?
- How can you help yourself and others be patient while living with an unresolved decision?

The course asserts that systems thinkers offer a perspective that encourages an appropriate balance between decision-making efficiency and effectiveness.

Course 12 Reflections

Much of this course suffers from the same limitations expressed for Course #11. Most of the content represents valid principles that contribute to good design decisions, but without directly teaching an executable and scalable Decision Analysis process. This is one of the common critiques of the series of courses, they provide sound logic for approaching the analysis in question but are vague when it comes to describing how to actually proceed with the analysis technique in a structured way. This critique does not take away from the values the course provides in providing a deeper picture of the various principles of systems thinking. Three quotes are reflect the mindset described above:

"Every day we are faced with decisions and choices, which oftentimes, deserve careful consideration. It is important to not jump to a conclusion, but rather to weigh options and the potential outcomes of our choices."

True, but shouldn't we as part of a design initiative not be surprised by the decisions (design questions/issues) that we face?

By the questions we ask, the perspectives we consider, and the consequences of actions we foresee, systems thinkers naturally integrate a process for fully considering an issue.

True, but why depend on individual skills to "naturally integrate a process" when proven processes for effective decision-making are widely taught. What if many members of your design team are not yet effective systems thinkers? In addition, we are all constantly learning. When faced with greenfield scenarios, using wisdom gained from past experience alone won't be sufficient to analyze the problem.

"Taking time to think things through and to consider an issue fully increases the likelihood of a high-quality outcome."

Time is one variable in decision quality, but without a definition of what is needed to "consider an issue fully" is there any confidence that more hours spent on decision analysis will yield better results? The course lacks any method to proactively identify a set of decisions and to plan the analysis to ensure that appropriate investment, rigor and participation is provided to inform the decision. Decisions are treated as everyday occurrences that "pop up", rather than fundamental questions that demand an answer (for any system) and which can be identified early in a project through the use of decision patterns. See *Introduction to Decision Patterns* in PPI SyEN Edition #107 (December 2021) for more details on the proactive use of decision patterns to create a Decision Breakdown Structure (DBS).

The course provides no mechanism for decision prioritization as the basis for setting decision analysis budgets or determining WHO should be involved in different steps in the decision analysis process to increase the likelihood of a good decision. There is no mention of using decision priorities to enable "scalable rigor", i.e., determining the level of effort appropriate to a specific decision.
However, the questions includes in practice exercises "back into" a reasonable analysis plan for a typical decision. They mirror some proven decision planning attributes such as:

- Decision Priority
- Target Date (to complete the decision analysis)
- Analysis Budget
- Decision Owner
- Analysis Method
- Analysis Plan

Decisions are the integrative mechanism of the design process. But without a well-defined and integrated methodology with discrete steps to balance all of the inputs, the likelihood of a poor decision is extremely high, even with the contribution of a few highly skilled systems thinkers.

Habits Course #13: Pays Attention to Accumulations and Their Rates of Change [Habit 12]

Habits Course #13 introduces the concept of accumulations, i.e., changes over time in the quantities or characteristics of elements within systems. It teaches designers how to affect these elements by taking (or avoiding) certain actions. Desired systems thinking skills include:

- Understanding and identifying accumulations in a system of interest.
- Recognizing how rates of change in a system affect accumulation.
- Identifying the connection between accumulations and reinforcing feedback.
- Learning the basics of a stock-flow map.
- Using a stock-flow map to demonstrate behavior in a system of interest.

An accumulation is defined as an element in a system that changes over time. Accumulations may be quantified numerically or as qualitative perceptions. Systems thinkers also refer to accumulations as *stocks*.

The course uses the example of a bathtub to clarify the concept of accumulations:

- The water in the tub represents the stock or accumulation.
- The rate of change that influences the stock is referred to in systems language as the flows.
- The inflow or bathtub faucet increases the stock.
- The outflow or bathtub drain decreases the stock.

Another metaphor for understanding accumulations is a bank account (with the account balance as the stock, deposits as inflows and withdrawals as outflows).

This course introduces a new notation, the stock-flow map, as a way to visualize accumulations. The stock-flow map comes from the field of System Dynamics, as do many of the other systems thinking concepts presented in the Waters Center courses.

Stock-flow maps include the following modeling elements:

- Accumulation (stock) = Water in the tub
- Inflow and outflow (shown as arrows) = Filling & Draining
- Converter = Need for a bath

Course 13 Reflections
The course states that:

"Systems thinking is derived from the field of system dynamics"

However, there is no evidence of which systems thinking concepts and artifacts as taught herein are directly pulled from systems dynamics sources. A trace or cross-reference between the two overlapping disciplines would be helpful in this context.

There is also no clear statement in this course (or the full Habits course series) of the relationships between the data elements visualized on the:

- *Causal Connection Circle (described in Course #2 – Habit 1 + Tools Course #6)*
- *Causal Loop Diagram (described in Habits Courses #9-10 + Tools Course #7-9)*
- *Stock-Flow Diagram (described in Habits Course #13-14 + Tools Course #3)*

Absent an explicit information metamodel or class diagram for these systems thinking visualizations, the authors can't discern with confidence whether they are different views of the same fundamental modeling language or distinct representations of different modeling constructs that can't be formally integrated and reconciled. Based on the previous knowledge of the authors regarding systems thinking tools, Causal Connection Circles are perceived to be an entry step to creating CLDs, they are like a scratch pad or brainstorming tool to be used on the way to developing the CLD. CLDs show relationships between elements and help to determine which of those elements are stocks. The stock-Flow diagrams then present this information in a way that is calculable via equations and by establishing units for stocks and flows.

"Accumulations are things that change. They are the nouns of systems."

Most systems engineering practitioners would match the nouns of the systems with physical elements, i.e., components and interfaces. Accumulations as defined herein appear to be either:

- Parameters associated with the system elements (acting as adjectives modifying the system nouns).
- Parameters that define how well the system functions (emerging from the system structure) are performed (acting as adverbs modifying the function verbs).

System functions (allocated to and performed by components) typically have one or more measures of performance (MOPs) that express how well the function is accomplished. System functions have inputs and outputs (information, matter or energy), typically captured as *item flow* in the system functional model.
The lack of an "official" information metamodel for stock-flow maps and CLDs leaves the following additional questions that warrant further research:

- How does item flow in a system functional model relate to stocks and flows in the systems

thinking/dynamics model?
- What is the corollary in a system functional model for the Converter element in a stock-flow map?

Habits Course #14: Uses Understanding of System Structure to Identify Possible Leverage Actions [Habit 13]

This course uses the metaphor of leverage to illustrate how systems thinkers can use their knowledge of system structure and behavior to improve system performance. The skills taught in this course include:

- Understanding the meaning of "leverage" related to systems.
- Determining leverage actions in various scenarios.
- Using a causal loop map to identify leverage.

Methods of visualizing the dynamic behavior of a system (causal models) provide systems thinkers with the ability to identify points of leverage. Leverage is defined as *the ability to choose actions that intentionally influence people, events or decisions to resolve challenges*.

Causal maps are effective tools to help make system structure visible and to illustrate a system's interdependencies. Feedback loops provide an interdependent picture of a system and can lead to the identification of leverage actions. When viewing a causal map, some strategies for finding leverage points includes:

- Looking for loops that are friends and foes. Which loops do we want to maintain? Which do we want to see changed or removed?
- Looking for the elements that have the greatest number of connections to other system elements, or the element that has the most number of incoming arrows. Consider that a change in that one element will have a significant ripple effect to other aspects of the system.
- Considering how to strengthen, weaken or break a causal link.
- Adding a loop that will positively impact the whole.
- Periodically asking: what is missing? What have we not yet considered?

The course also recommends use of reflection questions throughout the mapping process to uncover possible leverage actions.

Course 14 Reflections

While the overall objectives and intention of this course are valuable and reasonable, the concept of leverage presented in this course lacks engineering rigor and appears to be an inefficient approach to improving system performance by changing system structure.

"A magnet is leverage in locating a very small piece of metal in a large pile of straw"

The authors propose that the magnet, as the physical implementation of a technology, is one method by which the Locate Metallic Objects function may be accomplished to some desired level of performance (e.g., location time, location accuracy, false positive rate). A causal map would show the relationships between these system-level performance variables for the Magnet-based solution. A separate causal map would be created for a solution that used different technologies (e.g., differences

in mass, particle size and density or response to radiation) to distinguish or separate the metallic objects from the straw.

"A deep understanding of system structure is necessary when determining leverage actions".

This appears to be a restatement of the basic principle from Course #8 (A System's Structure Generates its Behavior). Failure to understand how the current structure of a system generates its current behavior makes changes to that structure highly risky.

A more rigorous and proven approach to design should include at least the following steps:

- Frame the System Physical architecture as an explicit decision, worthy of full decision analysis rigor.
- Generate a range of solution concepts that combine different technologies into different physical implementations.
- Screen out the infeasible solution concepts against system requirements.
- Create an initial physical architecture concept for one or more feasible candidate solutions.
- Develop a functional architecture (with control flow and item flow) for feasible candidate solutions based on the physical solution concept.
- Iteratively align and refine the physical and functional architecture models.
- Flow down MOPs for each function as the system architecture is recursively decomposed.
- Mathematically model the relationships between MOPs at different level of functional decomposition, i.e., how the MOPs associated with child functions roll up to satisfy the levels of performance required by the parent function.
- Use behavioral and performance models to inform the architecture decision.
- Commit to the best overall solution architecture.
- Derive next-level requirements (functional, performance, interface, lifecycle, etc.) based on the solution architecture chosen.
- Repeat the previous steps for the next level of system physical architecture decomposition.

It is likely that other well-known innovation techniques could also more efficiently identify points of leverage that *weaken or break a causal link*:

- The Inventive Principles of the TRIZ methodology provide a way to sidestep conflicting performance parameters and constraints by changing the mathematical relationship between these parameters through a variety of structural innovations.
- The decoupling of functional requirements (FRs) and associated performance requirements within Axiomatic Design serves a similar purpose.

The authors note that this course uses the generalized term, *causal map*, in place of the more precise names causal loop diagram and stock-flow map. It's not clear whether the course recommends that a particular variant of causal mapping visualization is the best fit for the identification of leverage actions.

The reflection questions presented in this course would be better answered as part of the steps of system functional modeling with allocation/flow-down of performance requirements, followed by design decision-making to select between the physical solution alternatives. Causal models would be used to estimate the effectiveness of the proposed designs and design changes as part of the decision analysis (alternative evaluation) process.

Habits Course #15: Checks Results and Changes Actions If Needed: "Successive Approximation" [Habit 14]

The final Habits course teaches the concept of successive approximation – a continuous and incremental approach to improvement. Learning objectives for this course include the abilities to:

- Understand the successive approximation process.
- Identify gaps/plateaus and their influence on successive approximation.
- Use a behavior-over-time graphs to track desired change.

The technique of successive approximation has been adapted from W. Edwards Deming's, "Plan, Do, Study, Act" (PDSA) or Plan-Do-Check-Act (PDCA) cycle. The mindset behind successive approximation involves a willingness to take risks and overcome failure. Failure is presented as an opportunity for further improvement, a necessary step of learning, innovating and achieving goals.

Course 15 Reflections

Systems engineering practitioners are generally familiar with continuous improvement methodologies. Continuous improvement is also the basis for system development strategies (waterfall, incremental, evolutionary or spiral). What varies between these development strategies is the time-scale across which new increments are conceived and implemented and the way in which feedback triggers the next improvement cycle.

Conclusions

Contrasting systems thinking habits (as taught in the Waters Center courses) with systems engineering practices (from the experience of the authors and as taught in PPI's courses) has yielded numerous open questions for further research. In general, these questions address:

- Clarification of the systems thinking/dynamics modeling language that is the basis for proposed visualizations. An information metamodel in the form of an Entity-Relationship-Attribute (ERA) or Class Diagram is needed to complete the comparison with MBSE knowledge structures.
- Lack of a integrated systems thinking/dynamics methodology that shows the flow through a process that implements the habits. This is needed so that organizations can depend less on the heroics of a few highly-skilled system thinkers and more upon defined, measured and optimizing processes.

PPI SyEN readers should look for Part 3 of this series in which we will review the nine System Archetypes – behavioral model patterns - and explore how these patterns align with or complement other types of patterns used in the development of systems and products.

References

[1] Kepner, C. and Tregoe, B. 1997. The New Rational Manager: An Updated Edition for a New World, Kepner-Tregoe, Inc., Princeton, NJ (US), pp. 33-56.
[2] Pearl, J. and MacKenzie D. 2018. The Book of Why – The New Science of Cause and Effect. Basic Books, New York, NY (US).
[3] Brown, T., (2008), "Design Thinking". Harvard Business Review, June, 2008, pp. 84-92.
[4] IDEO U, 2024. "Design Thinking". IDEO University web page. https://www.ideou.com/pages/design-thinking

[5] Stanford University, 2024. "Start with design". Dschool web page. https://dschool.stanford.edu/resources/get-started-with-design
[6] Systems Engineering Body of Knowledge (SEBoK), version 2.6. PDF extraction from www.sebokwiki.org, Systems Engineering Research Center (SERC), 2021.
[7] Suh, N.P., 2001. Axiomatic Design: Advances and Applications, Oxford University Press, 2001, ISBN 0-19-513466-4
[8] Altshuller, Henry. 1994. The Art of Inventing (And Suddenly the Inventor Appeared). Translated by Lev Shulyak. Worcester, MA: Technical Innovation Center. ISBN 0-9640740-1-X

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Within the field of systems engineering, John's career has focused on decision management, requirements management, risk management, systems design & architecture, product/technology road-mapping and innovation. In addition to defense/aerospace, John has guided initiatives in domains such as communications systems, software, energy, nanotechnology, medical devices, manufacturing systems, knowledge management and business process improvement.

René King is a Senior Engineer and Business Development Manager with Project Performance International (PPI). René has a BSc in Mechanical Engineering from the University of Witwatersrand, South Africa. René completed her Master of Science (MSc) in Systems Engineering in 2020. As part of her degree, she completed courses in Requirements Analysis, Systems Integration, Verification and Validation and Architectural Design. Her thesis topic encompassed evaluation of operational capacity for a freight railway network. This topic required a large amount of synthesis as this is a green-field area of research.

In 2019, René became Managing Director of PPI's daughter company, Certification Training International. In this role her activities include managing the quality of course content, ensuring continuous improvement of processes, writing up contracts for staff and driving the business forward to meet its objective of increasing the number of certified systems engineering professionals in the world.

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E-Learning Courses

NAFEMS offers a diverse range of code-independent, in-depth online training courses on engineering analysis and simulation. Upcoming courses beginning in February, March and April 2024 include:

Understanding Solid Mechanics: Applied Stress Analysis (4 sessions; 1 – 22 February)
This course aims to provide an understanding of the calculations required to determine the internal forces and stress distributions that correspond to the external loads applied on different structures utilized for their efficiency under certain conditions. The course deals with beams that support bending forces acting along their length, shells and cylinders that support normal forces acting on their surfaces and shafts that support torsional forces.

Non-Linear FEA (6 sessions; 6 February – 12 March)
This course addresses the important features of non-linear FEA. You will focus on key background and practical tool-independent hints and tips, covering topics including:

- Background to non-linear FEA
- Nonlinear analysis strategy
- Geometric nonlinearity
- Material nonlinearity
- Contact nonlinearity
- Explicit analysis background

Next Steps with Multibody Dynamics Simulation (3 sessions; 6 – 20 February)
This course offers guidance on how to assess and plan the task of carrying out advanced Multibody Simulation Analysis of systems and mechanisms. By attending, you will build a theoretical, numerical and methodological background which will allow you to build advanced MBD models. Examples are discussed in detail to illustrate the different technologies. Focus is put on how to introduce more realism in an MBS model so to better replicate the physics, ending up with latest trends in the discipline, and special focus on the observed convergence between MBD and Finite Element Analysis.

Fundamentals of Multibody Dynamics Simulation (3 sessions; 7 – 21 February)
This course explains what you need to know to perform Multibody Simulation Analysis of systems and mechanisms. You will learn about the theoretical, numerical, and methodological background which will allow you to build your first Multibody Dynamic (MBD) models, and then progress to more complex ones. Examples will help you to understand not only model construction but how and why a given model has been built that way. The examples will illustrate the use of multiple commercial MBD software packages.

Introduction to Practical CFD (3 sessions; 9 – 13 February)
This course offers attendees the fundamental knowledge for using Computational Fluid Dynamics

(CFD) in real-life engineering applications. Through a simple and moderately technical approach, this course describes the steps in the CFD process and provides benefits and issues for using CFD analysis in understanding of complicated flow phenomena and its use in the design process. Best practices for reducing errors and uncertainties in CFD analysis are also presented.

Practical Modelling of Joints and Connections (3 sessions; 22 February – 7 March)
Most structures involve some form of jointing or connection. The engineer is faced with a difficult decision when attempting to simulate such connections and joints within a Finite Element Analysis (FEA). In many cases, the details of each individual connection can be ignored if an overall stiffness or strength assessment is to be made and the connection is assumed reasonably continuous. However, there may be doubts about the local flexibility and load paths developed with this assumption.

The objective of this course is to review the various connection and joint technologies in use, give an overview of the physics involved and show how to successfully implement practical solutions using Finite Element Analysis.

10 Steps to Successful Explicit Dynamic Analysis (3 sessions; 26 – 29 February)
This course provides a basic overview of explicit dynamics simulation methods, briefly describing the theoretical nature together with its software implementation and its advantages and disadvantages. It should help engineers carry out explicit dynamics simulations, ensuring accurate and robust solutions with correct analysis choices avoiding possible pitfalls. It should also help engineers distinguish problems that should be solved explicitly or implicitly, thereby providing the least time to obtain a solution.

Basic Finite Element Analysis (6 sessions; 21 March – 25 April)
The course offers excellent guidance on how to assess and plan the task of carrying out structural analysis using FEA. Content includes:

- Background to FEA
- Defining your objectives and planning your analysis
- Making healthy models
- Real-world constraints and loading
- Engineering assessment – is your model realistic
- Integrating with CAD and geometry
- Checking the answers – guilty until proven innocent!

Elements of Turbulence Modeling (2 sessions; 22 – 29 March)
Turbulence models based on Reynolds-Averaged Navier Stokes (RANS) equations are the most common and practical approaches for turbulence simulation. This course provides the attendees with basic understanding of complexities in turbulence simulation and introduces them to most used turbulence models with their advantages and limitations. Questions to be answered include:

- What are the challenges faced in 3-D turbulent flow simulations?
- What are practical approaches to simulate turbulent flows?
- There are many turbulence models. What are the bases for these models?
- What are the advantages and limitations of each model?
- How do I select a turbulence model for my applications?

Introduction to Dynamics using FEA (6 sessions; 26 March – 30 April)

This course will cover a range of topics, all aimed at structural designers and engineers who are moving into the area of dynamic analysis, including:

- Normal Modes Analysis
- Damping
- Modal Coordinates
- Modal effective Mass
- Transient Response
- Frequency Response

Understanding Solid Mechanics: Stress Analysis Approaches (5 sessions; 4 April – 2 May)
This course is a starting point towards understanding solid mechanics - to enable application of good practice in finite element analysis. Content includes:

- Statics, Forces and Equilibrium in Design
- Elasticity, Stresses and Strains
- Constitutive/Material relationships
- Hand (or 'Back-of-the-envelope') calculations
- Boundary Conditions and Applied Loads

CFD for Structural Designers & Analysts (3 sessions; 12 – 26 April)
This course will cover a range of topics, all aimed at the structural designer and analyst who needs to get to grips with CFD, including:

- Principles of fluid dynamics
- Important flow phenomena
- Basics of the CFD process
- Turbulence modelling
- Fluid-structure interaction

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The Knowledge Hub (kHUB) of the Product Development Management Association (PDMA) offers a wide variety of product development and innovation management resources in the form of blogs, podcasts, videos, conference presentations, feature articles and whitepapers.

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- A "Jobs To Be Done" Case Study
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- Designing Effective Organizations for Product Innovation
- Find Pearls and Drive More Innovation in Your Portfolio
- Function Analysis: Foundation to Concept Development

- Improve your Facilitation Skills
- Improving Innovation Decision Making
- Know Your Customer
- Lenny's Newsletter (Podcast)
- Serial Innovators: How Individuals Create and Deliver Breakthrough Innovations in Mature Firms
- Steve Jobs: A Product Developer's Perspective

Access to kHUB is free and open to the public.
Create a guest account or join PDMA here.

System Dynamics Courses to Consider

The System Dynamics Society (SDS) is the source for multiple courses that teach system dynamics fundamentals, advanced topics, and application skills. Two new courses are available from the SDS affiliate, strategy dynamics, that may be of interest to systems engineering practitioners.

Strategy Dynamics for Leaders
This online, on-demand course will teach you how to build strategic plans with a *digital twin* of your business or challenge. Learning outcomes include:

- Use powerful research-backed frameworks.
- Exploit a "digital twin" of your business.
- Watch your decisions play out like a movie.

Course structure:

- Class 1: Specifying your desired performance outcomes.
- Class 2: How resources drive performance.
- Class 3: How customers, staff, products, and capacity are built and sustained.
- Class 4: How resources work as a system, driving performance.
- Course wrap-up.

Two variants of this course, Full and Essentials, are available. Learn more here.

Enroll in Strategy Dynamics for Leaders.

Dynamic System Modeling
This online, on-demand course will teach you how to create a "digital twin" of your business that offers quantified, time-based, visual simulations of how the business actually works, with associated inter-dependencies, tipping points and feedback loops. Learning outcomes include:

- Modeling Performance Over Time.
- Factors Driving Performance Outcomes.
- How resources accumulate.
- Connectedness, feedback, and growth.
- Build a complete model from scratch.

- Build a model to tackle any issue.
- Build living plans for any function.
- Selling Dynamic Business Models.

Course structure:

- Class 1: Specifying your desired performance outcomes.
- Class 2: How resources drive results.
- Class 3: How customers, staff, products, and capacity accumulate and deplete.
- Class 4: How resources work as a system, driving performance.
- Course wrap-up.

Two variants of this course, Full and Essentials, are available. Learn more here.

Enroll in Dynamic System Modeling.

Note a discount is available for SDS members for both courses. Join SDS here.

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Tomorrow's Engineering Research Challenges

The United Kingdom's Engineering and Physical Sciences Research Council has published a 100-page study, titled "*Tomorrow's Engineering Research Challenges (TERC) - Visions from the UK Research Community*" that outlines how the UK's engineering research community can align scientific discovery with solution engineering. The report summarizes the key findings in the form of a spectrum of challenges presented at different levels: High-Level Priorities, Cross-Cutting Themes and Technological Challenges.

High-Level Priorities
The High-Level Priorities highlight the most pressing actions for the wider engineering community to enable researchers to address future challenges:

- Promote inclusive engineering outcomes for all with more diverse input.
- Strengthen mechanisms to facilitate and fund multidisciplinary and interdisciplinary research.
- Re-engineer the discipline of engineering.
- Convene and connect with the professional engineering community to enhance impact.
- Encourage diverse, agile and impactful skills.
- Inspire the next generation.

Cross-Cutting Themes
Cross-Cutting themes represent opportunities for engineering and engineers to contribute across all sectors and technologies:

- Achieving net zero and sustainability.

- Faster digital design.
- Greater access and use of data.
- Increasing human resilience.
- Understanding complex systems.
- Harnessing disruptive, emerging technologies.
- Underpinning tools and techniques.

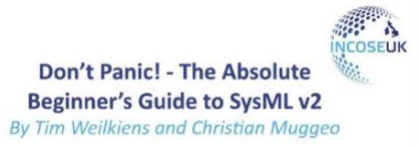
Technological Challenges
Technological Challenges represent situations where novel approaches and creative engineering research will be vital to make progress across specific domains:

- Ensure space research is sustainable, and design and develop technologies that will be used to explore and sustain life in space and on Earth.
- Develop sustainable, integrated, and equitable transportation systems.
- Accelerate environmentally sustainable and socially responsible creation and utilization of materials.
- Improve whole-life health and wellbeing by developing sustainable, inclusive, and resilient healthcare systems and technologies.
- Co-design and embed robotics and AI into engineering while ensuring ethical use with transparent and equitable decision making.
- Foster socially and environmentally responsible approaches to engineering guided by our understanding of human behaviors and needs.
- Unlock the full potential of nature-based engineering.
- Deliver adaptable global engineering solutions that are compatible with our understanding of the planet's ecosystem.

Though written from the UK's perspective, PPI SyEN readers may find many of the concepts in the TERC report relevant to their research and development efforts.

Download the TERC report.

Book: Don't Panic: The Absolute Beginner's Guide to SysML 2.0



A recent addition to the INCOSE UK's Don't Panic series is *Don't Panic: The Absolute Beginner's Guide to SysML 2.0* by Tim Weilkiens and Christian Muggeo. As with other books in the Don't Panic series, this work provides a throrough, digestible and succint guide to this important topic.

New and existing users of SysML will benefit from this publication as it explores the major differences between SysML 1.n and SysML 2.0. SysML 2.0 has been developed from scratch and is no longer dependent on the UML2 metamodel, but is based in a new metamodel called KerML - the Kernel Modelling Language.

This book in available in both paperback and e-book formats from the INCOSE UK Store.

Read the INCOSE UK's LinkedIn announcement.

Featured Organization: The Design Society

The Design Society (DS), established in 2000, is an interdisciplinary community of academics and industry practitioners with the goal of developing and promoting a robust, usable and scalable means of designing complex solutions that a sustainable and globalized society needs to thrive, in the 21st century.

The objectives of the Society are to promote the development and propagation of design knowledge across all disciplines by:

- creating and evolving a formal body of knowledge about design and designing.
- supporting and improving design research, education, practice, and management.
- promoting co-operation among design researchers, practitioners, educators and managers.
- promoting design publications and their dissemination.
- organizing international and national conferences, workshops, and student events.
- operating Special Interest Groups on different design topics and regional Chapters.
- co-operating with other bodies with similar and complementary design interests.

The Design Society collaborates with Cambridge University Press in publishing original quantitative and qualitative research in the creation of artifacts and systems, and their embedding in our physical, virtual, psychological, economic, and social environment. *Design Science* is an international open access journal. *Design Science* aims to serve as the archival venue of science-based design knowledge across multiple disciplines.

The Society offers a rich, searchable library of resources, including:

- Design Society publications
- Design Journals (including Design Science and many more)
- Video Library
- Design Society Exchange
- Design Practice Speaker Series

Although many resources are open access, others require DS membership. Join here.

Members may engage with the Society through multiple organizational elements:

- Special Interest Groups (SIGs)
- Regional Chapters, including Asia, Nordic and North American
- Initiatives, e.g. Africa Design

Much of the collaborative work of the Society takes place through a variety of events. A sample of these events for 2024 include:

- International Upcycling Festival 2024 (IUF2024) on 11-12 April in Leicester, UK.
- 18th International Design Conference (Design2024) on 20-23 May in Dubrovnik, Croatia
- 6th International Summer School on Product Architecture Design (PAD2024) on 17-21 June in Hamburg, Germany
- Design Computing and Cognition'24 (DCC'24) on 8-10 July in Montreal, Canada.

- NordDesign 2024 on 12-14 August in Reykjavík, Iceland.
- 26th International Conference on Engineering & Product Design Education (E&PDE 2024) on 5-6 September in Birmingham, UK.

The Society's premier event, the International Conference on Engineering Design (ICED) occurs biennially. ICED2025 will take place in Dallas, Texas, USA on 11-14 August 2025.

Follow the ICED Conference on LinkedIn.

Technology Showcase: Digital Twins for Public Safety

The Digital Twin Consortium (DTC) has developed a Technology Showcase, i.e., a reference library that chronicles the evolution of digital twins and elaborates on use cases that demonstrate how consortium members have deployed digital twins to create new value. A new use case has been added to this library.

Digital Twins For Public Safety
This use case is an Artificial IoT (AIoT) safety solution that provides comprehensive safety intelligence to help save people who are involved in active shooter incidents. During an active shooter incident, the use case helps to minimize the damage. It presents the best courses of actions to those at the scene during the "golden time" before the police and the fire department arrive.

By linking 3D visualization of target facilities with CCTV footage, the digital twin shares real-time data about the situation with safety managers, local police, and fire departments. It also supports realistic safety training using 3D simulations.

Download the use case.

The new use case complements the six previously published applications of digital twin technology:

- Buildings As Batteries
- Emergency Communication Services
- Infectious Disease Management
- Manufacturing Quality Control Via Remote Operator
- Scope 3 Carbon Emissions Reporting
- Wind Farms Remote Operations Center

Learn more about the Digital Twin Consortium.

FINAL THOUGHTS FROM SYENNA

Picture this: you're an SE practitioner, armed with your laptop, a cup of coffee that's been reheated thrice, and a mind buzzing with ideas about potential solutions to solve a customer's ongoing IT problem. 'This should be a straightforward project' you think to yourself, but there's an issue – every stakeholder sees it differently.

The Optimist's View
"This system is nearly perfect!" declares the optimist. They see a world where every system crash is just an unplanned stress test.

The Pessimist's View
The pessimist is convinced the system was designed by a committee of Murphy's Law enthusiasts. To them the system can only fail, it probably already has – but nobody's noticed yet.

The Realist's View
The realist, armed with metrics and data, tries to bridge the gap. They see the system as a delicate balance of functional and dysfunctional, just a firmware update away from either excellence or catastrophe.

The Customer's View
To the customer, the system doesn't care about how it works, as long as it does – and when it doesn't, they assume it's powered by some sort of dark magic.

The Developer's View
Ask a developer, and they'll tell you the system is a maze of legacy code, held together by digital duct tape. It's a miracle it runs at all, and each new feature is a high-stakes game of Jenga.

The Project Manager's View
The project manager sees the system as a Gantt chart brought to life – to them, the system isn't just software; it's a ballet of resources, timelines, and budget forecasts.

The End User's View
Finally, there's the end user, who just wants the system to work without having to call tech support every five minutes.

You reflect on these views and realise the problem isn't so simple to solve after after all however you appreciate that every viewpoint offers its own unique insight as well as its cognitive bias.

And if all else fails, just turn it off and on again – that usually works.

Syenna