



31st Annual **INCOSE**
international symposium

VIRTUAL EVENT

July 17 - 22, 2021

Accelerating through Adversity

Book of Abstracts

Status as of July 14, 2021

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Keynote - Plenary

Closing Address

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Presented on: Thursday, 16:30-17:00

Countering Digital Authoritarianism

Victoria Coleman (USAF Chief Scientist - Senior Advisor to the Director at CITRIS & the Banatao Institute, University of California Former Director of DARPA)

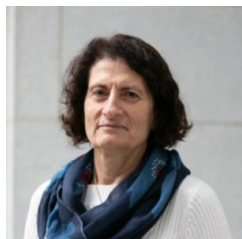
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Presented on: Monday, 08:00-09:30

Abstract. Digital authoritarianism—the use of information technology by authoritarian regimes to surveil, repress, and manipulate domestic and foreign populations—is on the rise globally. In Myanmar, a military coup has instituted a nightly internet shutdown and has blocked Facebook and Twitter since early February 2021. In China, facial recognition technology and a widespread mobile hacking campaign have been deployed to target and oppress ethnic minorities. Aiming to gain call logs, precise locations, contacts, photos, and other information, similar surveillance of mobile phone apps has emerged in Iran, North Korea, and Syria. In Mexico, spyware procured by the government to fight terrorism is being turned on its citizens to silence dissidents.

Countering digital authoritarianism requires not only technical innovation, but also new policy and governance strategies within the public and private sectors. To start, the US must develop a new strategic framework to combat the rise of high tech illiberalism. This political and legal framework cannot be enacted without coordinated federal action. This much is clear. What remains unclear is the appropriate strategy to do so. This talk will explore the creation of such a strategic R&D agenda and policy framework.

Biography



Victoria Coleman (USAF Chief Scientist - Senior Advisor to the Director at CITRIS & the Banatao Institute, University of California Former Director of DARPA)

Dr. Victoria Coleman is the former Director of DARPA. She serves as Senior Advisor to the Director of the Center for Information Technology Research in the Interest of Society (CITRIS) at UC Berkeley where she is leading microelectronics technology policy. Prior to DARPA she served as the Chief Executive Officer of Atlas AI P.B.C, a Silicon Valley startup that brings world class AI solutions to sustainable development. By combining satellite data with other data sets, Atlas AI's proprietary deep learning models create actionable insights for governments, NGOs, and commercial

companies. Prior to joining Atlas AI, Coleman was the Chief Technology Officer at the Wikimedia Foundation, the nonprofit that supports Wikipedia, where she oversaw the organization's Technology department and technical roadmap, and was responsible for the evolution, development, and delivery of core platforms and architecture. In this role, Dr. Coleman worked to ensure an accessible and performant technology infrastructure and anticipate scale and capability challenges for the Wikimedia projects. She was previously a Senior Vice President at Technicolor where she served as the CTO of the Connected Home Business. Prior to Technicolor she was Senior Vice President R&D for Harman's Infotainment Division. As Vice President Engineering at Yahoo! she was responsible for membership services, presentation layer technologies and developer relations. At Nokia as Vice President, Emerging Platforms she led a multi-disciplinary team creating strategic products including the Nokia Z Launcher and the Nokia X line of smartphones. As Vice President, Software Engineering at HP Palm GBU leading the webOS Platform team she built the HP Touchpad. As Vice President with Samsung's Advanced Institute of Technology in charge of the Computer Science Laboratory in San Jose, CA she initiated the development of Tizen and the Samsung Knox line of smartphones. She was previously Intel's Director for Security Initiatives and the Director of the Trust and Manageability Laboratory in Intel's Corporate Technology Group. She joined SRI International in 1998 after 10 years as a tenured professor in the University of London. She became the founding Director of SRI's System Design Laboratory in 1999. She was a member of the Defense Science Board, a member (and founding Chair) of DARPA's Microsystems Exploratory Council, a member of Lockheed Martin's Technology Advisory Group, a member of Airbus Industries Starboard and a member of Santa Clara University's Advisory Board for the Department of Computer Engineering. She also served on the Board of Directors of the Public Library of Science.

How systems engineering made solar cars a reality

Lex Hoefsloot (Co Founder of Lightyear)

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Presented on: Wednesday, 08:00-09:30

Topics. 3. automotive; 1.6. systems thinking;

Abstract. Lex and his co-founders have been working on solar cars for 9 years. In the early days, they drove the first 4-seater solar car in the world championship for solar cars in Australia and won the first time they participated. From that moment on, all of their focus has been on how to make the first customer-ready solar cars and they strongly leveraged systems engineering to make it happen. Lex will talk around the why, how and the what. Why has system engineering been so crucial for them?

Biography



Lex Hoefsloot (Co Founder of Lightyear)

After long-nights of research and brainstorming, we founded Lightyear in 2016. The company has grown exponentially, we have over 34 patents pending, over 100 early pre-orders, first driving prototypes and working towards production for a first Exclusive Series of cars and setting up the High-Volume Series. Lightyear is prepared to make a dent in the universe by putting a high comfortable 4-seater car on the Earth, free from the grid, enabling clean mobility for everyone everywhere. In the summer of 2017, I was lucky to be selected as one of the 90 people from all corners of the planet to participate in the Singularity University Global Solutions Program with

the goal of accelerating companies that solve climate change. As a participant, I was coached by the world's best thought leaders, entrepreneurs and investors in leading transformative companies. This leadership program is recognized as one of the most forward thinking in the world and provides access to a network of more than 10,000 highly successful individuals and alumni of Singularity University. With a bachelor's in mechanical engineering and a master's in automotive technology, Lex was the team manager and co-founder of Solar Team Eindhoven. Solar Team Eindhoven has won the last 4 editions World Solar Challenge Cruiser Class by designing, building and competing with most efficient multiple seater vehicles on the planet. More than 35 students helped to get our first car on the road.

Keynote - Plenary#PresidentPanel

Presidents' Panel: Accelerating through Adversity - Back to the Future!

Marilee Wheaton (INCOSE President Elect)
Donna Rhodes (2000)
David Long (2014-2015)
Alan Harding (2016-2017)
Kerry Lunney (2020-2021)

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Presented on: Thursday, 15:30-16:30

Abstract. This panel provides a rich set of perspectives on INCOSE's past and present to see how well we have prepared and positioned our organization and the systems community for the future. It will provide insights into the good, the bad, the ugly, and the unknown.

Keynote - Plenary#K2

The role of architecture in achieving Society 5.0

Masayoshi Arai (Director-General, Commerce and Information Policy Bureau Ministry of Economy, Trade and Industry (METI), Government of Japan)

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Presented on: Tuesday, 08:00-09:30

Topics. 20. industry 4.0 & society 5.0;

Abstract. This presentation will introduce the concept of Society5.0, proposed as a future society by Government of Japan, and digital policies toward Society 5.0 with emphasis on the impact of architecture. Society 5.0 means "A human-centered society that balances economic advancement with the resolution of social problems by a system that highly integrates cyberspace and physical space." Government of Japan established Digital Architecture Design Center (DADC) in order to design digital architecture in Society 5.0 and has just started some projects while gathering the wisdom of industry, academia and government. DADC will promote digital transformation of society as a whole by collaborating with Digital Agency, which will be established in this September.

Biography



Masayoshi Arai (Director-General, Commerce and Information Policy Bureau Ministry of Economy, Trade and Industry (METI), Government of Japan)

Mr. Arai is Director-General, Commerce and Information Policy Bureau, Ministry of Economy, Trade and Industry (METI), Government of Japan. Prior to his current position, he served as Director-General for Policy Planning and Coordination and other two positions in Minister's Secretariat since 2016, where he coordinated wide range of economy and industrial policies. Before 2014, he worked for the Information, Communication, and Electronics Division of METI for 2 years. He has contributed to the growth of electric industries of Japan and expanded its communications and friendships with overseas IT companies. Before 2012, Mr.Arai was based in Washington DC and New York for 3 years. As representative of METI, his responsibilities included TPP (Trans Pacific Partnership), Natural Gas and nuclear energy cooperation between the U.S and Japan, Iranian sanction, China's Rare Earth issue, Electric industries, etc.. He also lived in U.S from 1994 to 1996 and earned his M.B.A in finance from the Wharton School of the University of Pennsylvania. He also graduated from the prestigious Waseda University in Tokyo, where he earned a Bachelor of Political Science degree.

Keynote - Plenary#TwP

Time with Presidents

Kerry Lunney (INCOSE President (2020-2021))
Marilee Wheaton (INCOSE President Elect) - mar

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Presented on: Wednesday, 06:00-06:45

Paper

Paper#81

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

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Presented on: Thursday, 09:15-09:55

Keywords. System Models; Specific Models; Digital Thread; Model-Based Systems Engineering; Connection of Models; Identification of Models

Topics. 1.1. Complexity; 2.4. System Architecture/Design Definition; 3. Automotive; 5.3. MBSE;

Abstract. This paper describes the concept of a method that uses an existing system model to select the most suitable component or specific model for inclusion. The term model is understood to encompass models that are used during the development of systems that: have a certain degree of formalism, are digitizable, connectable and processable. The method describes how specific models that are required can be identified and how they could be connected. The approach is explained using a well-understood example taken from the development of automotive powertrains. After stating current challenges and problems in the development of complex systems in the automotive domain, a system cube is used as a structuring principle for models that describe certain system aspects such as structure and behavior. This concept acts as a starting point for the selection of the most suitable specific models allocated to system models based on the functional description of the system. Finally, the contribution of this research to the realization of a digital thread is discussed and future research topics are outlined.

Biography

Matthias Bajzek (Graz University of Technology) - matthias.bajzek@tugraz.at
Dipl.-Ing. Matthias Bajzek, BSc is PhD student at the Graz University of Technology. He achieved bachelor and Master degrees in mechanical engineering and business economics. His research activities focus on systems engineering foundations and its application in automotive engineering. Emphasis is put on modeling of descriptive functions and its role in mechatronic system development.

Hannes Hick (Graz University of Technology) - hannes.hick@tugraz.at
Univ.-Prof. Dipl.-Ing. Dr.-techn. Hannes Hick is professor and head of the Institute of Machine Components and Methods of Development at the Graz University of Technology. His research focuses on systems and component engineering, with a special focus on systems research and development methods on different system levels starting from the overall system architecture definition to the specific component research for advanced powertrain solutions. Hannes Hick' professional career included the development methods management at AVL List GmbH Graz and the investigation of testing strategies and evaluations. Additionally, he is a member of The Scientific Society of Product Development (WiGeP).

A Framework for Identifying and Managing New Operational Requirements during Naval Vessel Batch-Building Programs

Brett Morris (Naval Group) - b_a_morris@hotmail.com

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Presented on: Wednesday, 10:00-10:40

Keywords. Naval Vessels;Batch-building;Evolutionary development;Operational requirements

Topics. 13. Maritime (surface and sub-surface); 2.4. System Architecture/Design Definition; 3.1. Acquisition and/or Supply; 3.7. Project Planning, Project Assessment, and/or Project Control; 6. Defense;

Abstract. One approach to building a class of naval vessels that has recently been adopted in Australia is to fix a design for a subset of the total number of vessels to be built. These subsets can be termed batches, or flights of vessels. The batch-building approach allows incremental changes to be made to the design for the follow-on batches and is analogous to evolutionary systems development. These design changes will be a response to updated operational requirements that typically result from the maturation of technology that needs to be integrated into the design or shifting geo-political circumstances that change the capability needs. A third key driver of new operational requirements that is not currently managed in a robust, traceable manner is the need to adapt the design of the vessel to account for how it is actually being used in-service. This need arises due to the potential mismatch between the operational scenarios and operational profiles developed during requirements definition activities and the operational profile the crew adopts when actually using the vessel in operations. Such a mismatch between the owner's original operational requirements and the in-service operational profile can result in sub-optimal outcomes for the vessel's performance.

This paper investigates the research question: "how can new operational requirements be identified, managed and integrated to the design of follow-on batches of vessels in a naval vessel batch-building program?" The paper begins with an introduction into the effect a mismatched design and in-service operational profile can have on vessel performance. It is followed by a review of the open literature covering naval vessel batch-building and evolutionary system development. From this review, a high-level framework for incorporating updated operational requirements based on in-service operational data, new technology, or changes in strategic circumstances into the design of follow-on batches in naval vessel batch-building programs is synthesized. The paper concludes with some initial observations on how the framework's implementation could be supported by digital engineering and outlines key aspects that are required to support its implementation.

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

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Presented on: Wednesday, 15:10-15:50

Keywords. Software;System-Software Interface;Organizational Process Improvement;Software terminology;Software Organization Operational Model

Topics. 1.1. Complexity; 2.2. Social/Sociotechnical and Economic Systems; 3. Automotive; 5.1. Agile Systems Engineering; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Many software-dominant organizations, such as the FAANGs (Facebook, Apple, Amazon, Netflix, and Google), evolved quite quickly from coders and software engineers who have not been familiar with the advantage of the big-picture view of the software or of the organizations developing the software. INCOSE's Systems and Software Interface Working Group (SaSIWG) has been reading a fable of such an organization that found itself in a typical terrible state, unable to respond quickly and effectively to customer needs because it was tied up in a complex mess of silos, dependencies, management rules, and blame. While the book has been praised as the answer to many software organizations' problems, it quite significantly omits any mention of systems engineering and most positive mention of even software architecture or project management. In response, the SaSIWG has been working on a set of tools to help systems engineers understand 1) how such systems engineering-deficient organizations actually work, 2) what their vocabulary means at a top level, in a view that doesn't take a computer science degree to understand or a day to look up, 3) How to break into the software engineering conversation and not leave it feeling defeated and overwhelmed by the unfamiliar jargon, but rather knowing you can be and have been useful, and 4) How to develop a program to assist in engineering the complex system that is the software development enterprise and ecosystem, that which is not always acknowledged as a system needing engineering but is universally acknowledged as "the problem" when it is not well engineered.

This paper provides an overview of the tools that are being developed and outlines the guide that the group is hoping to develop.

A Method to Visualize the Relationship between Regulations and Architectural Constraints

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Presented on: Wednesday, 15:55-16:35

Keywords. regulation by architecture;visualization method;architectural constraints

Topics. 2.4. System Architecture/Design Definition; 20. Industry 4.0 & Society 5.0; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.);

Abstract. The increasing influence of technologies like IoT and AI has made “regulation by architecture” an important discussion point. Architecture does not require awareness of the regulated objects and inhibits suspicious behavior automatically and in advance, providing efficient governance. Previous researches were concerned about regulation by architecture owing to a property called “awareness-lessness.” This concern should be avoided by visualizing architectural constraints. However, a concrete visualization method has not been proposed.

We propose method to visualize the relationship between architecture and regulations and architectural constraints on stakeholders’ behavior. The method comprises four steps, from classifying the regulated object to identifying the constraint imposed by the architecture. System engineers use this method to reveal the constraints faced by users owing to the architecture and verify that there is no deviation from the regulations.

We interviewed legal and engineering experts and concluded that the proposed method is effective under certain conditions.

A Metrics Framework to Facilitate Integration of Disaggregated Software Development

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Presented on: Thursday, 14:15-14:55

Keywords. Systems and software metrics; Agile software development; Systems of systems

Topics. 11. Information Technology/Telecommunication; 2.5. System Integration; 3.6. Measurement and Metrics; 5.1. Agile Systems Engineering; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 6. Defense;

Abstract. Contemporary defence information system developments are moving towards utilising Continuous Iterative Development (CID) employing cloud native software development approaches involving many contractors delivering various components. The key questions for capability managers not familiar with CID developments revolve around knowing how well the developing is progressing and understanding how well the constituent systems to be delivered will integrate as time goes by. The authors were tasked to produce a metrics framework to address these questions and the resulting new construction is presented along with the key metrics: integration matrices. The paper concludes that the matrices will readily identify integration issues very early in the program because their instantiation will necessitate the evaluation of all nominated services between the constituent systems of the development effort at the various system and solution demonstrations that are inherent in CID approaches. Future work will evaluate the utility of the framework for planning CID measurement programs and evaluating their progress.

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

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Presented on: Tuesday, 10:45-11:25

Keywords. Systems Engineering; Robotic Baby; Artificial Intelligence; Robotics; Natural Language Processing

Topics. 14. Autonomous Systems; 2.4. System Architecture/Design Definition; 5.11 Artificial Intelligence, Machine Learning;

Abstract. In this paper, a novel architecture, Baby, for robotic babies is proposed with a systems engineering design approach. A robotic baby is an autonomous learning system with minimal structures at the beginning of its life, aiming to gradually learn languages and actions from interactions with human parents and the world. Throughout the paper, the philosophy and the reasoning behind a robotic baby with a systems engineering design approach is discussed. With the architecture, system verification and validation are conducted, which shows convincing language skills in parsing, similar to observed human cognitive behaviors. A proof of concept demonstration involving an integration with a 3D printer is also presented. With preliminary results, the roadmap for further development and the positioning of the architecture are presented.

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

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Presented on: Monday, 12:30-13:10

Keywords. Product Line Engineering; Model-Based Systems Engineering; Arcadia; Capella

Topics. 16. Rail; 2. Aerospace; 2.1. Business or Mission Analysis; 2.3. Needs and Requirements Definition; 2.4. System Architecture/Design Definition; 3.5. Technical Leadership; 5.3. MBSE; 5.5. Processes; 5.6. Product Line Engineering; 6. Defense;

Abstract. Pushed to the edge of their capabilities in a highly competitive world market, organizations everywhere look for efficient means to innovate and develop their products and services. This paper proposes and illustrates a holistic integration of Product Line Engineering (PLE) and Model-Based Systems Engineering (MBSE) to connect and align market and business analysis, architecting, design, and engineering. This value-driven, integrated approach capitalizes on MBSE best practices to tackle the concrete challenges of product line engineering.

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

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Presented on: Monday, 12:30-13:10

Keywords. agility; agile-systems; agile-operations; agile-development; agile-workforce

Topics. 5.1. Agile Systems Engineering; 5.2. Lean Systems Engineering;

Abstract. The Future of Systems Engineering (FuSE) is an INCOSE led multi-organization collaborative activity focusing on many initiatives to identify and shape the future of systems engineering. For systems engineers who desire to integrate agility into their systems thinking and system designs, the FuSE Agility collaboration provides an initial roadmap of foundational concepts with which to explore agility throughout the system lifecycle. There are four objectives to integrate agility in people (agile-workforce), process (agile-development), technology (agile-solutions), and environment (agile-operations). This paper explores concepts of System of Innovation, Technical Oversight for Agile Projects, Stakeholder Engagement, Agility across Organizational Boundaries, Long Lead Time, Continual Integration, Orchestrating Agile-Operations, Quantifying Agility for Agile-Operations, and Harmonizing Risk in Agile-Operations to instigate and inspire thought, research, development, and implementation of agile-systems.

Biography

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Rick Dove is an independent researcher, systems engineer, and project manager generally focused in the system security and system agility areas; and an adjunct professor at Stevens Institute of Technology in the School of Systems and Enterprises. He chairs the INCOSE working groups for System Security Engineering, and for Agile Systems and Systems Engineering. He is an INCOSE Fellow, and author of Response Ability - the Language, Structure, and Culture of the Agile Enterprise.

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

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Presented on: Tuesday, 13:15-13:55

Keywords. system;systems theory;theory of systems engineering;foundations of systems engineering

Topics. 1.5. Systems Science; 1.6. Systems Thinking;

Abstract. Definitions describe the meaning of terms in any area of scientific study. Thus, a good set of definitions aids scientific process by enabling researchers to communicate in a common language. In this regard, the Systems Engineering community has allocated significant effort in understanding the nature and scope of common definitions of a system. However, little attention has been given to studying if the common definitions of a system are adequate to begin with. In this paper, we show that the common definitions of a system are limited in their ability to adequately define a system's boundary. We argue that the common definitions rely on context and prior understanding to communicate the boundary of a system. Finally, by using concepts from philosophy and mathematical logic, we show that the common definitions of a system are nominal in their ability to define a system's boundary.

An Elaboration of Service Views within the UAF

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Presented on: Wednesday, 10:45-11:25

Keywords. Service Oriented Architectures;MOSA;UAF;MBSA;Architectures;Services

Topics. 18. Service Systems; 2.4. System Architecture/Design Definition; 22. Social/Sociotechnical and Economic Systems; 5.3. MBSE; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Services in the Unified Architecture Framework (UAF) are not just software services nor are they an implementation. Services can include transport, surveillance, communications, providing healthcare and medical services, etc. The UAF implements DoDAF using the Systems Modeling Language (SysML) as well as the British MODAF and NATO NAF. The DoDAF Service views implement services by duplicating the systems views and labeling the systems elements as services. This causes some confusion with engineers who either implement solution-based service views or ignore them completely. Even when implemented, they can cause confusion in the model as it becomes difficult to tell if a model element describes a service or a system implementing a service. The UAF implementation of the MODAF services views provides a distinct set of views, concepts and traceability. The Service Oriented Views do not specify how the service is to be implemented, but the requirements for the services. The Resources (Systems) Views implement services in various phases and their deployment will modify the configurations of the system at the very highest level. This paper will show how services views trace from capabilities and how that can be used to define system resource requirements.

Analyzing Standard Operating Procedures Using Model-based System Engineering Diagrams

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Presented on: Thursday, 10:30-11:10

Keywords. Standard Operating Procedures; Human Performance Modeling; Human Factors Design; Procedure Design and Test; User-Interface Design

Topics. 4.1. Human-Systems Integration; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis;

Abstract. Standard Operating Procedures (SOPs) are critical for the safe operations of complex, hazard-sensitive systems. The SOPs are particularly important for dealing with non-normal operations in which the human operator must intervene and/or provide instructions to the automation. Under these rare circumstances, the appropriate human operator actions are defined by SOPs. The SOPs must be completed within an Allowable Operational Time Window (AOTW) to avert a hazardous outcome. In many cases, the AOTW is not fixed, but exhibits variance due to complex non-linear, plant dynamics. The Time on Procedure (ToP) is also subject to variability due to human factors such as experience, proficiency, fatigue, and the efficacy of the SOPs and the supporting automation user-interface. For this reason, it is critical to evaluate the dynamic performance of the SOP in the context of the operations and determine the likelihood of the ToP exceeding the AOTW.

This paper describes how to model SOPs and perform SOP analysis using LML/SysML Action/Activity Diagrams that can be found in most Model-based System Engineering (MBSE) tools. The method enables the SOP designer to assess the performance of the SOP by accounting for human factors and operation dynamics. The ability to test the procedures in a MBSE tool can inform the system design and verify the procedure design early in the development life-cycle. The implications and limitations of this approach are discussed.

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

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Presented on: Tuesday, 14:00-14:40

Keywords. Concept evaluation;Systems Architecting;A3AO

Topics. 13. Maritime (surface and sub-surface); 15. Oil and Gas; 2.4. System Architecture/Design Definition; 3.3. Decision Analysis and/or Decision Management;

Abstract. This research investigates the application of A3 Architecture Overviews (A3AOs) in subsea front-end engineering studies. A3AO is a valuable method to support multi-disciplinary communication and share architectural knowledge in complex engineering domains. The method captures key information of an overall system and displays the system overview in a standard A3 format. In this paper, we investigate the beneficial impact a global subsea supplier can gain by applying A3AO as part of their concept evaluation process in the early phase study. Through interviews and a survey, we identified company's main challenges in concept evaluation of tie-in and connection system. We then applied the A3AO method to investigate its mitigating effect in early phase concept evaluation. We found that the company resources found the A3AO to provide a holistic system overview and support knowledge sharing. Overall, our research supports the use of A3AO as a method to promote common understanding.

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

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Presented on: Wednesday, 13:15-13:55

Keywords. MBSE; requirement engineering; requirement management; natural language processing

Topics. 2. Aerospace; 2.3. Needs and Requirements Definition; 3. Automotive; 5.3. MBSE;

Abstract. Today, manufacturing companies are confronted with an enormous number of product requirements, which increasingly demand an interaction of the different engineering disciplines mechanics, E/E and software. At the same time, companies must realize a shorter time to market, lower costs and higher quality. As a result, development methods are required, which support the fast, flexible and structured transfer of numerous requirements into products despite this increased complexity in processes and products. In this context, Model-Based Systems Engineering (MBSE) takes advantage of the increasing digitalization of products and development processes. It provides structures and processes for the efficient processing of requirements by fostering the collaboration between different engineering disciplines and enabling early validation of the product. In this context, it is often challenging that requirements are not structured, but rather unstructured and heterogeneous. For the processing within MBSE, text-based requirements today usually still have to be prepared with high manual effort. This paper presents a methodology that supports the transformation of unstructured and heterogeneous text-based requirements using Natural Language Processing in order to prepare them for further processing within MBSE.

Application of T-shaped engineering skills in complex multidisciplinary projects

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Presented on: Thursday, 12:00-12:40

Keywords. T-shape;Systems engineer;Technical expert;Multi-disciplinary;Proficiencies

Topics. 1. Academia (curricula, course life cycle, etc.); 1.5. Systems Science; 4.5. Competency/Resource Management; 5.9. Teaching and Training; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. In this research, we study the application of T-shaped engineering profile skills in complex multi-disciplinary projects. Literature survey revealed a close relation between the systems engineers and technical experts; we explore this relation a further here. Data collection was through a survey with practicing engineers, technical managers, and academics with industrial experience. Research findings revealed that the 'systems engineering discipline' shall be used as a common language between systems engineers and technical experts in projects. We identified notable gap between the design and production lifecycle stages. Questionnaire respondents confirmed this gap during validation, and mentioned the lack of 'operational context' as a challenge in the system development process. There is a clear interest in acquiring T-shaped skills through training. To achieve this, the technical experts shall use training programs within their organization, by focusing on the 'systems engineering discipline' and 'system's domain & operational context' proficiencies.

Biography

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Satya Kokkula, joined the University of South-Eastern Norway in 2017, as an Associate Professor of Systems Engineering. He has more than 10 yrs of experience from Oil & Gas industry as a Specialist Structural Analysis Engineer. He obtained his PhD degree in 2005 from Norwegian University of Science and Technology.
Dr. Kokkula is a INCOSE Certified Systems Engineering Professional (CSEP), and a Senior Member of the Institute of Electrical and Electronics Engineers.

Applying Systems Engineering framework for architecting a Smart Parking System within a Smart City

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Presented on: Monday, 10:45-11:25

Keywords. SysML; Smart Parking; Smart City; MBSE; Agent Based Model; Architecture; Stakeholder Value Network

Topics. 2.4. System Architecture/Design Definition; 21. Urban Transportation Systems; 22. Social/Sociotechnical and Economic Systems; 5. City Planning (smart cities, urban planning, etc.); 5.3. MBSE; 5.4. Modeling/Simulation/Analysis;

Abstract. A Smart Parking System is an important feature in any Smart City, as it hopes to address a persistent challenge in urban mobility. Various technology-based solutions have been developed. However, in such complex societal systems, it is important to consider various stakeholders and interfaces with other systems to choose an architecture that works efficiently for the given context. In this paper, we present the application of the Systems Engineering framework to develop a Smart Parking System architecture to meet the needs of a hypothetical Smart City. The framework shows the application of methods to analyse the context, prioritise needs, define and formally model alternate architectures, choose between the alternatives, and the use of a simulation model to validate requirements derived for the chosen architecture. Such systematic application of Systems Engineering methods can help planners and designers to negotiate complexities and avoid getting locked into sub-optimal technological solutions.

Biography



Nikhil Joshi (HCL Technologies) - najoshi@gmail.com
Dr. Nikhil Joshi is a researcher in Systems Engineering based in India. His research covers System Architecture, MBSE, and simulation using System Dynamics and Agent Based Modeling. He is an active member of INCOSE participating in different working groups. He co-leads the INCOSE India Chapter's MBSE Chapter working group. He presently works as the Head of the MBSE COE at HCL Technologies in India.

Aspect-Oriented Architecting Using Architecture Frameworks

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Presented on: Monday, 12:30-13:10

Keywords. architecture;architecture framework;architecture views;aspect oriented;perspective

Topics. 2. Aerospace; 2.4. System Architecture/Design Definition; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. In the early days of systems engineering, we had a few tried and true methods for depicting the structure and behavior of a system, such as functional flow diagrams, control flow diagrams, state transition diagrams, schematic block diagrams, and system breakdown structure. Nowadays we have a wider variety of choices when it comes to the creation of architecture views. The Unified Architecture Framework, for example, defines 71 possible architecture views that can be created. An easy and intuitive way to navigate the many available offerings was needed. Hence, most architecture frameworks have adopted a “grid” approach to help organize the various views. One of the key dimensions of this organizing approach is the use of architecture aspects. This paper will examine the various frameworks to determine how they organize their views and how they address the different aspects and perspectives of the architecture being described. These concepts were used as the basis for an aspect-oriented architecting approach reflected in the recently revised version of the ISO 42010 standard on architecture description.

Paper#2

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

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Presented on: Tuesday, 12:30-13:10

Keywords. Systems thinking;casual loop;pandemic;conceptagon;leverage points

Topics. 1.6. Systems Thinking;

Abstract. Having faced difficulties in 2008 and 2014 with a sudden drop in oil prices, the industry must accept that 2020 will be included in the future list of disastrous years. However, it was even harder to prepare for the oil crisis of 2008 and 2014. This paper aims look at Nexans Norway and the situation during and following the COVID-19 pandemic; with a system thinking perspective. System thinking models such as casual loop, CATWOE and conceptagon will be applied in an effort the describe the Nexans system, environment and possible leverage points to improve the protentional outcome of these uncertain times.

Paper#34

Challenges in Detecting Emergent Behavior in System Testing

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Presented on: Thursday, 13:30-14:10

Keywords. System Integration;Automated Testing;Automation;Verification;Emergence;Emergent Behavior;Anomaly Detection;Complex Systems;Acceptance Criteria;Systems Engineering

Topics. 1. Academia (curricula, course life cycle, etc.); 1.1. Complexity; 2. Aerospace; 2.5. System Integration; 2.6. Verification/Validation; 3.1. Acquisition and/or Supply; 3.2. Configuration Management; 4.3. Reliability, Availability, and/or Maintainability; 4.6. System Safety; 5.12 Automation; 6. Defense;

Abstract. System integration testing in the defense and aerospace industry is becoming increasingly complex. The long lifetime of the system drives the need for sub-system modifications throughout the system life cycle. An extensive test regime is required to ensure reliability and robustness of the system. Typical challenges with current test practice include late detection of unwanted system behavior, high cost of repetitive manual processes, and risk of release delays due to late error detection. This paper reviews the state-of-practice at a case company in the Defense and Aerospace industry. We use an industry-as-laboratory approach to explore the situation in the company. The research identifies the challenges and attempts to quantify the potential gain from improving the current practice. We find

that the current dependency on manual analysis generates resources and scheduling constraints as well as communication issues that hinder efficient detection of system emergent behavior. We explore two approaches to automate anomaly detection of system behavior from test data. The work lays the foundation for further research of automated anomaly detection in system testing.

Biography



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Kent Aleksander Kjeldaas is a project engineer in Kongsberg Defence and Aerospace. He has 3 years of experience from research and development of missile systems, where he has worked within the software and system engineering field. He holds a bachelor's degree in computer engineering from 2017. This report is the result of the research done for his master's degree in Systems Engineering from the University of South-Eastern Norway in 2020.



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Rune André Haugen is an industrial-PhD candidate at the University of South-eastern Norway (USN). He was in service with the Royal Norwegian Air Force (RNoAF) from 1997 to 2003, including graduation from the RNoAF Officer Candidate School in Stavern (1999) and the RNoAF Academy in Trondheim (2001). He holds both a bachelor's degree (2006) and a master's degree (2013) in Systems Engineering from USN. He has worked as a design engineer at FMC Kongsberg Subsea from 2006 to 2008 (3D modelling), and as a system engineer at Kongsberg Defence and Aerospace (KDA) since 2008 (system design and system test).



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Elisabet Syverud received her MSc in Aerospace Engineering from the University of Kansas, US, and her Dr.Ing in Thermal Energy from the Norwegian University of Science and Technology in Trondheim, Norway. She started her industrial career in 1993, and has worked in multiple roles in the oil&gas and defense industries for almost 20 years. Since 2019, she is Associate Professor of Systems Engineering and Head of Department Science and Industry Systems at USN.

Conceptual modeling of energy storage systems

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Presented on: Monday, 10:00-10:40

Keywords. systems architecting; conceptual model; energy storage

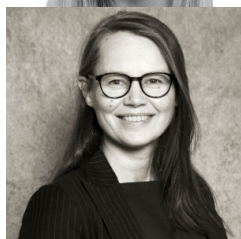
Topics. 2.4. System Architecture/Design Definition; 8. Energy (renewable, nuclear, etc.);

Abstract. Intermittent production of power from renewable energy, such as solar and wind, gives variations in supply. Energy storage can ensure flexibility and guarantee supply of renewable energy, as a part of the transition towards a carbon neutral energy system. The sizing strategy for energy storage systems is challenging because both the supply side and the demand side from the storage varies with time. In this paper, we investigate how energy storage technologies can provide seasonal storage for an existing energy system with excess electric power production during the summer months. We have reviewed pumped hydro energy storage, hydrogen storage, and brine technology. We create conceptual models of the energy systems to help compare cost and technology. We find that conceptual models help us reason about the size of the storage system and the components. The conceptual models are effective in communicating the constraints and opportunities of the system. However, it can be difficult to find the correct balance between comprehension that requires simplification, and accuracy that requires details.

Biography



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Therese Vrenne received her MSc in Systems Engineering with Industrial Economics from the University of South-Eastern Norway (USN) in 2020. She also holds a Bachelor degree in Mechanical Engineering from USN. After graduating, she started her industrial career as Project Engineer in Kongsberg Defence & Aerospace.



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Elisabet Syverud received her MSc in Aerospace Engineering from the University of Kansas, US, and her Dr.Eng in Thermal Energy from the Norwegian University of Science and Technology in Trondheim, Norway. She started her industrial career in 1993, and has worked in multiple roles in the oil&gas and defense industries for almost 20 years. Since 2019, she is Associate Professor of Systems Engineering and Head of Department Science and Industry Systems at USN.



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Gerrit Muller, originally from the Netherlands, received his master's degree in physics from the University of Amsterdam in 1979. He worked from 1980 until 1997 at Philips Medical Systems as a system architect, followed by two years at ASML as manager systems engineering, returning to Philips (Research) in 1999. Since 2003, he has worked as a senior research fellow at the Embedded Systems Institute in Eindhoven, focusing on developing system architecture methods and the education of new system architects, receiving his doctorate in 2004. In January 2008, he became a full professor of systems engineering at University of South-Eastern Norway in Kongsberg (USN), Norway. He continues to work as a senior research fellow at the Embedded Systems Innovations by TNO in Eindhoven in a part-time position. Since 2020, he is INCOSE fellow and Excellent Educator at USN.

Conceptual Modelling of Seasonal Energy Storage Technologies for Residential Heating in a Dutch town Best

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Presented on: Monday, 10:45-11:25

Keywords. Conceptual modeling; Energy Storage; Sustainability

Topics. 1.6. Systems Thinking; 10. Environmental Systems & Sustainability; 12. Infrastructure (construction, maintenance, etc.); 4.2. Life-Cycle Costing and/or Economic Evaluation; 5.4. Modeling/Simulation/Analysis; 8. Energy (renewable, nuclear, etc.);

Abstract. The increasing growth of modern renewables in countries with significant seasonal variations leads to a growing amount of excessive energy generated in peak seasons. This combined with the shortage of renewable energy in off-peak periods, creates an emerging need for seasonal energy storages. Best is a town located south in the Netherlands. Heating with natural gas in the cold season is the major energy consuming function in the residential sector, in Best. In this paper, we investigate storage technologies that have the potential to replace natural gas as a source of heating in Best. We observe and analyze Best and investigate storage technologies to uncover key considerations. We create conceptual models of three suitable storage technologies. We use these models to compare the storage technologies and enable discussion around the key considerations. The conceptual models provide insight and understanding of the technologies and the considerations. The comparison points to power-to-gas (PtG), with the production of methane and supply of electricity to heat pumps, as the most suitable technology for Best.

Biography



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Erik Drilen completed his bachelor's degree in mechanical engineering, in 2018, and received his MSc in Systems Engineering with industrial economics from the University of South-Eastern Norway, in 2020. He works as International Sales Manager at Alfa Nordic.



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Gerrit Muller, originally from the Netherlands, received his master's degree in physics from the University of Amsterdam in 1979. He worked from 1980 until 1997 at Philips Medical Systems as a system architect, followed by two years at ASML as manager systems engineering, returning to Philips (Research) in 1999. Since 2003, he has worked as a senior research fellow at the Embedded Systems Institute in Eindhoven, focusing on developing system architecture methods and the education of new system architects, receiving his doctorate in 2004. In January 2008, he became a full professor of systems engineering at University of South-Eastern Norway in Kongsberg (USN), Norway. He continues to work as a senior research fellow at the Embedded Systems Innovations by TNO in Eindhoven in a part-time position. Since 2020, he is INCOSE fellow and Excellent Educator at USN.



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Elisabet Syverud received her MSc in Aerospace Engineering from the University of Kansas, US, and her Dr.Ing in Thermal Energy from the Norwegian University of Science and Technology in Trondheim, Norway. She started her industrial career in 1993, and has worked in multiple roles in the oil&gas and defense industries for almost 20 years. Since 2019, she is Associate Professor of Systems Engineering and Head of Department Science and Industry Systems at USN.

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

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Presented on: Tuesday, 15:10-15:50

Keywords. Complex system; COVID-19; System resilience; Systems approach; Governance

Topics. 1.1. Complexity; 1.6. Systems Thinking; 4.4. Resilience;

Abstract. The continuing spread of COVID-19 has triggered a global health crisis with raising a series of problems in healthcare, economics, policymaking and environment, which significantly affected the resilience of the whole societal system. We emphasize the societal system, as an adaptive and complex system, has a fundamental impact on the spread of the virus linked to individual behavior change and disaster governance system. This paper combined system thinking and resilience thinking to visualize the complexity and understand the governance system under global pandemic threats towards recovering the resilient society. We underline the societal system can be affected by the pandemic, and in turn, impinge on the individual behavior and governance with a proposed multi-stage and multi-scalar framework dealt with the process from crisis to recovery. Meanwhile, a qualitative system dynamics model is proposed inspired by the general Susceptible-Infected-Recovery (SIR) model with multiple interactions and interdependency of intervention policies, human psychological factors and mobility-related factors to explore the influence on the societal system with time effect. Through this perspective, we should enhance the sense of crisis and integrate resilience thinking into the current hazards and recovery process combined with the interconnectedness among societal system in the future.

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

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Presented on: Tuesday, 10:45-11:25

Keywords. Value of Systems Engineering; Return on Investment (ROI); Professional Standard of Care; Liability Protection; Risk Management; Construction Specifications

Topics. 1.1. Complexity; 1.6. Systems Thinking; 12. Infrastructure (construction, maintenance, etc.); 15. Oil and Gas; 16. Rail; 17. Sustainment (legacy systems, re-engineering, etc.); 2.3. Needs and Requirements Definition; 2.4. System Architecture/Design Definition; 2.6. Verification/Validation; 21. Urban Transportation Systems; 3.1. Acquisition and/or Supply; 3.5. Technical Leadership; 3.8. Quality Management Process; 5. City Planning (smart cities, urban planning, etc.); 5.5. Processes; 8. Energy (renewable, nuclear, etc.);

Abstract. One of the most difficult challenges systems engineers face when attempting to introduce or expand the application of systems engineering (SE) is the demonstration of the systems engineering value, or in business terms, the return on investment (ROI). As SE is an upfront investment that may not pay dividends before sometime in the possibly distant future, business leaders unfamiliar with the process can be skeptical about the value of SE, especially in industries where SE is still an emerging discipline without a proven track record.

Sometimes, however, the value of systems engineering can be demonstrated by the increased risk of NOT applying systems engineering, for example the Central Artery/Tunnel Project (CA/T), commonly known as the Big-Dig. Designed and built between 1982 and 2007, it was the most expensive highway project in the US at the time, and was plagued by thousands of water leaks, design flaws, charges of poor execution, use of substandard materials and other issues, which eventually led to the death of a motorist and criminal arrests (Wiki, 2020, NTSB, 2006). The project managing consortium agreed to pay \$407 million in restitution and several smaller companies agreed to pay a combined sum of approximately \$51 million (AP, 2008). The settlement agreement included a statement of facts as the basis for liability, specifically addressing several areas of construction management oversight failures, including the use of non-specified material, the use of substandard materials, as well as ignored observations of failing epoxy bolt load tests (AP, 2008). The consortium was paid more than \$2 billion in fees (AP, 2008) that would have resulted in approximately \$160M in profit (applying an 8% profit target). Looking at this project purely from an ROI perspective, however, the consortium not only lost all profit, but faced an additional \$247M (\$407M - \$160M) in losses.

The issues identified above are typically addressed in construction specifications describing in detail the scope of work, materials, installation, and quality of workmanship. The Big Dig example should provide a cautionary tale of the risks associated with managing and overseeing construction projects, such as infrastructure, transportation, water, energy, or other projects.

This paper describes the application of systems engineering principles to construction specifications in a large infrastructure project using a case study approach. The paper demonstrates the systematic exercise of a reasonable level of care, diligence, and skill, commonly described as the professional standard of care, thereby demonstrating the value of systems engineering as a successful liability protection and risk mitigation strategy.

Developing a Model Based Systems Engineering Architecture for Defense Wearable Technology

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Presented on: Thursday, 10:30-11:10

Keywords. MBSE system architecture;wearable health and performance monitoring;capability needs analysis

Topics. 2.3. Needs and Requirements Definition; 2.4. System Architecture/Design Definition; 4. Biomed/Healthcare/Social Services; 5.3. MBSE; 6. Defense;

Abstract. The rapid advancement of commercial wearable sensing technologies provides an unprecedented opportunity to gather information that improves warfighter performance during military activities and to detect the onset of illness (such as COVID-19) through surveillance. However, the promise of improved performance and illness prevention through these technologies remains unfulfilled because of the complexity of guaranteeing that technology development outside of the standard military acquisition cycle will meet military requirements. The key to meeting this challenge is to facilitate coordination among R&D efforts, commercially developed products, and military acquisition strategies. To address this, we developed an MBSE architecture and methodology for validating independently developed wearable system designs against military end-user needs. This methodology includes developing a conceptual framework, a model library, and a capability needs matrix that maps defense mission characteristics to physiological states and product design implementations. This architecture allows military stakeholders to determine where capability gaps or opportunities for wider application of commercial technologies exist, thus providing a bridge between externally developed wearable sensing technologies and military acquisition strategies.

Developing a Topic Network of Published Systems Engineering Research

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Presented on: Monday, 15:10-15:50

Keywords. Systems Engineering; Research; Topic Modelling; Social Network Analysis; Bibliometrics

Topics. 1. Academia (curricula, course life cycle, etc.); 5.11 Artificial Intelligence, Machine Learning;

Abstract. This paper investigates the structure of past systems engineering research through developing a network of research topics from an extensive corpus of publications. The analysis of the bibliometric data from the published research articles provides valuable information on past progress and future opportunities in a scientific discipline. Topic modelling, a form of unsupervised machine-learning-based natural language processing, is applied to extract the main topics from the titles and abstracts of a wide range of papers published about systems engineering. The co-occurrence of research topics in these papers provides the data for generating network diagrams. A visual social network analysis of these diagrams should reveal interesting information about research in the field of systems engineering.

Developing domain-specific AI-based tools to boost cross-enterprise knowledge reuse and improve quality

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Presented on: Tuesday, 10:00-10:40

Keywords. knowledge management; knowledge reuse; artificial intelligence; quality management; nonconformity handling

Topics. 15. Oil and Gas; 3.3. Decision Analysis and/or Decision Management; 3.4. Information Management Process; 3.8. Quality Management Process; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. MHWirth observed that several quality issues surfaced during the product commissioning phase causing a negative impact on project cost, delivery time and customer satisfaction. By using root cause analyses, this research found several links between poor quality and lack of proper knowledge management. With better knowledge management, most of these quality issues could be addressed and solved at an earlier stage of the product life cycle. Today different barriers are preventing organizations from taking full advantage of previously generated valuable knowledge. This paper explores how the use of Artificial Intelligence can boost knowledge reuse. The goal is to empower faster and more informed decision-making based on lessons learned in the past to minimize waste, rework, re-invention and redundancy.

Employing a Model Based Conceptual Design Approach to Design for Resilience

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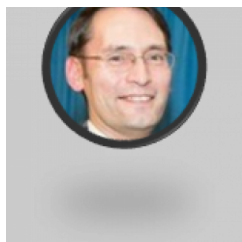
Presented on: Tuesday, 12:30-13:10

Keywords. Model Based Conceptual Design;Architecture;Resilience

Topics. 12. Infrastructure (construction, maintenance, etc.); 17. Sustainment (legacy systems, re-engineering, etc.); 2.3. Needs and Requirements Definition; 4.4. Resilience; 5.4. Modeling/Simulation/Analysis; 7. Emergency Management Systems;

Abstract. During the development of a conceptual system, it is common to address the capability gaps or create additional capabilities in the system concept. The Model Based Conceptual Design (MBCD) approach can be helpful to identify, catalogue, trace, and develop these capabilities, particularly as they cross different domains. This paper explores the use of MBCD to insert and improve resilience within an existing MBCD schema. An approach is offered to evaluate how resilience may be viewed and analyzed by using an MBCD approach.

Biography



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David Flanigan is a member of the Principal Professional Staff for The Johns Hopkins University Applied Physics Laboratory, providing systems engineering services to various Department of Defense and Department of Homeland Security clients, and has 20 years of active duty and reserve service with the US Navy. A graduate of the University of Arizona, he holds a MS in Information Systems and Technology, a MS in Systems Engineering from the Johns Hopkins University, and a PhD in Systems Engineering and Operations Research from George Mason University. Dr. Flanigan is a

member of INCOSE, INFORMS, and MORS.



Kevin Robinson (Shoal Group) - kevin.robinson@shoalgroup.com

Kevin Robinson is the Head of Innovation and Engineer at Shoal Group with a distinguished career in the field of Guided Weapons in both the UK's Ministry of Defence and Australia's Department of Defence. He has made significant contributions to the development of advanced guided weapons through modelling and analysis, research, and leadership of large cross discipline teams. Throughout his career, Kevin has taken a leadership role in advancing the field of Model-Based Systems Engineering (MBSE) via his publications and contributions to the systems engineering community. He initiated and chaired Australia's first annual MBSE

Symposium, formed and chaired INCOSE's Model-Based Conceptual Design Working Group, delivered a keynote address to INCOSE's international symposium in 2016, and has made contributions to INCOSE's Systems Engineering Handbook and related standards. Recently he has joined INCOSE's Future of Systems Engineering initiative core team.

Enhancing Enterprise Architecture with Resilience Perspective

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Presented on: Thursday, 13:30-14:10

Keywords. Enterpriser Architecture;Capability Systems;Resilience;Resilience Attributes;Resilience viewpoint;Department of Defence Architecture Framework (DoDAF);Uncertainty and adversity

Topics. 1.1. Complexity; 1.6. Systems Thinking; 2.4. System Architecture/Design Definition; 2.5. System Integration; 3.6. Measurement and Metrics; 4.4. Resilience; 5.1. Agile Systems Engineering; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. The research literature has found current Enterprise Architecture (EA) methods are limited in dealing with uncertainty and pathologies of complex systems to enable design and operation of a resilient enterprise. To some extent, EAs' approaches persist in applying textbook plans and activities in the face of mounting evidence of changing circumstances and the challenges of uncertainty. They rely on a qualitative shift in assessment, priorities, or response strategy, that often lead to a 'failure to adapt adequately.' To address this gap in EA resilience representation, we have combined several prior research proposals to produce a wholistic Department of Defence Architecture Framework (DoDAF) resilience architecture and enhanced that with our original underpinning resilience framework. Despite still being in an ongoing major case study, our comprehensive resilience representation shows promise of assisting all enterprise stakeholders with adapting this representation to their capability systems. Doing so will better incorporate resilience considerations in capability systems' design and likely help capability stakeholders to evolve capability systems with appropriate levels of resilience throughout their life cycle.

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

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Presented on: Monday, 14:00-14:40

Keywords. enterprise;architecture;process;unified architecture framework;modeling methodology

Topics. 2. Aerospace; 2.4. System Architecture/Design Definition; 5.4. Modeling/Simulation/Analysis; 5.5. Processes; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. This paper describes a process for creating Enterprise Architecture (EA) views in accordance with the Unified Architecture Framework (UAF) standard published by the Object Management Group (OMG). This process will be the foundation for a new EA Process Guide to be published as part of the OMG standard. The nine steps of the process are laid out in alignment with the stakeholder domains in the UAF for producing the requisite UAF views in each of those domains. This architecture description process can be used in conjunction with processes for the conceptualization and evaluation of an architecture, and also used as the basis for an EA modeling methodology, architecture development planning, MBSE capability assessment, and modeling project organization. The Guide covers architecting of the enterprise as well as architecting (at a high level) of a major entity within the enterprise. We will provide an understanding of what the Guide will contain and how it could be used.

Evaluation of Requirements Management Processes Utilizing System Modeling Language (SysML) Executable Models

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Presented on: Tuesday, 13:15-13:55

Keywords. Requirements Management;Process;MBSE Simulation

Topics. 3.3. Decision Analysis and/or Decision Management; 3.7. Project Planning, Project Assessment, and/or Project Control; 5.4. Modeling/Simulation/Analysis; 5.5. Processes; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Like many project processes, requirements management can be time consuming and costly if not well planned. The fundamentals of the process steps can be obtained through literature search, however the variation of application can lead to program cost challenges if not tailored for the project's risk posture and budget scope. This paper investigates various published requirements management processes, presents a fundamental process model, demonstrates a method to capture the process steps using a Systems Modeling Language (SysML), and shows the results of a simulation of the process steps enabling a comparison of outcomes for the project. This method investigates an option of using duration constraints to calculate labor hours based on process steps, as well as an option of calculating systems engineering labor hours utilizing the Constructive Systems Engineering Cost Model (COSYSMO) based on requirement quantity inputs from the SysML model. This work is intended to show how SysML can be used to support development and refinement of project processes in general, with specific focus on how this method can enable implementation of requirements management in a way that provides insight into potential cost and schedule impacts to the project.

Experience in Designing for Cyber Resiliency in Embedded DoD Systems

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Presented on: Monday, 10:45-11:25

Keywords. Cyber Resiliency; Modeling for Analysis; Embedded Design; AADL

Topics. 17. Sustainment (legacy systems, re-engineering, etc.); 2.4. System Architecture/Design Definition; 4.4. Resilience; 4.7. System Security (cyber-attack, anti-tamper, etc.); 6. Defense;

Abstract. In DoD systems, software component reuse is highly valued, and development is rarely started from scratch. Most embedded weapon systems are a heterogeneous mixture of new, modified, and legacy components. This mixture not only drives an increased impetus to improve upon the existing system's model, but also creates an opportunity to assess potential cyber vulnerabilities earlier in the lifecycle. In this paper, we describe our experience in developing an experimental platform, which is a representative testbed that incorporates legacy, modified, and new components, using a process where we address cyber resiliency early in development— during the design phase. We give accounts of where each of the parts of our representative testbed originated, either from legacy, or new/modified, what modeling decisions we made, and how we analyzed cyber vulnerabilities. We also propose a system engineering process, based on architectural modeling of the system, which introduces analysis early in the design for cyber resiliency. We are developing an approach to use advanced tools to find vulnerabilities and to develop cyber resiliency requirements to counter those vulnerabilities. The creation of the model and documentation of cyber resiliency requirements and design decisions provide a positive impact on the system lifecycle and future integration of the system.

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

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Presented on: Wednesday, 15:10-15:50

Keywords. Feature-based Product Line Engineering; DoD Adaptive Acquisition Framework; Acquisition pathways

Topics. 5.6. Product Line Engineering;

Abstract. Systems and Software Product Line Engineering (PLE) is a general approach to engineer a portfolio of related products in an efficient manner, taking advantage of the products' similarities while re-specifying and managing their differences. The key to the approach is managing the product portfolio as a single entity, as opposed to a multitude of separate products. Feature-based Systems and Software Product Line Engineering ("Feature-based PLE") is a specific form of PLE that became available in the early 2000's with the arrival of industrial-strength commercially-available tool support. Feature-based PLE has become widely practiced in industry as well as the DoD, where it has been shown to accrue cost avoidance from tens to hundreds of millions of dollars, including in DoD programs. The authors of this paper are all PLE advocates within their respective organizations, which include four of the world's six largest defense contractors. We believe that Feature-based PLE plays, or should play, an important role in many, if not most DoD acquisitions. In this paper, we'll explain why and, more importantly, how Feature-based PLE supports each of the acquisition pathways in the DoD's Adaptive Acquisition Framework.

Biography

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Rowland Darbin has been with General Dynamics Mission Systems for 17 years and currently leads the Product Line Engineering (PLE) Center of Excellence facilitating the adoption of PLE factory principals across project teams. Prior to his current position, Rowland was the product line manager for the consolidated product line management program coordinating systems engineering efforts across the US Army's Live Training Transformations (LT2) family of live training systems, balancing the needs training portfolio with the needs of the individual training ranges. Rowland is also the chair of the International Council on Systems Engineering PLE International Working Group as well as a reviewer for the International Organization for Standardization for the 26580 standard on product line engineering.

Formulas and Guidelines for Deriving Functional System Requirements from a Systems Engineering Model

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Presented on: Monday, 13:15-13:55

Keywords. MBSE;Systems Engineering;Requirements;Functional Requirements;Formulas

Topics. 2. Aerospace; 2.3. Needs and Requirements Definition; 2.4. System Architecture/Design Definition; 3.4. Information Management Process; 5.3. MBSE; 5.5. Processes; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Within this paper, we discuss a specific approach to system-level modeling with the goal of writing English-language requirements for the System of Interest (SOI), and then using formulas which interact with the model to proceduralize the authorship process. This overall approach makes it possible for most technical participants in a program to do most of their development work in a collaborative modeling environment, spending most of their time dealing with technical issues rather than language issues, while implementing a rapid translation to English-language functional requirements toward the end of the process.

Biography

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John Shelton graduated from the University of Colorado at Boulder with a Bachelor's of Science in Aerospace Engineering, and from the University of Denver with a Master's of Science in Systems Engineering and Mechatronics. John has worked in the aerospace industry for 13 years, starting at Lockheed Martin, and now working for Johns Hopkins University Applied Physics Laboratory. John specializes in requirements management and Model-Based Systems Engineering.

Framework for Formal Verification of Machine Learning Based Complex System-of-System

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Presented on: Tuesday, 10:00-10:40

Keywords. Complex System-of-Systems; Emergent Behavior; Machine Learning; Formal Verification

Topics. 14. Autonomous Systems; 2. Aerospace; 2.6. Verification/Validation; 5.11 Artificial Intelligence, Machine Learning; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.);

Abstract. A complex system is characterized by emergence of global properties which are very difficult, if not impossible, to anticipate just from complete knowledge of component behaviors. Emergence, hierarchical organization and numerosity are some of the characteristics of complex systems. Recently, there has been an exponential increase on the adoption of various neural network-based machine learning models to govern the functionality and behavior of systems. With this increasing system complexity, achieving confidence in systems becomes increasingly difficult. Further, ease of interconnectivity among systems is permeating numerous system-of-systems, wherein multiple independent systems are expected to interact and collaborate to achieve unparalleled levels of functionality. Traditional verification and validation approaches are often inadequate to bring in the nuances of potential emergent behavior in a system-of-system, which may be positive or negative. This paper describes a novel approach towards application of machine learning based classifiers and formal methods for analyzing and evaluating emergent behavior of complex system-of-systems that comprise a hybrid of constituent systems governed by conventional models and machine learning models. The proposed approach involves developing a machine learning classifier model that learns on potential negative and positive emergent behaviors, and predicts the behavior exhibited. A formal verification model is then developed to assert negative emergent behavior. The approach is illustrated through the case of a swarm of autonomous UAVs flying in a formation, and dynamically changing the shape of the formation, to support varying mission scenarios. The effectiveness and performance of the approach are quantified.

Biography



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Dr. Ramakrishnan Raman received B.Tech and MS degrees from IIT Madras, and PhD from IIIT-Bangalore. He is a certified Six Sigma Black Belt and is INCOSE certified Expert Systems Engineering Professional - ESEP. He has extensive systems and software engineering experience in domains of Building/ Industrial Automation, and Aerospace. He has been the Lead Systems Engineer and Architect for the design of many complex systems globally over the years. He is currently Principal Systems Engineer at Honeywell Technology Solutions, Bangalore, India

From Brownfield to Greenfield Development - Understanding and Managing the Transition

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Presented on: Wednesday, 13:15-13:55

Keywords. Large scale systems development; Aerospace and defense; Green field development

Topics. 1.6. Systems Thinking; 2. Aerospace; 3.5. Technical Leadership; 5.5. Processes; 6. Defense;

Abstract. This paper addresses the experiences where an organisation is starting developing a new system - Greenfield development - after continuously extending an existing one - Brownfield development for a long period of time. This situation is getting increasingly common in many industry sectors. The paper characterises how development changes in the transition and illustrates the challenges in the organisation during the transition. A key message in the paper is that an organisation optimised for Brownfield development, is inherently unsuitable for the challenges in Greenfield development. The situation is further aggravated by the longevity of contemporary systems. When an organisation makes the transition, it is likely that there are only a few leaders, if any, who have experienced a previous transition. Consequently, the organisation may neither be aware of the scope nor be pre-pared for the consequences of the pending change, which can be distinct or gradual. The paper also presents some indications of an approaching transition, together with a number of management strategies for preparing the organisation for a successful transition to Greenfield de-velopment.

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

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Presented on: Tuesday, 15:10-15:50

Keywords. System of Systems Engineering; Model-based Systems Engineering; Digital Continuity; Unified Architecture Framework; Systems Modelling Language

Topics. 2.1. Business or Mission Analysis; 5.3. MBSE; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.);

Abstract. The fourth industrial evolution, Internet of Things, and large-scale machine-to-machine interactions are driving digital transformation in the industry. Model-based Systems engineering (MBSE), as a new paradigm of capturing and analyzing knowledge about the system, is one of the core factors to drive this transformation. MBSE practices are more and more widely applied to system-of-systems (including enterprise and mission) engineering, which becomes a crucial part of the successful digital transformation. The core challenge today is how digital continuity can be maintained by connecting system models to system-of-systems models, especially when multiple parties are involved in their creation and exploration. This paper studies Systems Modeling Language (SysML) as the standard language to model systems, and Unified Architecture Framework (UAF) as the framework and Unified Architecture Framework Profile (UAFP) as the language to model system of systems and proposes an approach for transitioning from one to another in an integrated modeling environment.

How can simplified requirements affect project efficiency - A case study in oil and gas

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Presented on: Tuesday, 10:45-11:25

Keywords. requirements;oil and gas;project efficiency;complex projects;stakeholder requirements

Topics. 15. Oil and Gas; 2.3. Needs and Requirements Definition; 3.7. Project Planning, Project Assessment, and/or Project Control; 4.2. Life-Cycle Costing and/or Economic Evaluation;

Abstract. Requirements engineering is a constant challenge for companies executing complex projects. The oil and gas industry has been renowned for stringent stakeholder requirements driving costs. When the oil price plummeted six years ago, the industry had to adapt to make projects economically viable. Over the last four years, a major supplier to the industry has been executing three subsea production system projects as part of a frame agreement for a client. This case study investigates requirements engineering with a focus on cost savings. The paper examines data sources from the contractor and interviews with key project personnel. The main finding is that the contractor and client's efforts to simplify requirements have improved project efficiency. However, it has not been possible to quantify the exact benefit. Furthermore, the requirements engineering has been dependent on soft factors and collaboration during early study activities. This paper contributes with a description of a requirements engineering method. This is a collaborative method where the supplier adjusts the systems requirements, in close collaboration with the client, based on detailed design in a very early phase of systems engineering. The research can also give additional insight into requirements engineering for other industries executing complex projects.

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

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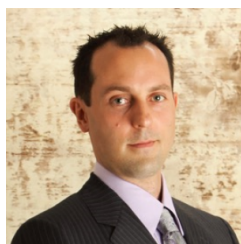
Presented on: Wednesday, 15:55-16:35

Keywords. Feature-based Product Line Engineering; Model Based Engineering; Missile digital twin

Topics. 5.6. Product Line Engineering;

Abstract. This paper describes a new approach to designing and building missiles by Raytheon Missile and Defense Systems. Key aspects of the approach include (1) modular common components connected through identified standards, (2) modular open systems approaches and standards based interfaces, (3) Feature-based Product Line Engineering (FbPLE) practices for identifying commonality and managing variation, and (4) implementing digital transformation through digital engineering capabilities to begin a missile's digital twin. Much more ambitious than simply reusing existing component designs from previously built missiles, this approach involves automatic generation, exploration, and pruning of an automatically generated trade space of possible missile designs that satisfy a given set of requirements. The goal is to radically lower development and production costs by rapidly settling on a viable design that can be taken to design validation, then complete design and production, all in a digital ecosystem. The paper focuses on the FbPLE aspect of the engineering approach and shows how its technology is used to create and manage the trade space, and then create a digital twin of a chosen design.

Biography



Jeffrey Turpin (Raytheon Missiles & Defense) - jeffrey.d.turpin@raytheon.com
Jeffrey Turpin has been at Raytheon for the past 7 years as a product line engineering subject matter expert and champion. He has helped Raytheon construct from the ground up their radar, missile, and combat management system production lines. Jeffrey's other engineering duties consist of system engineering; modeling, simulation, and analysis; wireless embedded systems; and artificial intelligence solutions architecture with a focus in deep and reinforcement learning. Jeffrey is also an active INCOSE Product Line Engineering International Working Group member and reviewer of the recently submitted ISO/IEC standard 26580 "Software and Systems Engineering - Methods and Tools for the Feature-Based Approach to Software and Systems Engineering

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

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Presented on: Thursday, 08:30-09:10

Keywords. Systems Engineering; Design Thinking; Systems Thinking; Very Small Entities; New Product Development; Innovation; Decision Making

Topics. 19. Very Small Enterprises; 2.3. Needs and Requirements Definition; 3.3. Decision Analysis and/or Decision Management; 3.9. Risk and Opportunity Management;

Abstract. Very Small Entities (VSE) delivers a substantial percentage of the world's product and services. These agile and innovative companies approach their market in a flexible, informal, and human-centered approach. Their transformation from startup phase to an established company can be problematic. As they grow, the VSE must put more emphasis on incorporating formal organizational structure and processes to cope with the increased size and complexity. Failure in adapting often results in a negative market effect. Systems Design Thinking (SDT) is a combination of Systems Engineering, Systems Thinking, and Design Thinking. There is an increased awareness that the perspectives of SDT bring value to organizations. However, the advantage of SDT is not well understood for VSEs that are in the maturing phase. In this work, the researchers explore the value of SDT for very small enterprises transitioning from infancy to adolescence. The article presents a new method for idea development based on SDT principles and tailored to the needs of a VSE. Case-based research is applied in a small company to understand the needs and verify the desirability, feasibility, and viability of our proposed method. The results suggest that an SDT approach improves the company's ability to capture and develop ideas and can help grow the company.

Biography



Elisabet Syverud (University of South-Eastern Norway) - elisabet.syverud@usn.no
Elisabet Syverud received her MSc in Aerospace Engineering from the University of Kansas, US, and her Dr.Ing in Thermal Energy from the Norwegian University of Science and Technology in Trondheim, Norway. She started her industrial career in 1993, and has worked in multiple roles in the oil&gas and defense industries for almost 20 years. Since 2019, she is Associate Professor of Systems Engineering and Head of Department Science and Industry Systems at USN.

Implementation of tailored requirements engineering and management principles in a supplier to the oil and gas industry

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Presented on: Tuesday, 13:15-13:55

Keywords. Requirements Engineering; Requirements Management; Tailoring; Analysis; Oil and gas

Topics. 13. Maritime (surface and sub-surface); 15. Oil and Gas; 2.3. Needs and Requirements Definition; 5.5. Processes; 5.6. Product Line Engineering; 8. Energy (renewable, nuclear, etc.);

Abstract. This article investigates the implementation of a tailored requirement management system. Umbilical systems have grown complex over time. This imposes a threat, as a focus of lower cost and short project duration is inevitable to win contract awards. The authors have investigated the use of a new system for requirements engineering and managing in an industry, by interviewing stakeholders and analyzing the current state of the company. Based on the findings, this paper proposes a requirements template and tailored functionalities to aid with requirements engineering and management. Results indicate that the use of requirement elicitation increased by 62% through implementation of the proposed system. A survey conducted indicates that stakeholders are positive to a future implementation of the proposed system. In conclusion, the tailored requirements management system will be a step in the right direction for the managing of requirements and better control for members of the project teams.

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

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Presented on: Wednesday, 10:00-10:40

Keywords. Feature-based Product Line Engineering; Product Line Engineering; feature catalog; shared assets; Northrop Grumman; BigLever

Topics. 2. Aerospace; 5.6. Product Line Engineering; 6. Defense;

Abstract. This paper discusses our experience applying Feature-based Product Line Engineering (PLE) to a product line of hardware modules designed for use in space-based and airborne systems. Feature-based PLE involves the automatic configuration of engineering artifacts (maintained as supersets) into product-specific instances based on that product's feature selections. We observed a 40% reduction in non-recurring engineering costs in this product line. The paper also discusses an innovative approach we used to extend the ability of the PLE configurator tool to interface with analysis and simulation tools for which no actual tool integration currently exists.

Biography



June Kobayashi (Northrop Grumman Space Systems) - June.Kobayashi@NGC.com
June Kobayashi is the Common Products Infrastructure and Product Line Engineering Lead at Northrop Grumman Space Systems (NGSP) Sector, where she stood up the processes and technology infrastructure to support PLE for several years. She has trained and guided the team members for many product lines across the enterprise and has advised other sectors within Northrop how to stand up product lines and best practices to implement Product Line Engineering. Prior to this, she managed and developed RF and Mixed Signal electronics for Northrop Grumman and other defense and commercial companies for over 35 years. She has BSEE and MSEE degrees from the University of California in Los Angeles.

Insights for Systems Security Engineering from Multilayer Network Models

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Presented on: Monday, 15:10-15:50

Keywords. Systems Security Engineering; Multilayer Networks; High consequence security

Topics. 4.7. System Security (cyber-attack, anti-tamper, etc.); 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 6. Defense;

Abstract. Next-generation systems security engineering approaches for high consequence facilities (HCF) need to address challenges stemming from complex risk environments, innovative adversaries, and disruptive technologies. Key insights from complexity, systems, and network theories—and support from subject matter expert (SME) elicited empirical data—support using a multilayer network model for HCF security to address these challenges. Early results of modeling HCF security system performance in terms of multilayer network characteristics seemed to meet the needs expressed in the SME data, provide a suite of mathematically tractable metrics to describe more complex security behaviors, and align with characteristics related to incorporating systems security engineering into the future of systems engineering.

Integrated Security Views in UAF

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Presented on: Monday, 10:00-10:40

Keywords. Security;Cyber;MBSE;UAF;DoDAF

Topics. 2.4. System Architecture/Design Definition; 2.2. Social/Sociotechnical and Economic Systems; 4.7. System Security (cyber-attack, anti-tamper, etc.); 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Architectures, Systems, subsystems and the data that they contain are valuable assets. Systems engineers and architects must plan for system security from system concept inception to retirement to ensure that security is embedded into every part of every process, procedure, system and component as well as in the mindset of the people in the enterprise. While the various DoDAF views contain attributes of security, there are no views for defining system security goals, threats, risks, mitigating elements, etc. and demonstrating how these are integrated and implemented into the operational, system, standards and services views. The Unified Architecture Framework (UAF) has integrated a set of security views that provide engineers a means of defining security goals and requirements and demonstrating how these are implemented throughout the architecture.

Integrating Safety Analysis into Model-Based Systems Engineering for Aircraft Systems: A Literature Review and Methodology Proposal

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Presented on: Wednesday, 15:10-15:50

Keywords. Model based systems engineering;MBSE;Safety analysis;Aerospace

Topics. 2. Aerospace; 4.6. System Safety; 5.3. MBSE;

Abstract. Model-Based Systems Engineering (MBSE) has become increasingly popular within the aircraft industry in recent years. However, this model-based approach presents a challenge as traditional safety analysis practices are unable to keep up, resulting in inconsistency between the system and safety domains. This paper proposes a methodology tailored towards aircraft systems that addresses this issue by integrating safety analysis into MBSE. This is achieved by extending the Systems Modeling Language (SysML) profile to account for safety data in the system model and utilizing an Application Programming Interface (API) to automate the generation of safety analysis artefacts. The proposed methodology also allows for requirements management integration to increase the efficiency of the system development process.

Biography

Kimberly Lai (University of Toronto) - kimberly.lai@mail.utoronto.ca
Kimberly is a Master's student at the University of Toronto and is currently conducting research in Model-Based Systems Engineering and Safety Analysis. She holds a Bachelors degree in Engineering Science, majoring in Aerospace Engineering from the University of Toronto and has experience with implementing MBSE at Safran Landing Systems. The first iteration of this paper was written as part of her undergraduate thesis under the supervision of Dr. Olechowski.

Investigation of Remote Work for Aerospace Systems Engineers

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Presented on: Wednesday, 12:30-13:10

Keywords. aerospace;remote work;distributed teams;qualitative research;systems engineering;COVID-19

Topics. 1.6. Systems Thinking; 2. Aerospace; 2.6. Verification/Validation; 3.7. Project Planning, Project Assessment, and/or Project Control;

Abstract. In many industries, remote work is becoming increasingly common. The global COVID-19 pandemic has accelerated this shift, which poses a particular challenge to aerospace systems engineers (ASEs). ASE work is complex, consisting of a number of tasks that are traditionally largely conducted in person. Little literature exists to establish a basic understanding of remote work in the context of aerospace systems engineering development projects.

This paper presents the results of an interview study, where hypotheses are explored to provide initial understanding of remote work in this context, and to motivate future studies. Analysis revealed: Design reviews experienced both challenges and benefits; Remote work has complicated collaborative work with artifacts; Assembly, Integration and Testing activities experienced significant challenges; Solutions have been thought of or implemented by ASEs, in particular the use of Slack and strategies managers may use to support their team members. Several additional research questions are motivated.

Biography

Eric van Velzen (University of Toronto) - eric.vanvelzen@mail.utoronto.ca

Eric completed his undergraduate degree in the Aerospace specialization of the Engineering Science program at the University of Toronto. In his final year, Eric conducted his undergraduate thesis research with aerospace engineers in industry under the supervision of Dr Olechowski in Ready Lab. He investigated the impact of remote work on aerospace engineers in industry resulting from COVID-19 pandemic restrictions. This work led to his publication in INCOSE IS 21. Eric has spent several years in leadership roles on the University of Toronto Aerospace Team's Space Systems division, which is a student team that builds and launches small spacecraft. During his time on the team Eric has filled many roles including technical, leadership, and mentorship, while fostering his interest in space systems engineering. In the fall of 2021 Eric will begin his Master of Applied Science degree at U of T's Space Flight Laboratory where he will join projects to design and deliver small spacecraft to organizations around the world.

Alison Olechowski (University of Toronto) - olechowski@mie.utoronto.ca

Alison Olechowski is an Assistant Professor in the Department of Mechanical & Industrial Engineering and the Troost Institute for Leadership Education in Engineering (Troost ILead). She completed her PhD at the Massachusetts Institute of Technology (MIT) studying product development decision-making during complex industry projects. Dr. Olechowski completed her BSc (Engineering) at Queen's University and her MS at MIT, both in Mechanical Engineering. Dr. Olechowski studies the processes and tools that teams of engineers use in industry as they design innovative new products. She has studied engineering products and projects in the automotive, electronics, aerospace, medical device and oil & gas industries. Website: readylab.mie.utoronto.ca

Is CAD A Good Paradigm for MBSE?

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Presented on: Monday, 14:00-14:40

Keywords. MBSE; model-based systems engineering; value of systems engineering

Topics. 5.3. MBSE; 5.5. Processes;

Abstract. Those looking to advocate for MBSE in the Systems Engineering field often turn to more established fields that have made a similar transition to models to assure others it will be beneficial. One practice that is often compared to MBSE is Computer-Aided Design (CAD) from the field of mechanical engineering. However, when examining the definitions of MBSE against CAD, it is evident that while CAD can be considered a method of mechanical drawing, MBSE cannot be described as only a method. MBSE is more than installing and utilizing software, it is a process in and of itself. Comparing MBSE to CAD runs the risk of oversimplifying the MBSE process and setting up expectations that may not be met. Therefore, while CAD represents the same paradigm shift as MBSE, it may not serve as an adequate paradigm. In this paper, we characterize and compare CAD and MBSE and identify the similarities and differences between them. We use the resulting insights to level the expectations of adopting and using MBSE.

Measuring performance and identifying metrics of machine protection systems for particle accelerators

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Presented on: Wednesday, 10:45-11:25

Keywords. machine protection;availability;downtime;research facility;particle accelerator;neutron spallation source

Topics. 1. Academia (curricula, course life cycle, etc.); 2.2. Manufacturing Systems and Operational Aspects; 2.4. System Architecture/Design Definition; 3.6. Measurement and Metrics; 8. Energy (renewable, nuclear, etc.);

Abstract. Machine protection systems are used at high power particle accelerators in order to prevent long downtimes due to equipment damage. Due to the fact that there are very few particle accelerators in the world and that they have been built in different times, all facilities have had different goals and hence different requirements on the machine protection systems. In order to optimize machine protection systems for the specific needs of the currently designed and constructed European Spallation Source (ESS), different concepts and designs for machine protection have to be evaluated. In order to compare and evaluate the performance of different options, in a systematic and objective way, a suitable performance metric has to be identified and used. This presentation is part of a work to define the problem from the perspective of a recently initiated PhD-student project. The paper discusses the lack of metrics for machine protection systems, the need for performance metrics and the difficulties involved in this work.

Model-Based Systems Product Line Engineering of Physical Protection Systems

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Presented on: Monday, 10:00-10:40

Keywords. Physical Protection Systems;Product Line Engineering;Model-Based Systems Engineering

Topics. 2.4. System Architecture/Design Definition; 5.3. MBSE; 5.6. Product Line Engineering;

Abstract. A physical protection system (PPS) aims to protect a system against adversarial attacks by deterrence, detection, delay, and response. PPSs have targeted the protection of various systems each of which has its specific requirements. On the other hand, PPSs also share a large set of features that are implemented for each system. To reduce the development cost, reduce time-to-market, and increase the quality of systems, a large-scale systematic reuse approach as defined by systems product line engineering (SPLE) can be applied. So far, PPS methods have mainly considered the systems engineering of single PPSs. In this paper, we report on our industrial experiences and lessons learned for adopting SPLE for PPSs. With this, we consider an explicit model-based systems engineering approach in which the focus is on the formalized application of models in the overall systems engineering life cycle. Thus, the presented approach adopts and integrates model-based systems engineering, product line engineering, and PPS method to provide a systematic large scale reuse approach for systems engineering of PPSs. We discuss the detailed steps of the approach and report on the lessons learned for adopting model-based systems product line engineering for PPS.

Network Rail's Systems Integration for Delivery (SI4D) Framework

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Presented on: Wednesday, 12:30-13:10

Keywords. Management;Characterisation;Engagement

Topics. 12. Infrastructure (construction, maintenance, etc.); 16. Rail; 2.5. System Integration; 3.5. Technical Leadership; 5.10. Diversity (cultural boundaries, diverse engineering teams, training underserved groups, etc.); 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. In the United Kingdom Network Rail delivers hundreds of infrastructure projects every year to enhance and renew the national rail network. This forms a capital delivery portfolio measured in Billions of pounds per year, from platform extensions to large scale nationwide upgrades.

This paper presents a case study of the development and implementation of Network Rail's System Integration (SI) for Delivery framework. The focus here is on

- drivers for a new framework,
- implementation embedded with existing management systems,
- language and terminology used to communicate the new framework.

The framework is designed to be flexible in terms of effort relative to complexity and benefit and aims to optimise the performance of new infrastructure delivered by Network Rail.

The framework consists of a suite of competence management, training, processes, products and tools that have been embedded within existing management systems to support a consistent and cohesive approach to delivery of capital projects.

Biography

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Derek's career has largely been focused on the application of systems thinking to major infrastructure projects across transport, power and defence industries. He has worked on both sides of the fence as well as sitting on it - suppliers, consultancy, approvers/regulators, owners, operators, and has seen the state of practice develop over 2 decades now.
His current role for Network Rail is "Technical Head of Discipline (Systems Integration)" to Direct, Plan and Assure System Integration activities related to delivery of projects and programmes across Network Rail's Infrastructure Projects.
Derek is proud to be a founder member of the INCOSE UK Rail Interest Group and is Network Rail's representative on the INCOSE UK Advisory Board.

His hometown is Darlington, where the world's first public passenger steam railway "SYSTEM" started service in 1825. Derek certainly didn't set out to become a Railway Man but the complexities, scale of challenge, and opportunity to forge a path as a systems engineer in this critical sector became irresistible.

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

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Presented on: Thursday, 11:15-11:55

Keywords. Function Modeling;System Model;Simulation Model;Ontology;Inference engine;Similitude metrics;Search engine;Model Identity Card

Topics. 5.4. Modeling/Simulation/Analysis;

Abstract. Today's highly competitive industrial environment is leading companies to drastically reduce their development time for an increasingly early time-to-market, while maintaining a low level of risk. In this context, simulation-based design has become widespread among design teams. Yet, the complexity of today's systems related to the integration of more new information and communication technologies requires multidisciplinary simulations. In charge of designing a simulation architecture that meets a request from system architects, simulation architects specify the simulation models to be provided by disciplinary experts. In this context, to accelerate the design process, capitalization and reuse processes can support the search for similar models in an existing database. Therefore, we propose to develop a search engine for simulation models. This paper focuses on the presentation of our initial works around an ontology-based search engine of simulation models representing the behavior of a given system function. The developed algorithms and similarity metrics are based on both reference functions and ports. The corresponding inference engine has been applied on an autonomous vehicle scenario.

Opportunities and Challenges of Sociotechnical Systems Engineering

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Presented on: Tuesday, 14:00-14:40

Keywords. Sociotechnical Systems Engineering; Framework; Natural Systems; Business Models; 4th Industrial Revolution

Topics. 1.3. Natural Systems; 1.5. Systems Science; 1.6. Systems Thinking; 10. Environmental Systems & Sustainability; 2.1. Business or Mission Analysis; 2.3. Needs and Requirements Definition; 20. Industry 4.0 & Society 5.0; 22. Social/Sociotechnical and Economic Systems; 3.3. Decision Analysis and/or Decision Management; 3.6. Measurement and Metrics; 4.1. Human-Systems Integration; 4.4. Resilience; 5.10. Diversity (cultural boundaries, diverse engineering teams, training underserved groups, etc.); 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.);

Abstract. The term Sociotechnical Systems was coined by Eric Trist, Ken Bamforth and Fred Emery in the 1950's and was based on their work with English coal miners at the Tavistock Institute in London. Originally, Sociotechnical systems in organizational development recognized the interactions between workers and (then current) technology in their workplace (extracted from Wikipedia, Oct 2019). In the intervening decades, the term has expanded to cover the social aspects of people and society in addition to the technical aspects of structure and process; i.e., the interrelatedness of social and technical aspects of systems deployed in society. In this current definition, humans are considered to be an integral part of the system as are hardware and software configuration items. In this modern construct, humans influence and are influenced by the performance of the physical systems we deploy. The intent of this paper is to clearly distinguish the unique elements of what constitutes Sociotechnical Systems Engineering (STSE) and a framework to integrate those elements. The proposed framework will then serve as the foundation for further discussion related to the opportunities and challenges associated with this evolving perspective on Systems Engineering (SE). The authors conclude that Systems Engineering in terms of its framework, practice and processes remain essentially intact. Furthermore, the application of a sociotechnical framework may unlock the potential for significantly greater improvements in our quality of life as well as the potential for lessening waste, inefficiency and undesirable emergent behaviors. It is also apparent that the outcomes we experience do not lie in our definition of Systems Engineering or Sociotechnical Systems Engineering as much as they may lie in our deeper motivations for doing either.

Paper#41

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

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Presented on: Tuesday, 15:55-16:35

Keywords. Project failure prediction; Schedule slips; Missed requirements; Project risk assessment; Design-based student projects

Topics. 1. Academia (curricula, course life cycle, etc.); 2. Aerospace; 3.7. Project Planning, Project Assessment, and/or Project Control; 5.11 Artificial Intelligence, Machine Learning; 5.9. Teaching and Training; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Systems engineers and project managers have a wide range of tools and approaches they use to assess risk, but these approaches have not helped to reduce failures as much as hoped. Post-failure analyses may not be enough to prevent a future failure, even at the same organization. In this paper, we present a risk assessment prototype that goes beyond collecting information about the failures or failure causes themselves and aims to consider the human actions that lead to failure. Our method adds “crowd signals” to capture the human actions and behaviors that we know eventually lead to failures. We collected data from 18 different engineering student teams at “Anonymized affiliation for double-blind review” and built two types of models: one to predict schedule failures and one for technical requirements failure. In both cases, we found that a failure during the previous week increases the likelihood of the same type of failure the following week. Some human behaviors such as the students knowing more about their teammates, understanding all implications of their project actions, and not wasting time discussing trivial matters help reduce the likelihood of failures. In contrast, when students are not learning anything new through their involvement with the projects, postponing or cancelling required meetings or tasks, or having problems resurface due to poor solutions, the likelihood of failures increases.

Paper#38

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

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Presented on: Thursday, 10:30-11:10

Keywords. Systems Engineering; portfolio management; configuration management

Topics. 2.2. Manufacturing Systems and Operational Aspects; 3.2. Configuration Management; 4.2. Life-Cycle Costing and/or Economic Evaluation; 5.6. Product Line Engineering; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Managing mature products with high variability is an increasing concern for industrial companies. Product variability affects the operational streamlining efforts from product design to production, inventory, selling, and service. In this research, we follow a case where the company faces challenges in manufacturing cost and configuration of both existing and new variants. The purpose of this study is to investigate how product portfolio mapping can structure technical product data to ease the challenges. This study analyzed more than 13,000 sales orders executed between 1997-2019 of a mature sub-system with large variability. We added interface mapping, the manufacturing view, and the logistic view to enhance product portfolio analysis found in literature. We used Systems Architecting principles in combination with requirements from manufacturing and logistics to create a generic architecture that allows variability in the manufacturing flow. Further-more, we created a dynamic cost calculator that estimates manufacturing cost by selecting the design decision factors. We evaluated our results by comparing the "As-Is" situation versus our pro-posed "To-Be" situation and found significant improvements both in configuration time and the cost prediction accuracy. The company evaluated this as an overall quality improvement that standardizes the workflow and remove existing bottle necks. Our approach to product portfolio analysis helps structure mature products with large variability. We recommend further research to confirm if our findings are applicable in other similar industries and companies.

Biography



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Gerrit Muller, originally from the Netherlands, received his master's degree in physics from the University of Amsterdam in 1979. He worked from 1980 until 1997 at Philips Medical Systems as a system architect, followed by two years at ASML as manager systems engineering, returning to Philips (Research) in 1999. Since 2003, he has worked as a senior research fellow at the Embedded Systems Institute in Eindhoven, focusing on developing system architecture methods and the education of new system architects, receiving his doctorate in 2004. In January 2008, he became a full professor of systems engineering at University of South-Eastern Norway in Kongsberg

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Elisabet Syverud received her MSc in Aerospace Engineering from the University of Kansas, US, and her Dr.Ing in Thermal Energy from the Norwegian University of Science and Technology in Trondheim, Norway. She started her industrial career in 1993, and has worked in multiple roles in the oil&gas and defense industries for almost 20 years. Since 2019, she is Associate Professor of Systems Engineering and Head of Department Science and Industry Systems at USN.

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

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Presented on: Wednesday, 10:00-10:40

Keywords. Social Systems;Socio-technical Systems;Social Systems Engineering;INCOSE SE Vision 2025

Topics. 1. Academia (curricula, course life cycle, etc.); 22. Social/Sociotechnical and Economic Systems;

Abstract. Expanding the capacity of systems engineering to include evaluating and designing social systems is a desired goal as stated in the INCOSE SE Vision 2025. Systems engineering applications in socio-technical contexts, from management and organizational to learning and education studies is already documented. There is room for adaptability in systems engineering methodology to accommodate a further reach into the social domain. The growing interest in this expansion is leading to the establishment of the term: social systems engineering. Social systems engineering is a re-ciprocal relationship between systems engineering and the social sciences. More specifically this means: 1) adapting/applying systems engineering methods/tools in a range of social policy areas in industry, government and academia; and 2) developing/applying social science theory and methods for the integration of teams and communities that are engineering systems. In this paper, we provide an overview of the history of social systems engineering and develop the concept to provide systems engineers with a conceptual foundation for using social systems in their systems engineering practice.

Requirement Patterns in the Construction Industry

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Presented on: Tuesday, 10:00-10:40

Keywords. Construction Specifications;Infrastructure;Building Information Management;Requirements;Specifications;Natural Language Processing;Automation

Topics. 12. Infrastructure (construction, maintenance, etc.); 2.3. Needs and Requirements Definition; 3.4. Information Management Process; 5. City Planning (smart cities, urban planning, etc.); 5.12 Automation;

Abstract. Requirement patterns for construction projects have evolved significantly in recent years to adapt to the digital transformation of the industry. The current pattern for specifications resembles System Modeling Language (SysML) blocks in that it provides a concise set of model-ready properties and operations relevant to construction and asset management processes. This paper compares the characteristics of modern construction requirements to those listed in the INCOSE Guide for Writing Requirements. As a case study, this paper presents the methods and data required to convert a set of 262 legacy specification sections written in “natural language” into requirements that conform to the current pattern for construction specifications. Those specifications, along with project-specific drawings, align much of the subsequent processes in a construction project

Biography



Ron Claghorn (Saudi Arabia Bechtel Company) - ron@austintechpubs.com
Ron is currently working for the Saudi Arabian Bechtel Company as the requirements manager for the Royal Commission in Jubail, Saudi Arabia. Ron holds a Bachelor degree in Biomedical and Chemical Engineering from the University of New Mexico, USA. He has more than 30 years of experience in several engineering and management roles in the nuclear and construction industries. He is a Certified Systems Engineering Professional, a Professional Chemical Engineer, and is certified as a Construction Documentation Technologist by the Construction Specifications Institute.



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Hussam is currently working as a systems engineer for the Royal Commission in Jubail, Saudi Arabia. He holds Bachelor degree in Instrumentation and Control Engineering from Jubail Industrial College, Saudi Arabia, and a Master's degree in Electrical Engineering from the University of Victoria, Canada. He has more than five years of experience in systems engineering processes, specifically, research, systems analysis and development, design development, technical monitoring and control, and requirements management. Hussam recently passed the INCOSE knowledge exam in preparation for ASEP and CSEP certification.

Resilience Requirements Patterns

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Presented on: Tuesday, 14:00-14:40

Keywords. resilience;requirements;patterns;loss-driven systems engineering;quality;MBSE;DE

Topics. 1.5. Systems Science; 2.3. Needs and Requirements Definition; 2.4. System Architecture/Design Definition; 3.6. Measurement and Metrics; 4.4. Resilience; 5.3. MBSE; 7. Emergency Management Systems;

Abstract. In recent years, achieving resilience has become an important objective in many system development efforts. Resilience is defined as a system's ability to deliver required capability in the face of adversity. Developing resilient systems often depends on first establishing good resilience requirements. Resilience requirements are complex compound requirements and developing high quality resilience requirements is a challenge. In this paper we follow both a deductive and inductive approach to identify the critical content and structure of resilience requirements. We develop a pattern that represents that information and model that pattern in three forms, which contain the same information: 1) natural language, 2) entity-relationship diagram, 3) an extension to SysML. These forms make the pattern easily developed, understood, and validated by stake-holders who are not modeling experts, and at the same time is formal, precise and computation-ally consumable. The resulting resilience requirements are consistent with systems engineering methodologies and are easily utilized in Model Based Systems Engineering and Digital Engineering environments.

Return on Investment in Model-Based Systems Engineering Software Tools

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Presented on: Wednesday, 12:30-13:10

Keywords. investment;return;software;tools;capability;productivity;challenge

Topics. 1. Academia (curricula, course life cycle, etc.); 3.3. Decision Analysis and/or Decision Management; 3.6. Measurement and Metrics; 5.3. MBSE; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. This paper investigates a means of determining the return of an organization's investments in software tools to support system engineering activities. The paper considers a range of organizational attributes, including size of the system engineering labor force, type of engineering activities to be performed, level of difficulty of the activities, and organizational objectives. The re-search considers three categories of software tools including modern SysML and LML engineering tools. The paper develops a model of financial metrics based on capabilities of each tool, its costs, and the engineering processes to which it can be applied. The paper finds that considerable organization returns are realized with investments in such tools, most significantly the reduction in engineering labor needed to perform engineering tasks. Additional returns can be expected in terms of engineering project performance (success) and also in the ability of an organization to pursue larger or more challenging engineering projects.

Paper#45

Security as a Functional Requirement in the Future of Systems Engineering

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Presented on: Monday, 14:00-14:40

Keywords. system security engineering; security requirements; functional requirements

Topics. 1.6. Systems Thinking; 2.3. Needs and Requirements Definition; 4.7. System Security (cyber-attack, anti-tamper, etc.);

Abstract. The Future of Systems Engineering (FuSE) Security project is an INCOSE-led multi-organizational collaboration exploring a roadmap of foundational topics for integrating security into systems engineering thinking and practices. Security as a Functional Requirement elaborates on one topic to help identify where in the systems engineering processes to integrate security, standard security concepts with which to engage stakeholders, and establish security as an infinite game that requires security be an active consideration throughout the system lifecycle including operations.

Paper#49

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

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Presented on: Monday, 13:15-13:55

Keywords. Security; Future of Systems Engineering; FuSE

Topics. 2. Aerospace; 3. Automotive; 4.7. System Security (cyber-attack, anti-tamper, etc.); 6. Defense;

Abstract. The Future of Systems Engineering (FuSE) is an INCOSE-led multiorganizational collaborative initiative pursuing INCOSE's Vision 2025 and beyond. To accomplish this the FuSE initiative encompasses a number of topic areas with active projects to shape the future of systems engineering. This paper addresses the FuSE Security topic area and provides a roadmap of eleven foundational concepts for building the security vision. The purpose of this paper is to instigate and inspire thinking and involvement in the realization and practice of the foundational concepts. These foundational concepts are: Security Proficiency in the SE Team, Education and Competency Development, Stakeholder Alignment, Security as a Functional Requirement, Loss Driven Engineering, Architectural Agility, Operational Agility, Capability-Based Security Engineering, Trust in Security Modeling, Security Orchestration, and

Techno-Social Contracts.

Biography

Rick Dove (Independent) - dove@parshift.com

Rick Dove is an independent researcher, systems engineer, and project manager generally focused in the system security and system agility areas; and an adjunct professor at Stevens Institute of Technology in the School of Systems and Enterprises. He chairs the INCOSE working groups for System Security Engineering, and for Agile Systems and Systems Engineering. He is an INCOSE Fellow, and author of Response Ability – the Language, Structure, and Culture of the Agile Enterprise.

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Dr. Keith D. Willett is a senior strategist and enterprise security architect for the United States Department of Defense. He has a PhD in systems engineering from Stevens Institute of Technology. He is co-chair for the INCOSE working groups on Systems Security Engineering and Agile Systems & Agile SE. Dr. Willett is sole author of Information Assurance Architecture and coauthor of three books including Multi-systemic Resilience – Adaptation and Transformation in Contexts of Change (Oxford Press) February 2021.

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Tom McDermott is the Deputy Director and Chief Technology Officer of the Systems Engineering Research Center at Stevens Institute of Technology in Hoboken, NJ. He leads research on Digital Engineering transformation, education, security, and artificial intelligence applications. Mr. McDermott also teaches system architecture concepts, systems thinking and decision making, and engineering leadership for universities, government, and industry. He serves on the INCOSE Board of Directors as Director of Strategic Integration.

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Holly Dunlap is a Senior Principal Engineer at Raytheon Technologies with over 20 years experience. Ms. Dunlap is responsible for a holistic approach to program protection to manage and balance the security-relevant risks within platforms or embedded defense systems. Ms. Dunlap is currently the chair of the National Defense Industrial Association (NDIA) Systems Engineering Division and has chaired the NDIA Systems Security Engineering (SSE) Committee for 9 years.

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Delia Pembrey MacNamara is current President of the International Society for the Systems Sciences and chairs the Science, Spirituality and Systems Sci-ence Special Integration Group. She is on the Board of Trustees for the American Society for Cybernetics and is a PhD candidate at the University of Hull in the UK researching the systems concept of 'Boundary', applying general systems theory, critical systems thinking and cybernetics. Delia works for the Australian Government in the artificial intelligence, automation and ethics domain.

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Cory Ocker is a Secure Systems Engineering Manager at Raytheon Technologies focused on securing embedded systems. He previously served as a government civilian securing multiple systems including the F-15, AIM-260, and various other weapon programs as an Agent of the Security Control Assessor. He chairs the NDIA Systems Security Engineering (SSE) Committee where he works with the Office of the Secretary of Defense and other services on establishing policy, practices, and guidance for the SSE community.

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

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Presented on: Wednesday, 10:45-11:25

Keywords. social systems;social science;organizations;organizational psychology;social psychology;embedding systems engineering;socio-technical systems

Topics. 22. Social/Sociotechnical and Economic Systems;

Abstract. There have been many calls for systems engineering to bring the social sciences into systems engineering practice and research, as systems engineers have a host of issues in their practice that could benefit from engaging in a number of social science disciplines. With an organizational case study, this paper describes the problems in systems engineering practices stemming from social systems. Need statements collected from participants highlight what is needed for a social systems primer. The needs can be categorized into three broad themes: (1) A better understanding how social systems are different from technological systems; (2) How, therefore, social science theories and methods can improve our tailoring of systems engineering to different circumstances, and finally (3) how the findings from the social sciences can help engineers, as individuals, be more effective in their work. We discuss these need statements in relation to the development of the Social Systems Primer.

Biography

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Richard Beasley joined Rolls-Royce in 1986 with a Physics Degree from Bristol University, and an MSc in Gas Turbine Engineering from Cranfield University. After working on Integration Aerodynamics, Safety, Reliability and Life Cycle Engineering, he became the Global Chief of Systems Engineering and in 2011 was made a Rolls-Royce Associate Fellow in Systems Engineering. He was part of the BKCASE SEBoK author team, one of the leading authors on the INCOSE SE competency framework, is a Past-President of the UK INCOSE Chapter, and currently Deputy Director of Services for INCOSE. He is a Chartered Engineer, Fellow of the Royal Aeronautical Society, INCOSE ESEP, and was a Visiting Fellow to the Systems Centre at Bristol University.

Solar Energy Investment Framework for Real Estate in Norway - a Case Study in Systems Engineering

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Presented on: Wednesday, 14:00-14:40

Keywords. renewable energy;investment framework;business analysis

Topics. 12. Infrastructure (construction, maintenance, etc.); 2.1. Business or Mission Analysis; 3.3. Decision Analysis and/or Decision Management; 4.2. Life-Cycle Costing and/or Economic Evaluation; 8. Energy (renewable, nuclear, etc.);

Abstract. The last decade has brought an increased focus on sustainability for real estate asset managers in Norway. The asset managers are exploring new ways to reduce their real estate's climate footprint by using green energy as energy supply. The use of solar power systems has become a popular way to achieve this goal. However, the asset managers are struggling to defend these investments, as they do not have the wanted profitability. The investment decision process is time and resource demanding. This paper looks at the investment process that asset managers conducts when investing in solar power systems for a building. The researchers explore the drivers and barriers for solar energy investments and maps the current market actors. We establish an investment framework that aims to improve the resource utilization and reduce risk in renewable energy investments. The paper provides insights in how an abstract principle can help improve specific and executable practices through the holistic and structured approach of systems engineering.

Biography



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Elisabet Syverud received her MSc in Aerospace Engineering from the University of Kansas, US, and her Dr.Ing in Thermal Energy from the Norwegian University of Science and Technology in Trondheim, Norway. She started her industrial career in 1993, and has worked in multiple roles in the oil&gas and defense industries for almost 20 years. Since 2019, she is Associate Professor of Systems Engineering and Head of Department Science and Industry Systems at USN.

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Karsten Hofstad Bak received his MSc in Systems Engineering with Industrial Economics from the University of South-Eastern Norway in 2020. Previously he has a bachelor's degree in Mechanical Engineering from the Norwegian University of Science and Technology in Trondheim, Norway. He is currently working as an Automation Engineer with focus on energy-saving systems within building automation and HVAC.

STPA-Sec Analysis for the DevSecOps Reference Design

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Presented on: Monday, 15:55-16:35

Keywords. cybersecurity;resiliency;DevSecOps;requirements analysis;software factory;systems security engineering

Topics. 11. Information Technology/Telecommunication; 4.4. Resilience; 4.7. System Security (cyber-attack, anti-tamper, etc.); 5.7. Software-Intensive Systems; 6. Defense;

Abstract. This work describes a top down systems security requirements analysis approach for understanding and eliciting general security requirements for securing Software Factories (SF). More specifically, the System-Theoretic Process Analysis approach for Security (STPA-Sec) is used to understand and elicit systems security requirements for SFs. The effort employs STPA-Sec on the DoD Enterprise DevSecOps Reference Design to detail a conceptual approach to analyze SFs. The intent is to develop functional-level security requirements, design-level engineering considerations, and architectural-level security specification criteria early in the system life cycle. The aim is to secure the SFs themselves, enhancing the security of resulting software generated from the SF. These details were elaborated during a summer collaborative research effort by two United States Air Force Academy Systems Engineering cadets, working with a MITRE team of subject matter expertise (SME's), and guided by their instructor. This work provides insight into a viable systems security requirements analysis approach which results in traceable security, safety, and resiliency requirements that can be designed-for, built-to, and verified with confidence.

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

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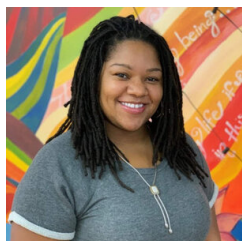
Presented on: Wednesday, 12:30-13:10

Keywords. Systems thinking; socially engaged design; service learning; community engagement

Topics. 1. Academia (curricula, course life cycle, etc.); 1.6. Systems Thinking; 22. Social/Sociotechnical and Economic Systems;

Abstract. Socially engaged design programs, community development coalitions, and intentional and unintentional design spaces are rich with expertise and thinkers that are developing solutions to very pressing, yet complicated problems. Little research is conducted on the expertise and sense-making of the community partners present. The goal of this research endeavor is to unpack the ways various community partners make meaning of their design experiences by answering: What evidence of system's thinking can be seen in the way community partners describe their work or context? A qualitative research study has been conducted in which fifteen community partners have been observed and interviewed at various points of their engagement within socially engaged design programs. Resulting codes and competencies can be used to expand scholarly conceptions of community cultural wealth, social resistance and much more. Further, this research has implications for more novel and genuine ways to situate design learning within systems thinking competencies.

Biography



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Born and raised in Detroit, Michigan, Chanel Beebe is a creative writer, artist and educator who designs, implements and conducts research on S.T.E.A.M. programming. In 2021, Chanel will graduate with both a master's degree in Industrial Engineering and a Ph.D. in Engineering Education and plans to continue to study socially situated design and learning experiences. As a growing "socio-technical activist," Chanel seeks to blend her values of creativity, equity, health and sustainability with her formal training as an Industrial Engineer. Ultimately, Chanel hopes her contributions will transform the experience of social reform and well-being

for historically disenfranchised people. More of Chanel's work and progress can be found at ChanelBeebe.com.



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C. Robert Kenley is a Professor of Engineering Practice in Purdue's School of Industrial Engineering, where has been developing courses and curricula to support the educational objectives of the Purdue Systems Col-laboratory. He has over thirty years' experience in industry, academia, and government as a practitioner, consultant, and researcher in systems engineering at Lockheed, the Idaho National Lab, MIT, and Purdue. He has a Ph.D. and M.S in Engineering-Economic Systems from Stanford, an M.S. in Statistics from Purdue, and an S.B.in Management from MIT. He has published papers on systems requirements, technology readiness assessment and forecasting,

Bayes nets, applied meteorology, the impacts of nuclear power plants on employment, and model-based systems engineering, and agent-based modeling for systems of systems. He is an expert system engineering professional (ESEP) and a Fellow of INCOSE.

Systems Thinking: A Critical Skill for Systems Engineers

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Presented on: Tuesday, 14:00-14:40

Keywords. Systems Thinking; Systems Engineering Skills; Systems Theory

Topics. 1.5. Systems Science; 1.6. Systems Thinking; 5.9. Teaching and Training;

Abstract. This paper examines Systems Thinking (ST) as a critical skill for systems engineers. There is neither a universally accepted definition nor agreement of the knowledge base for ST or how this 'thinking skill' is acquired. However, there is general agreement that ST is "good" and an essential skill for a future workforce, including systems engineers. Systems engineers must confront increasingly complex systems and their problems elevating ST as an essential skill. To examine ST for systems engineers, two primary objectives are developed. First, we offer a review of the different literature and perspectives of what constitutes ST. This provides a foundation for the central themes that dominate the ST literature. Second, a framework depicting the nature, role, and utility offered by ST for systems engineers is developed. This framework provides the conceptual underpinnings of ST in relationship to Systems Theory. Emphasis is placed on 'actionable' ST skill development. The paper concludes with suggestions for the inculcation of ST into the development landscape for current and future systems engineers.

Technical Leadership of Virtual and Remotely Distributed Teams

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Presented on: Thursday, 13:30-14:10

Keywords. Technical Leadership; Distributed Teams; Leadership Practices; Virtual; Remote Environment

Topics. 3.5. Technical Leadership;

Abstract. Abstract. The world is increasingly virtual and complex, with many relationships and teams at a global scale. The situation will not be changing any time soon. Sometimes, it is only possible to interact at a distance, of not only time zones and space, but also sometimes interpersonal distance, where names and voices make up another person. Regardless, technical teams will need good leadership to address complex situations in these virtual and remotely distributed (VaRD) environments. So, in a VaRD environment, do leadership practices and skills have to change? Do the tools, techniques, and technology make current practices for leadership in general, and the application of those practices obsolete? Maybe not.

This paper seeks to examine the nature of what is really changing when leading in a VaRD environment through the lens of engineers leading teams in global and complex technical challenges. Those perspectives are analyzed to determine the factors that go into a VaRD environment, how it compares to an in person technical environment, the application of leadership practices in this environment, and potential ways to tailor technical leadership for these new environments.

Biography



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Francesco Dazzi is currently Senior Systems Engineer at the Cherenkov Telescope Array Observatory, Technical Director of AISE (INCOSE Chapter Italy), and member of the INCOSE Institute for Technical Leadership. He has nearly 20 years of experience mainly dedicated to the construction of ground-based telescopes and technical management of scientific projects. He has a degree in Physics, a PhD in Mathematics and Physics, and about 200 publications including journal articles and conference proceedings. In 2018 he obtained the CSEP (Certified Systems Engineering

Professional) certification. In his free time, Francesco practices various sports, coaches in rugby, and he is a strength and conditioning coach for rugby.



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Mark McKelvin is a Senior Project Lead in Digital Engineering at The Aerospace Corporation and a Lecturer in the System Architecting and Engineering graduate program at the University of Southern California, Viterbi School of Engineering. In his current role at The Aerospace Corporation, he serves as the technical authority for implementing digital engineering across the space enterprise for a variety of customers. He is a Senior Member of the American Institute of Aeronautics and Astronautics, and a member of the leadership board for the International Council on Systems Engineering, Los Angeles Chapter. He earned a Ph.D. in Electrical

Engineering and Computer Sciences from the University of California, Berkeley and a Bachelor of Science in Electrical Engineering from Clark Atlanta University. In his spare time, Mark enjoys motorcycle rides,

playing video games, and mimosas at brunch.



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Ms. Elena Gallego Palacios is Solution Engineer Manager at Thales in The Netherlands. Leading the Engineering process, practices and tools for Above Water Warfare System Solutions. Elena has developed skills in SE from her participation in private funding projects in industries such as the aerospace, defense, railway or automotive industries, as well as a researcher in different EU projects. Her topics of interest include Requirements Engineering, MBSE, Digital Transformation, Team Management and Leadership. Elena received her bachelor's degree in Electrical Engineering from the Universidad Carlos III de Madrid - UC3M (Spain), and her master's degree in Computer Science and Artificial Intelligence at the same University. Elena holds the ASEP (Associate Systems Engineering Professional) certification by INCOSE, and is part of the INCOSE Institute for Technical Leadership.

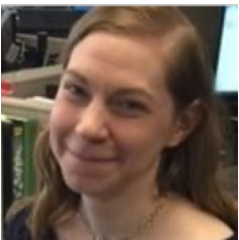


Sean McCoy (Trane Technologies) - sean.mccoy.csep@gmail.com

Sean McCoy is the Chief Architect for controls at Trane. He received his CSEP in 2016, has 13 patents, holds a 6-Sigma black belt, and has over 37 years of experience designing and developing software systems. 25 of those years have been at Trane developing Building Automation Systems and helping develop Trane's Systems Engineering discipline. Sean has been an active member of INCOSE since 2011 and is the President of the North Star Chapter for 2021. He has been on the GLRC conference planning committee for 2017-2019, and he is a member of the INCOSE Institute for Technical Leadership. His most recent work assignment was leading the effort to develop a holistic System Architecture for Building Automation Systems - from machine controls to the cloud. In his spare time, Sean likes to play guitar and is often seen at Rock Camp Experience events in the Twin Cities.

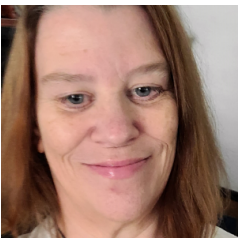
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Patrick Keen is a Systems Engineer at Lockheed Martin Space and is the Integration lead for Model-Based Engineering internal re-search and development. Prior to joining Lockheed Martin in 2018, Patrick worked at NASA Marshall Space Flight Center to apply model-based systems engineering to liquid propulsion systems. Patrick received his bachelor's degree in Mechanical Engineering from the University of Arkansas and is currently pursuing a master's degree in Systems Engineering with software concentration from Stevens Institute of Technology. Patrick has a passion for digital engineering solutions and industry-wide digital transformation. Patrick is a member of the 5th cohort of the INCOSE Institute for Technical Leadership. In his free time, Patrick loves to fish, golf, and work in his garden.



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Allison Weigel is a Senior Technical Engineer in Product Lifecycle Management and Configuration Management at Toray Composite Materials America. She has a background in materials, with a Bachelor of Science in Materials Science Engineering from Purdue University. In her current position, she is the subject matter expert in her company on effective systems engineering practices, and supports other engineers in the design, development, qualification, and manufacturing of prepreg for continuous fiber reinforced composites for customers in multiple industries. She has been part of INCOSE since 2015, and is part of the 5th cohort of the INCOSE Institute for Technical Leadership. Outside of engineering, Allison enjoys working out, cooking, reading, hiking, and cloudspotting.



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Lisa Ziliox is a Principle Systems Engineer at BAE Systems. Lisa has over 20 years of relevant technical and project experience in systems, and software engineering. She manages moderate size projects for meeting contractual, BAE Systems, and customer defined requirements of these assigned projects, including schedule, budget, technical quality, cost, performance, and innovation. She holds a MS degree in Management Information Systems from Notre Dame de Namur University, Graduate Certificate in Systems Engineering from Worcester Polytechnic Institute (WPI), and BS degree in Software Engineering from Notre Dame de Namur University. She has been a member of INCOSE since November 2008 and member of the INCOSE Institute for Technical Leadership. Outside of work, Lisa's interest includes spending time with her family, friends, reading, and playing video games.

The Benefits of Enhanced Contact Tracing and Quarantine to Resume and Maintain College-Campus Operations: An Agent-Based Probabilistic Simulation Analysis

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Presented on: Thursday, 12:00-12:40

Keywords. Agent-Based Simulation; Covid-19; Probabilistic Simulation

Topics. 4. Biomed/Healthcare/Social Services; 5.4. Modeling/Simulation/Analysis;

Abstract. Universities, K-12 schools, sports programs and businesses are operating (and generating revenue) during the COVID-19 pandemic. The key to operating safely is to manage the risk of infectious events that lead to an outbreak and require excess costs and/or lead to a complete shutdown of the enterprise. To operate through a pandemic, organizations must plan to accommodate the quarantine of exposed individuals and isolation of infected individuals (e.g. accommodations and food). To prevent or slow infections, organizations can implement mitigation options to: (1) reduce peer-to-peer transmission in operations (e.g. social distancing and protective equipment), (2) identify and quarantine individuals who have been exposed (e.g. daily symptom and exposure screening, randomized surveillance testing, timely contact tracing), and (3) test and/or isolate individuals who are infected (asymptomatic as well as symptomatic). Mitigation option #1 prevents individuals from becoming infected. Mitigation options #2 and #3 remove people who are infected from circulation, preventing them from infecting others. The efficacy of mitigations #2 and #3 have a non-linear impact due to the amplifying effect of circulating asymptomatic/symptomatic individuals.

An agent-based, probabilistic model measured the efficacy of contact tracing and quarantine on infection counts and lost productivity (i.e. total days in quarantine and isolation). Two modes of operations were evaluated: Cohort with no interaction with the community (i.e. hermetically sealed "bubble" with one undetected infection at start), Cohort with limited interaction with community (e.g. attending classes, take-out food court). For the No Community Interaction cohort, a contact tracing and quarantine with only 25% efficacy and compliance reduced the infection count from 60% to 6%. This yielded a reduction in total lost productivity days of 94%. In contrast, the Limited Community Interaction cohort required more than 75% efficacy and compliance in contact tracing and quarantine to reduce the infection count from 80% to 30%. This yielded a reduction in total lost productivity days of 30%.

These results highlight the role interaction with the general community has on a cohort's health. Further, the results emphasize the utility of contact tracing and quarantine within a cohort to mitigate community-wide practices that are not under jurisdiction of managers of the enterprise. The implications of these results and limitations of the model are discussed.

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

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Presented on: Wednesday, 14:00-14:40

Keywords. Systems Thinking;Competencies;HELIX

Topics. 1. Academia (curricula, course life cycle, etc.); 1.6. Systems Thinking; 22. Social/Sociotechnical and Economic Systems; 4.5. Competency/Resource Management; 5.9. Teaching and Training; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Today's systems are continuing to increase in complexity, and employers have placed a premium on critical and systems thinking skills. The World Economic Forum (WEF) reports that an increasing share of jobs are focused more heavily on soft skills or a combination of soft and technical skills. The WEF 5-year survey of most desired job skills highlight the growing focus on the cognitive and relationship-building aspects of the future workspace. "Complex Problem Solving" has topped the list in both the 2015 and 2020 reports. This paper consolidates and proposes a common framework for lifelong learning in the engineering domain, targeted at practical tools that help engineers solve complex problems, think and learn more holistically, and apply that learning to team leadership. Although the work has been focused on engineering roles, it may be generally applied to any domain where complex problem solving is at a premium. The framework identifies five complex problem-solving competency sets: sensemaking, adaptive and computational thinking, a design mindset, system architecting and communicating, and leading teams through cycles of learning. These competencies are developed through the experience of a learning infrastructure which integrates learning with the work to be done, through facilitating learning and performance in systems thinking, team leadership and personal learning power and self-leadership. This paper presents the framework, the background research that led to its development, and how it might be delivered through teaching and mentoring on complex projects.

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

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Presented on: Tuesday, 15:10-15:50

Keywords. systems engineering; risk management; safety; quality assurance; capability maturity model; risk maturity model

Topics. 1. Academia (curricula, course life cycle, etc.); 17. Sustainment (legacy systems, re-engineering, etc.); 22. Social/Sociotechnical and Economic Systems; 3.7. Project Planning, Project Assessment, and/or Project Control; 3.8. Quality Management Process; 3.9. Risk and Opportunity Management; 4.6. System Safety; 5.5. Processes; 6. Defense;

Abstract. Norwegian governmental institutions use their risk management regulations to acquire and manage projects and assess the institutional practices. After many years documenting a positive trend, the audit authority noticed a stagnation in process improvement across the organization. A literature review of the use of risk management maturity models from other industries suggested a method for achieving continuous improvement. A corresponding maturity model has been developed and tested with positive results.

This research developed a risk maturity model based on compliance requirements for the Norwegian defense sector. The intended use of this model is as the foundation for conducting assessments through audits and provide explicit guidance toward given requirements that facilitate extensive improvement in application of the risk management system.

Use of the model in performing maturity assessments of organizational elements within the defense sector showed that the model supports the subsequent improvement activities through providing better understanding of the existing situation, and explicit visual feedback on areas that are satisfactory and areas in need of improvement. A maturity model provides a stepwise path showing the next level of improvement on the way to achieve required performance.

The Systems Engineering Conundrum: Where is the Engineering?

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Presented on: Wednesday, 14:00-14:40

Keywords. Systems Engineering; Systems Management; SE Management; SE Core Competency; SE Technical Competency; Restoration of SE Discipline and Competency

Topics. 1.6. Systems Thinking; 2. Aerospace; 3.5. Technical Leadership; 3.7. Project Planning, Project Assessment, and/or Project Control; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Systems Engineering, as an emerging discipline for the “engineering of systems,” was transformed into a Systems Management approach over 60+ years ago to focus on “managing the development of systems.” As a result, SE technical competency has been largely ignored over the intervening years. Despite claims of “managing the development of systems” through the “transdisciplinary” integration of Engineering Disciplines on large, complex development efforts, projects continue to exhibit project technical, cost, and schedule performance issues originating from SE. SE has a conundrum: Where is the Engineering that completes SE’s core competency?

To answer the question, we explore the SE Technical Competency Void or Gap, what it is, and how it evolved; understand its devastating impacts on Engineering and project performance; examine how SE misinformation by self-appointed “experts” corrupt the integrity of the discipline knowledgebase, and provide a current solution that fills the Gap and restores SE Discipline and Technical Competency.

The value of trade-off studies for student projects

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Presented on: Wednesday, 13:15-13:55

Keywords. systems engineering;Cubesats;trade-off studies;project-based learning

Topics. 1. Academia (curricula, course life cycle, etc.); 1.6. Systems Thinking; 2. Aerospace; 2.4. System Architecture/Design Definition; 3.3. Decision Analysis and/or Decision Management; 3.7. Project Planning, Project Assessment, and/or Project Control; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. University student projects serve multiple purposes. They provide a realistic structure for students to apply their theoretical book-learning to a practical problem and in the course of their work the results increase the knowledge base of the university and related disciplines. However, student projects struggle with a continuous loss of continuity as the students' interests change or they graduate. This leads to increased project risk, development delays and loss of institutional knowledge. In an attempt to mitigate the loss of design rationale and accumulated competence, the Orbit AnonU1 project implemented a trade-off study process tailored to the experience level of students. The case study results suggest that it is possible to implement a single method that provides support for inexperienced students, while experienced students are able to "pick and choose" from the method and further adapt it to their documentation style. Both individual students and students performing trade-offs as part of a team produced vastly improved documentation while also spending less time when compared to earlier attempts at documenting design rationale. Consequently, the project has built up a useful archive in a very short time, and onboarding new students has resulted in faster assimilation into the project.

Towards a Software Defined Truck

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Presented on: Thursday, 08:30-09:10

Keywords. Systems Engineering;Software Engineering;Networking;Automotive embedded systems;SAE-J1939;System virtualization;Testbed

Topics. 1.6. Systems Thinking; 2.3. Needs and Requirements Definition; 3. Automotive;

Abstract. Heavy vehicles are part of the US Critical Infrastructure as they provide the means to deliver goods across the globe. To effectively manage the delivery of goods and improve the performance of the logistics operations, heavy vehicles have been increasingly equipped with wireless telematics systems that bridge the on-board vehicle networks with Internet based systems. The interconnection of these systems creates a complex system comprising both traditional information technology (IT) systems and automotive operational technology (OT) systems. Using a systems approach to the design, testing, and implementation of complex logistic systems requires a testing and verification strategy to encompass many configurations of vehicles. Using existing vehicles for comprehensive testing is cost prohibitive and building representative testbeds for each configuration of the vehicle is labor intensive. However, testing numerous configurations of heavy vehicles remains a necessity for proper systems evaluation and verification. To this end, a software defined truck (SDT) is proposed to rapidly test numerous vehicle configurations and achieve testing and verification tasks using automated techniques. This approach drastically expands the coverage of the testing and verification of technologies that leverage vehicle networks. The approach sets the requirements of the software defined truck, explains the advantages of using switched packet networking to virtually reconfigure the truck's network topology, and the appropriate use of simulation engines, emulated hardware, and actual hardware. The result is a scalable, sharable resource where organizations can conduct research, testing, and evaluation at significantly lower cost and wider coverage. This is particularly useful for performing cybersecurity testing, compliance testing, or evaluating other software driven solutions that use the vehicle's controller area network (CAN).

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

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Presented on: Monday, 13:15-13:55

Keywords. MBSE;UAF;Systems-of-Systems;Model;Architecture Frameworks

Topics. 2. Aerospace; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 6. Defense;

Abstract. The system model is defined as the main source of truth for systems engineering. Current MBSE methods are focused mainly on single systems. As per the literature, we lack the MBSE methods to develop the system models of System of Systems (SoS). Systems engineers use architecture frameworks for this purpose, but the huge number of views included within an architecture frame-work makes it difficult to select the appropriate views and expert knowledge is required to tailor the framework. The UAF (Unified Architecture Framework) Based MBSE (UBM) method described within this paper addresses this issue. This method uses a selected subset from the UAF domain model and defines a step by step procedure to construct the system model for a complex, System of Systems in a military domain.

Unlocking the power of big data within the early design phase of the new product development process.

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Presented on: Tuesday, 13:15-13:55

Keywords. Big data;Product Development;New Product Development;Knowledge Management;Unstructured Data;Data Driven Information;Early Design;Model Based Systems Engineering (MBSE)

Topics. 1.1. Complexity; 1.4. Systems Dynamics; 1.6. Systems Thinking; 2.2. Manufacturing Systems and Operational Aspects; 2.4. System Architecture/Design Definition; 2.6. Verification/Validation; 20. Industry 4.0 & Society 5.0; 3.3. Decision Analysis and/or Decision Management; 3.4. Information Management Process; 5.1. Agile Systems Engineering; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 5.5. Processes;

Abstract. The aim of this study is to investigate through a real industry problem how to exploit big data. Through this exploitation, we strive to increase knowledge in the early design phase within new product development. There is little research, and an especial scarcity of empirical studies, in utilizing big data within new product development in manufacturing industries. Shorter design cycles demand rapid decision-making and the need for data-driven information is evident. An increase of knowledge through big data analytics, closing the loop with a knowledge base, has become a critical success criterion within the various industries.

This paper reviews state of the art in academic literature and a case company. The study uncovered a gap of limited feedback into the early design phase. We developed a generic agile approach with the intention of extracting value through analyzing big data. To fill in the identified gap, we tested our approach on a sample of big data, including both internal and external user data. Positive feedback from a survey complemented by interviews indicates that our approach can aid decision making within the early design phase by acquiring more data-driven information.

Using Models and Simulation for Concept Analysis of Electric Roads

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Presented on: Wednesday, 13:15-13:55

Keywords. UAF;Electric Road;Climate Change;Green Energy;MBSE;Green Transport;Electro-Mobility

Topics. 10. Environmental Systems & Sustainability; 12. Infrastructure (construction, maintenance, etc.); 21. Urban Transportation Systems; 4.2. Life-Cycle Costing and/or Economic Evaluation; 5.4. Modeling/Simulation/Analysis; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.);

Abstract. Using electricity to directly power moving vehicles has been used for a long time as evidenced by trains, trams, and busses. Providing electricity to move heavy transport trucks on roads does therefore not represent a huge innovation. Electric roads (ERs) that can provide engine power to heavy road haulage, since heavy haulage traffic on roads represent a significant part of carbon dioxide emissions is seen as significant by the Swedish government (Bateman et al, 2018SP04EN). Several Swedish government authorities as well as private companies are actively testing equipment both for trucks as well as roads. ERs, once they have been deployed, will also provide benefits as regards air quality and traffic noise. This paper describes a concept analysis project that uses models and simulation to analyze electric road scenarios where electric road enabled trucks of different types run along an electric road and are subjected to different road conditions, speed restrictions as well as queues over a defined amount of time. The ability to analyze both management and energy consumption of an electric road is of paramount importance in determining its ability to accomplish the desired carbon-dioxide emission reductions. The analysis work is described, as well as the results achieved at the time when this was written.

Verification and Validation of SysML Models

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Presented on: Tuesday, 15:55-16:35

Keywords. SysML; SysML model verification and validation; SysML model correctness

Topics. 2.3. Needs and Requirements Definition; 3.8. Quality Management Process; 5.3. MBSE;

Abstract. Abstract Model Based Systems Engineering depends on correct models. However, thus far, relatively little attention has been paid to ensuring their correctness – particularly for larger system engineering models. This paper describes a methodology for performing verification and validation on models written in SysML. The method relies on a catalog of candidate requirements that can be tailored for a specific project. Many of these requirements can be verified automatically. Examples of diagrams taken from an independently created SysML model of a satellite are presented to show the effectiveness of the automated verification in identifying non-obvious modeling deficiencies

Biography

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Myron Hecht is a Senior Project Leader at The Aerospace Corporation where he specializes in Model Based System Engineering (MBSE) and in reliability, for complex weapons systems. He also is a consultant to the Nuclear Regulatory Commission and a lecturer at the UCLA School of Engineering and Applied Sciences. His current research is on application of MBSE to reliability, availability, and safety analysis. He has served on standards committees for reliability (IEEE 1332 and GEIA STD 009), computers in nuclear power plants (IEEE 7-4.3.2), software in avionics systems (RTCA DO 178C and 278A), and model-based safety and reliability for the Object Management Group (OMG). He is an author of more than 100 refereed publications in reliability, safety, products liability, and systems engineering. Myron holds B.S (Chemistry), M.S. (Nuclear Engineering), M.B.A., J.D. degrees all from UCLA.



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Jaron Chen is a Member of the Technical Staff at the Aerospace Corporation. He works in in the areas of Model Based System Engineering (MBSE), machine learning, software tools development, discrete event simulation, and integration of modeling techniques in support of space and ground communications systems. He holds an M.S. from Carnegie Mellon University and a B.S. from the University of California Irvine

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

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Presented on: Tuesday, 15:55-16:35

Keywords. Personal resilience; Systems engineering competencies; Creative problem-solving; Systems thinking; Design thinking

Topics. 1.6. Systems Thinking; 2.2. Social/Sociotechnical and Economic Systems; 3.5. Technical Leadership; 4.4. Resilience; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. This paper posits that individual or personal resilience, that is, the ability of a person to adapt to and recover from adversity (Public Health Emergency [PHE], 2020), is key to overcoming personal challenges and that personal resilience is important to organizational and societal resilience as well. Among the examples of personal resilience listed by Spacey (2017) are unaffectedness, tolerance for ambiguity, change agency, and big picture thinking. Arguably, these are characteristics possessed by systems engineers, hence the assertion that systems engineers may have an edge when it comes to personal resilience. This paper breaks down these characteristics further and relates them to the systems engineering competencies as they are described in the International Council on Systems Engineering's (INCOSE) Systems Engineering Competency Framework (Presland, Ed., 2018). It also provides a few suggestions on how to develop personal resilience.

You Don't Save Money by Doing Less Testing - You Save Money by Doing More of the Right Testing!

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Presented on: Wednesday, 15:55-16:35

Keywords. Testing;Certification;Model;Validation;Fatigue

Topics. 2. Aerospace; 2.6. Verification/Validation; 4.6. System Safety; 5.4. Modeling/Simulation/Analysis;

Abstract. Like so many aspects of life, we are looking for value-for-money. But we need to consider the value in terms of both short and long-term gains. Like saving for a pension, we experience a short term impact for a hopefully long term benefit. If you want more benefits, then pay more into your pension. Although certification standards require verification that requirements have been met, we need to recognize that verification is also there to bring value to a project and business. An error detected now is often cheaper to correct than one that escapes. But not all errors are equal - there are many classes of errors (error-types). And, not all verification methods are identical. Each verification method will detect a sub-set of the error-types. A project manager can optimize their verification by pairing up error-types with verification methods. If a specific error type does not exist, then some verification methods will add no value. So we can optimize verification under two conditions: Firstly, we can reliably predict what error-types are present. Secondly, we know which verification methods are most effective at detecting them.

Biography

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Andrew Pickard joined Rolls-Royce in 1977 after completing a Ph.D. at Cambridge University in Fatigue and Fracture of Metals and Alloys. He is a Rolls-Royce Associate Fellow in System Engineering, a Fellow of SAE International, a Fellow of the Institute of Materials, Minerals and Mining, a Chartered Engineer and a member of INCOSE. He is immediate past Chair of the SAE Aerospace Council, represents Rolls-Royce on the INCOSE Corporate Advisory Board and is Chief of Staff for INCOSE.

Richard Beasley (Rolls-Royce plc) - richard.beasley@rolls-royce.com
Richard Beasley joined Rolls-Royce in 1986 with a Physics Degree from Bristol University, and an MSc in Gas Turbine Engineering from Cranfield University. After working on Integration Aerodynamics, Safety, Reliability and Life Cycle Engineering, he became the Global Chief of Systems Engineering and in 2011 was made a Rolls-Royce Associate Fellow in Systems Engineering. He was part of the BKCASE SEBoK author team, one of the leading authors on the INCOSE SE competency framework, is a Past-President of the UK INCOSE Chapter, and currently Deputy Director of Services for INCOSE. He is a Chartered Engineer, Fellow of the Royal Aeronautical Society, INCOSE ESEP, and was a Visiting Fellow to the Systems Centre at Bristol University.

Panel

Panel#3

A Framework for Understanding Systems Engineering Principles and Heuristics

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Presented on: Tuesday, 10:00-11:25

Keywords. Heuristics;SE Principles;Systems Principles;Systems Science

Topics. 1. Academia (curricula, course life cycle, etc.); 1.5. Systems Science; 1.6. Systems Thinking; 3.5. Technical Leadership;

Abstract. A team of INCOSE Fellows was formed in early 2020, under the leadership of Dorothy McKinney charged with developing a set of updated heuristics fit for the 21st Century, building on the foundations laid by Rechtin and Maier some 20 years ago. They were to be made readily available to all practising systems engineers, updated and maintained by INCOSE.

In the course of working towards this goal - which is reported elsewhere - a number of key questions began to be asked: 'how do we differentiate between heuristics and principles?' and 'how should the set of heuristics developed by the Heuristics Team align with SE Principles?'. [The latter were exemplified by those developed by the SE Principles Action Team (SEPAT) under Dr Mike `Watson, and published in May 2019 INCOSE Insight article.]

A small team (so-called Bridge Team) was formed to investigate these issues. It was led Peter Brook with guidance of David Rousseau and additional membership of Mike Pennotti, all of whom are on the panel. The work has resulted in the development of a Conceptual Framework which links Principles and Heuristics and will be presented by each member of the Bridge team from their own perspective. The conclusions reached have implications both for the research agenda and for the future of INCOSE as it seeks to consolidate its foundations.

Biography

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Peter Brook FEng, INCOSE Fellow
Peter is now retired but remains active in professional engineering affairs. He has had a long career in defence and security systems, associated research and project support and audit, holding senior positions, for example as Director of Systems Engineering for DERA. He spent periods on secondment to MOD, most recently as Head of the Integration Authority. He has lectured and published widely in the field of SE, co-authored a standard textbook, and served on the INCOSE Board (1996-99). His current interests include Systems of Systems, in which he delivered a series of NATO lectures, spoken at Ecole Militaire in Paris, and given workshops and tutorials for INCOSE UK. As a consultant in QinetiQ and in a private capacity, he has advised Government Agencies on major projects and SE improvement programmes, and has chaired design reviews for DARPA in UK and US. He was appointed a visiting professor in the Defence Academy and fellow at Loughborough University. He is an active member of the team of INCOSE Fellows developing a set of SE Heuristics and of the Bridge Team, charged with forging a link between heuristics and principles. He is a fellow of the Royal Academy of Engineering.

Position Paper

As Moderator :
There is an enduring theme in the SE community to formulate principles and heuristics that could make the practice and teaching of SE more effective and efficient. We have many

such sets already, and new sets are in development. There are many overlaps and distinctions between them. However, we have no framework for relating them to each other, for assessing their quality, and to determine how comprehensively they cover the range of contexts in which SE operates. This panel will present a series of views on the challenges and opportunities we face in creating such a framework, and invite discussion on how INCOSE members can contribute to developing and refining such a framework and using it to expand, improve and standardize the set of principles and heuristics that good SE can leverage. As 3rd Panellist: We presently have a surfeit of proposals for SE principles and heuristics, and more are being assembled/developed/refined by various teams at present. Any simple survey of the literature easily identifies 300-800 SE principles/heuristics, and this is bad news from the point of view of teaching and practical applications. Clearly, we need a framework that will allow us to condense and assess our current set, to learn which to trust, and ensure our ability curate this knowledge base, making it easy to access and apply appropriately. We do not have such a framework yet, but we can conceive of a number of approaches, based on the range of contexts in which SE operates, and the wider knowledge base. Success would allow us to place SE on a principled, digestible, teachable and consistently actionable footing that recognizably adds value to how engineers address human needs and aspirations, and is capable of evolving as INCOSE transforms itself to address the complex problems increasingly thrown up by the modern world. We also need to better understand how the evolution of our principles drives the evolution of SE's practice, value and purposes, so we can grow the quality and scope of our principles in a way that nurtures the evolution of our discipline.

Michael Pennotti (Stevens Institute of Technology) - Michael.pennotti@stevens.edu

Dr. Michael Pennotti Mike is a Distinguished Service Professor and the former Director of Systems and Software Programs in the School of Systems and Enterprises at Stevens Institute of Technology. His research interests include technical leadership, the intersection of software and systems, and the implications of complexity for systems engineering and architecting. He is an INCOSE Fellow, a senior member of both the IEEE and the American Society for Quality and a cofounder and coach of the INCOSE Institute for Technical Leadership. Mike's industry experience includes systems engineering practice and leadership at Bell Laboratories, and executive positions at AT&T, Lucent Technologies and Avaya. He holds Ph.D. and M.S. degrees in electrical engineering from the Polytechnic Institute of New York, a B.E.E. from Manhattan College and is a graduate of the AEA/Stanford Executive Institute for Technology Executives.

Position Paper

Systems engineering emerged as a recognized discipline in the 1940s in response to the growing complexity of the systems being engineered at the time. In the decades since, it has had to evolve periodically to keep pace with continually increasing system complexity. From its origins as simply the application of systems thinking to engineering, formal processes were developed to describe how systems engineering is to be practiced, and as system complexity continued to increase, so too did the complexity of the processes. And when processes proved inadequate to handle the most complex problems, principles and heuristics were identified to guide practitioners in applying them. Today's challenges present us with the need for another such transformation.

In response, INCOSE and others have launched a number of initiatives to better understand and relate the principles that underlie our discipline. To establish a framework for these efforts, we have developed formal definitions for principles and heuristics, identified a variety of sources from which they have been and can be derived, traced their historical evolution and established the relationships between them. These efforts provide a firm foundation for developing improved systems engineering approaches to match our future needs.

David Rousseau (Centre for Systems Philosophy) - david.rousseau@systemsphilosophy.org

Dr David Rousseau, PhD BEng FRSA David is the Director of the Centre for Systems Philosophy in the UK, and a Research Associate in the College of Engineering in Oregon State University. He is the Chair of the INCOSE project "Scientific Foundations for SE" (SF4SE), which is part of INCOSE's "Future of SE" (FuSE) programme. He is a Past President of the International Society for the Systems Sciences (ISSS), the current Chair of their Board of Trustees, a member of the Scientific Council of the Bertalanffy Center for the Study of Systems Science in Vienna, Austria, and a Visiting Fellow in the Centre for Systems Studies in the University of Hull in the UK. His research is focused on applying Systems Philosophy to advance General Systems Theory (GST), and on developing methods based on Systems Philosophy and GST to analyze complex adaptive systems in nature and to support the engineering of elegant systems.

Position Paper

Large numbers of principles relevant to SE have been or are being collated. This is important for capturing key SE insights, but it creates problems for assessing their relevance, comprehensiveness and adequacy. To manage this problem, while increasing the leverage we can gain from our principles and heuristics, we need frameworks to help us:

classify kinds of principles in ways that would help us assess whether we have sufficient and adequate principles for each of the roles they could fulfil;

identify and learn from each of the sources from which we can draw principles;

identify the kinds of principles that are unique to SE's approach, that gives SE its special value as an engineering discipline, so we can appropriately nurture SE's evolution as a discipline distinct from other kinds of engineering; and

identify routes and means towards expanding and refining SE's core principles so that SE can sustain its ability to deliver distinctive value in the face of rising complexity.

Panel#8

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

Gan Wang (BAE Systems) - gan.wang@baesystems.com
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Peter Brook (Dashwood Systems Engineering) - peterbrook47@gmail.com
Dorothy McKinney (Advanced Systems Thinking, Inc.) - dorothy.mckinney@icloud.com
Sarah Sheard (Carnegie Mellon University (retired)) - sarah.sheard@gmail.com
Chandru Mirchandani (Leidos) - Chandru.mirchandani@gmail.com
Scott Jackson (Burnham Systems Research) - jackson@burnhamsystems.net

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Presented on: Monday, 15:10-16:35

Keywords. Heuristics;Principles;Guidance

Topics. 1. Academia (curricula, course life cycle, etc.); 1.1. Complexity; 17. Sustainment (legacy systems, re-engineering, etc.); 20. Industry 4.0 & Society 5.0; 3.7. Project Planning, Project Assessment, and/or Project Control; 5.9. Teaching and Training;

Abstract. INCOSE asked a group of Fellows to undertake an effort to identify heuristics useful in systems engineering today. In the current century, as systems and their cultural, political and social environments have become more complex, it is not immediately obvious whether heuristics used to guide systems engineering efforts in the past century are useful for our newer challenges, from complex systems to systems-of-systems to mission engineering. This panel shares a variety of viewpoints on this question, addressing insights and nuances which make the difference between a heuristic which is useful and one which may actually be dangerous to apply.

Biography

Peter Brook (Dashwood Systems Engineering) - peterbrook47@gmail.com
Peter is retired but remains active in professional engineering affairs, as a fellow of the Royal Academy of Engineering and INCOSE. He has had a long career in defence and security systems, associated research and project support and audit, holding a number of senior positions, including Director of Systems Engineering for the 9000-strong Defence Evaluation and Research Agency. He has spent periods on secondment to MOD, most recently as Head of the Integration Authority, responsible for establishing corporate capability to integrate systems in a networked environment. He has lectured and published widely in the field of SE, co-authored a standard textbook, and served on the INCOSE Board (1996-2000). His current interests include Systems of Systems, in which he delivered a series of NATO lectures, and at Ecole Militaire in Paris. He has advised Government Agencies on Projects and SE improvement programmes, and chaired design reviews for DARPA in UK and US. He was appointed a visiting professor in the Defence Academy and fellow at Loughborough University. He is an active member of the team of INCOSE Fellows developing a set of SE Heuristics and chairs the Bridge Team, charged with building a link between heuristics and SE principles, and the subject of another Panel session.

Position Paper

SE Heuristics represent the collective wisdom of the profession on how to undertake Systems Engineering – recorded in the knowledge base, for example books and on-line resources. In previous eras, before the emergence of relevant sciences, heuristics were the only way of passing expertise from one generation to another, which was done informally by rules of thumb

Modern interest in the subject stems from the work of Rechtin and Maier in the 1990s. They identified two contexts for their use, encapsulated in the following definitions:

“A Heuristic is a guideline for the conduct of systems engineering [architecting in the original]; lessons learned expressed as a guideline; a natural language abstraction of experience.”, and

“Heuristics ... are trusted, nonanalytic guidelines for treating inherently unbounded, ill-structured

problems. They are used as aids to decision-making, value judgments and assessments.” The first definition fits well with their use in encapsulating what we have learned about Traditional Systems Engineering, and the second applies to how Systems Engineering is coping with the more challenging 21st Century systems.

The boundaries between the two types of systems will be discussed along with examples of heuristics relevant to both types. The point will be made that we are now on a position not unlike that of our predecessors where we are building systems which outstrip our ability to reliably predict their performance.

Dorothy McKinney (Advanced Systems Thinking, Inc.) - dorothy.mckinney@icloud.com

Dorothy McKinney is the Director of Advanced Systems Thinking, a systems engineering consulting company founded in 2020. Previously, she was founder and CEO of ConsideredThoughtfully, a dot com start-up. Prior to that, she spent 34 years with Lockheed Martin and heritage companies, retiring as Fellow Emeritus. Other previous employment included ARGOSystems, a Boeing subsidiary, and Stanford Research Institute. In parallel, she spent 15 years as an adjunct professor at San Jose State University in California and Portland State University in Oregon.

Position Paper

Heuristics have been used for centuries to encapsulate wisdom gleaned from experience. In the last century, systems engineering authors notably including Maier and Rechtin collected and shared dozens of heuristics. In the current century, as systems and their cultural, political and social environments have become more complex, and the constraints on system designs have grown, questions have been raised about the applicability of heuristics developed in the past to today's systems engineering. INCOSE asked the Fellows to undertake an effort to identify heuristics useful in systems engineering today. The team working on this effort has a variety of views of whether heuristics from the past are applicable today, and when and how heuristics can best be used – as well as when they can be harmful. This panel discussion brings those various points of view to the INCOSE Symposium audience. There is no “silver bullet” in systems engineering, but there are different kinds of ammunition for different targets; perhaps heuristics can help systems engineers distinguish between these differences, and match the means to the appropriate need, at least in some cases.

Sarah Sheard (Carnegie Mellon University (retired)) - sarah.sheard@gmail.com

Sarah Sheard is an INCOSE Fellow, CSEP, and Founder's Award winner. An INCOSE member since 1992, she chairs INCOSE's SaSIWG. Her many systems engineering publications include 3 INCOSE “Best Papers.” When she retired in 2019, Dr. Sheard was a systems and software engineering researcher and consultant at CMU's Software Engineering Institute. Previously she worked at the Systems and Software Consortium, at Loral/IBM Federal Systems, and at Hughes Aircraft Company. She earned her 2012 PhD, which examined system development complexity, at the Stevens Institute of Technology. During this pandemic, she is postponing international travel and doing folk dancing by Zoom with her husband.

Position Paper

Twentieth-century heuristics, mostly systems architecting heuristics, captured good principles that helped engineers think about the multiple factors that would be needed in designing complex systems that would work in ever-evolving environments. We began this project assuming that the increasing complexity of today's systems, systems of systems, software-intensive systems, and their increasingly complex environments would mean that 20th century heuristics would no longer apply very well, we would need to come up with improved heuristics for these 21st century complex systems. However, during the effort I have come to the opposite conclusion. For the most part, the heuristics, particularly the best-vetted heuristics such as the Rechtin and Maier heuristics, are already geared toward ultra-reliability complex systems in complex environments.

There are a few improvements I have suggested that come out of complex systems theory, but these new heuristics have not been vetted as thoroughly as the best-vetted 20th century heuristics.

Chandru Mirchandani (Leidos) - Chandru.mirchandani@gmail.com

Chandru Mirchandani has a ME in Electrical Engineering from Rensselaer Polytechnic Institute; a MS in Reliability & Systems Engineering from University of Maryland and a PhD in Systems Engineering from George Washington University. He has worked in the research and development of integrated circuits and devices at Hewlett-Packard. Over 30 years as a Senior Staff Engineer (Lockheed Martin and heritage companies) in the research, development, design and integration of VLSI-based telemetry systems at NASA Goddard Space Flight Center. Lead System Engineer and Architect on conceptual designs and concepts for Advanced Traffic Management Systems and Intelligent Vehicle Highway Systems. Awarded a Fulbright Specialist Grant 2012, taught Risk Management in Large Scale Systems at the University of Sri Lanka. Currently, with Leidos, as a Qualified System Architect, Principal System Engineering Lead in Reliability, Maintainability and Availability Engineer, and SME in the Digital Engineering Center of Excellence. Concurrently, an Adjunct Professor at George Washington University teaching System Engineering for the past 10 years. Interests include research, design and model development of complex systems based on reliability, performance and cost; fault-tolerant systems; Bayesian processes and decision theory.

Position Paper

Heuristics can be dangerous – there are times they should not be used. Significant hurdles remain for

exploring, developing and designing systems to meet the challenges presented in the 21st century. For example, 'beyond visual line of sight' (BVLOS) operations in Unmanned Aircraft Systems (UAS) to ensure safe operation in a complex environment involving other aircraft and various types of airspace need to piggy-back on analogous behavior in existing systems. Additionally, the infusion of complex sensor technologies to detect and avoid in autonomous automobiles and the first generation of military drones levies the need to provide guidelines and perhaps the do's, but most definitely the don'ts. Our contention, my contention, is to pose the question "where can these heuristics be applied with efficacy; and where should they definitely not be used'. It may be possible to develop infrastructures that support a general class of systems, i.e. the ability to sense, monitor and record behavior. However, the depth and accuracy of these system processes and entities will differ from domain to domain and the system objective. The heuristics will provide the guidelines to evaluate the cost, extensibility, resilience and security aspects of this approach and most importantly identify elements that need further investigation and research, and the applicability and constraints.

Scott Jackson (Burnham Systems Research) - jackson@burnhamsystems.net

Dr. Jackson is an INCOSE Fellow and has written four books on systems engineering and architecting. He was a lecturer in systems engineering and architecting at the University of Southern California for 10 years following 40-plus years as a senior systems engineer at Boeing. His selection as INCOSE Fellow was based primarily on his publications on the application of systems engineering to the design of commercial aircraft. He is currently Associate Professor of Engineering Management and Systems Engineering at the Missouri University of Science and Technology (MST). His prior research and publications focused on the evaluation of the principles of resilience which form the basis of the heuristics to be discussed in this presentation. His book *Architecting Resilient Systems* (Wiley, 2010) documents these principles. Since publication, the principles have been presented in many forums and have withstood the test of time and have not been challenged or contradicted. This validates their use as heuristics. Dr. Jackson is also a member of the International Society for the Science of Systems (ISSS). He has also written chapters in seven books on systems engineering and systems architecting. Another specialty area in which Dr. Jackson has written multiple papers is irrationality in decision making.

Position Paper

The focus of Dr. Jackson's presentation is the set of heuristics that have been shown to enhance the resilience of engineered systems. To accomplish this, Dr. Jackson presents three primary heuristics that are derived from the principles that have been shown to be essential for achieving resilience in an engineered system. These principles are: (1) the functional redundancy principle, (2) the human in the loop principle, and (3) the restructuring principle. The case studies presented by Dr. Jackson that validate these principles, and hence the associated heuristics, are (in order) (1) US Airways Flight 1549, also called the Miracle on the Hudson, (2) Apollo 11, and (3) Apollo 13. The functional redundancy heuristic calls for a secondary but less capable response to any adversity. The US Airways Flight 1549 qualifies as a functional redundancy heuristic because the aircraft relied on a backup system to control the aircraft. The human in the loop heuristic calls for the use of human cognition when it is needed. Apollo 11 qualifies as a human in the loop heuristic because the operator Neil Armstrong landed the lunar module manually when the system computer overloaded. The restructuring heuristic calls for the restructuring of the system to allow it to adapt to the adversity. Apollo 13 qualifies as a restructuring heuristic because the crew used alternative system components to control the space craft. Dr. Jackson also presents two heuristics he calls counter-heuristics. These are heuristics that when incorrectly interpreted may lead to a system failure, or at least to a decline in the likelihood to achieve system success. These are (1) the customer is always right heuristic and (2) the boss is always right heuristic. Dr. Jackson suggests that the reason these heuristics are potentially detrimental is that they are widely believed to be literally true even though they have inherent vulnerabilities. The potential vulnerability of both heuristics is that either the customer or the boss may not understand the potential weaknesses in their desires. These heuristics imply that an understanding by customers and management is essential for system success.

Human-AI Teaming: A Human Systems Integration Perspective

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Michael Boardman (Ministry of Defence) - MJBOARDMAN@mail.dstl.gov.uk

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Mica R. Endsley (SA Technologies) - mica@satechnologies.com

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Presented on: Thursday, 08:30-09:55

Keywords. Human-Autonomy Teaming;Artificial Intelligence;Human Systems Integration;Flexibility in Design and Operations;Fourth Industrial Revolution;Safety;Efficiency;Comfort;Resilience;Organization Design and Management;Complexity Analysis and Management;Virtual Human Centered Design

Topics. 1.1. Complexity; 1.5. Oil and Gas; 2. Aerospace; 3. Automotive; 4.1. Human-Systems Integration; 4.4. Resilience; 4.6. System Safety; 6. Defense;

Abstract. How can humans and machines driven by artificial intelligence (AI) become partners? What are the principles of future human-AI systems? Human Systems Integration (HSI) currently investigates the evolution of human roles, responsibilities and capabilities within our growing digital world. Complexity and interconnectivity are increasing exponentially. How technology, organizations and human activities can be designed and developed for improved safety, security, efficiency, resilience and comfort? How maturity of organizations for the fourth industrial revolution can support these issues? Autonomy and flexibility have become real issues, not only on machine side, but also foremost on human side. The concept of virtual assistant makes emerge several crucial issues such as trust, collaboration and control. Panelist will discuss these interdependent topics toward a possible synthesis.

Biography

Guy Andre Boy (CentraleSupélec (Paris Saclay University) & ESTIA Institute of Technology) -

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Guy A. Boy is FlexTech Chair Institute Professor at CentraleSupélec (Paris Saclay University) and Chair of ESTIA Science Board, Fellow of the Air and Space Academy and Chair of the Human-Systems Integration Working Group of International Council on Systems Engineering (INCOSE). He was University Professor and Dean, Human-Centered Design Institute and HCD Ph.D. & Master's Programs at the Florida Institute of Technology (2009-2017), and a Senior Research Scientist at the Florida Institute for Human and Machine Cognition (IHMC). He was Chief Scientist for Human-Centered Design at NASA Kennedy Space Center (2010-2016). He was member of the Scientific Committee of the SESAR program (Single European Sky for Air Traffic Management Research) from 2013 to 2016. He was Chair of 2012 ISU (International Space University) SSP (Space Studies Program) FIT/NASA-KSC local organizing committee. He was President and Chief Scientist of the European Institute of Cognitive Sciences and Engineering (EURISCO, a research institute of Airbus and Thales). He co-founded EURISCO in 1992, and managed it since its creation to its closing in 2008. He is a senior member of the ACM-Association for Computing Machinery (Executive Vice-Chair of ACM-SIGCHI 1995-1999) and Chair of the Aerospace Technical Committee of IEA (International Ergonomics Association).

Position Paper

Human-AI teaming is a drastic evolution of human-automation cooperation: could we go from automation rigidity to flexible autonomy

Automation brought safety, efficiency and comfort benefits and issues for the last five decades. It also introduced rigidity, especially in emergency and unexpected situations. In such situations, procedure following, whether performed by people or machines, does not always work properly, and problem solving is at stake. Does artificial intelligence (AI) help in such situations? How people and AI systems could work together to bring correct solutions in such situations? More generally, how could people trust and collaborate with AI systems? The issue of autonomy relies on competence, skills and availability when needed. Could AI bring more autonomy to people in emergency and unexpected situations? In such situations, flexibility is required to handle uncertainty and even the unknown. Human systems integration

focuses on function allocation among people and machines not only in a procedural way, but also in problem-solving way. How can we formulate such function allocation? These questions deserve deeper discussions that I propose to entertain during the panel.

Nancy Cooke (Arizona State University) - Nancy.Cooke@asu.edu

Nancy J. Cooke is a professor of Human Systems Engineering at Arizona State University and directs ASU's Center for Human, AI, and Robot Teaming. She received her PhD in Cognitive Psychology from New Mexico State University in 1987. Dr. Cooke is a past President of the Human Factors and Ergonomics and recently chaired a study panel for the National Academies on the Enhancing the Effectiveness of Team Science. Dr. Cooke was a member of the US Air Force Scientific Advisory board from 2008-2012. Dr. Cooke's research interests include the study of individual and team cognition and its application to the development of cognitive and knowledge engineering methodologies, human-AI-robot teaming, cyber security, intelligence analysis, remotely-piloted aircraft systems, healthcare systems, and emergency response systems. Dr. Cooke specializes in the development, application, and evaluation of methodologies to elicit and assess individual and team cognition. Her work is funded primarily by DoD.

Position Paper

Artificial intelligence could be to assist in putting the right teammates together

A team is a heterogeneous group of individuals that are interdependent and that come together to work toward a common goal. This holds for human-machine teams as well. Therefore, a team is a small system and can be imbedded in a larger system of multiple teams and organizations that make up a complex sociotechnical system. Human Systems Integration (HSI) is well positioned to assess, model, and intervene in such systems. However, as system size and complexity increases there is need for assistance. One role of artificial intelligence could be to assist in putting the right teammates together for a given task, developing the team, and coordinating team process.

Michael Boardman (Ministry of Defence) - MJBOARDMAN@mail.dstl.gov.uk

Michael Boardman is a Principal Ergonomist within the UK Defence Science and Technology Laboratory (Dstl) Human and Social Sciences Group. He graduated in 1999 from the University of Birmingham with a BEng in Mechanical Engineering and in 2000 with an MSc in Work Design and Ergonomics. His career to date has included commercial consultancy, applied research, support to operations, acquisition project support, systems engineering, and the development of Defence, British and International Standards. In his current role he provides Science and Technology (S&T) advice to the UK MOD research programme in the fields of: Ergonomics, Human Machine Interaction, Human Machine Teaming, Human Centred Design and Human Factors/Systems Integration within capability acquisition. Michael's current research interests include Human Machine Teaming and Adaptive Autonomy, the application of human factors within systems engineering and novel human centred design approaches.

Position Paper

Creating Shared SA in Human-AI Teams: A Fundamental Basis for Effective Teaming

How can effective human-AI teams be created and developed? Human AI teams are currently limited by poor shared situation awareness (SSA) that undermines the ability of the team to effectively coordinate and collaborate. SSA is fundamental to supporting coordinated actions across multiple parties who are involved in achieving the same goal and who have inter-related functions. It is needed to ensure goal alignment in the human-AI team; support dynamic function allocation, with flexible levels of autonomy, as relative capabilities and states change; ensure the alignment of strategies, plans and actions across the team; and to be coordinated on interdependent tasks. Future AI systems will need the ability to develop accurate computational models of the world, and to support human understanding of that model through improved transparency, as well as facilities for supporting effective team behaviors. Methods for supporting SSA in future human-AI teams to improve their safety, efficiency and resiliency will be discussed.

Avigdor Zonnenshain (TECHNION) - avigdorz100@gmail.com

Dr. Avigdor Zonnenshain is currently the Senior Research Fellow at The Gordon Center for Systems Engineering and at the Neaman Institute for National Policies Research at the Technion, Haifa, Israel. He has a Ph.D. in Systems Engineering from the University of Arizona, Tucson, USA. Formerly, He held several major positions in the quality, reliability and systems engineering areas in RAFAEL & in the Prime Minister's Office. He is an active member of the Israel Society for Quality (ISQ). He was also the Chairman of the Standardization Committee for Management & Quality in the Standardization Institute of Israel. He is a Senior Adjunct Lecturer at the Technion-Israel Institute of Technology. He was a member of the Board of Directors of the University of Haifa. He is an active member of INCOSE & INCOSE_IL (past president). He is a Fellow of INCOSE.

Position Paper

How the maturity of organizations for the fourth industrial revolution can support AI-Human Teaming?

In the last decade, industries in advanced economies have been experiencing significant changes in engineering and manufacturing practices, processes, and technologies. These changes have created a resurgence in engineering and manufacturing activities. This phenomenon is often referred to as the Fourth Industrial Revolution or Industry 4.0. It is based on advanced manufacturing and engineering technologies, such as massive digitization, big data analytics, advanced robotics and adaptive automation, additive and precision manufacturing (e.g., 3-D printing), modelling and simulation, artificial intelligence,

and the nano-engineering of materials. This revolution presents challenges and opportunities for the organizations and companies in effectively implementing these innovative technologies and processes. Based on our studies there is a way to assess the maturity of the organizations for the 4th industrial revolution by evaluating several capabilities of the organizations. We will discuss during the panel the following questions: (1) How to assess the maturity of the organizations for the 4th Industrial revolution? (2) How this maturity supports the implementing of HSI approach? (3) Which organizational capabilities are needed for implementing AI-Human teaming?

Ido Lev-Ran (RAFAEL) - idolevran@gmail.com

Ido Lev-ran is Head of RAFAEL human factors department. He has over 15 years of experience in designing interfaces for highly complex systems. His academic background includes B.A. in Psychology & Communication and M.Sc. in human factors engineering with research in learning and decision making. His main areas of interest are human factors for complex systems with advanced technologies. Last and not least, he is married to Shir and they have three wonderful kids and a lovely Shih Tzu dog, and they all reside in the wonderful city of Haifa.

Position Paper

Integrated Systems of People with AI

It is well established that Artificial intelligence (AI) technologies have the potential to dramatically disrupt markets and economies but also to design processes of systems and jobs. But it seems that technologically (and some may add also culturally), this vision of ubiquitous and flawless AI is still many years off. As a result, in the coming years, we'll see more systems where humans and AI work as a team, each bringing to the table his strengths. Such "symbiotic" teams (as head of DARPA in the 60s J.C.R. Licklider coined) have the potential to produce breakthroughs. But undoubtedly, team collaboration produces significant human factors challenges. In my part in the panel, I will focus on these challenges and share first thoughts and insights on designing optimal human-AI teams in a user-centric approach.

Mica R. Endsley (SA Technologies) - mica@satechnologies.com

Mica Endsley is President of SA Technologies and is the former Chief Scientist for the US Air Force. She has also held the positions of Visiting Associate Professor at MIT in the Department of Aeronautics and Astronautics and Associate Professor of Industrial Engineering at Texas Tech University. She was formerly an Engineering Specialist at the Northrop Corporation. Dr. Endsley is a Fellow and Past-President of the Human Factors and Ergonomics Society. She received a Ph.D. in Industrial and Systems Engineering from the University of Southern California. Dr. Endsley is a recognized world leader in the design, development and evaluation of systems to support human situation awareness (SA) and decision-making, and the integration of humans and automation. She has authored over 200 scientific articles and is the co-author of Analysis and Measurement of Situation Awareness and Designing for Situation Awareness.

Position Paper

Effective integration of humans and artificial intelligence

Future operating environments are likely to require the effective integration of humans and artificial intelligence (AI) enabled systems within decision-making processes. As these AI-based systems are adopted it will become increasingly important to ensure that appropriate human control is maintained for big data analytics and decision support systems. Meaningful human control (MHC) can be described as the ability to make timely, informed choices to influence AI-based systems that enable the best possible operational outcomes. There are a number of factors contributing to MHC including freedom of choice and sufficient human understanding of the situation and system. We should discuss the importance of maintaining human control within military, AI enabled systems.

Panel#9

Investigating transdisciplinary systems approaches for health care access

Leonard Bruce - lfbruce@asu.edu

Shamsnaz Bhada (Worcester Polytechnic Institute) - shamsv@gmail.com

Alex Agloro (Arizona State University) - alex.agloro@gmail.com

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Presented on: Wednesday, 15:10-16:35

Keywords. Health Care Access;Accelerating through Adversity;Transdisciplinary Approaches;MBSE

Topics. 22. Social/Sociotechnical and Economic Systems; 4. Biomed/Healthcare/Social Services; 4.1. Human-Systems Integration; 5.10. Diversity (cultural boundaries, diverse engineering teams, training underserved groups, etc.);

Abstract. Diversity of health access remains the frontline for collective public health outcomes especially during the Pandemic of 2020. The challenges include from access to telehealth, to lack of testing, to lack of data reporting allocating resource allocation and lack of medical professionals. Some countries such as Norway are doing a better job than USA to combat these crises. This problem screams to implement a transdisciplinary approach that can be customized to rise to the global public health challenge. Such transdisciplinary approach may include variables from social sciences, technology and culture, policy studies and systems engineering.

In this panel we will discuss issues impacting health care access from viewpoints of systems engineer, cultural technologist, social scientist and data scientist addressing themes such as rural broadband access, diversity of data allocation, policy modelling and other social issues. The panel will then discuss the amalgamation of ideas that can be cultivated to improve the health care access and public health outcome globally.

Biography

Leonard Bruce - lfbruce@asu.edu

Leonard Bruce is a member of the Gila River Indian Community of Arizona and a PhD student in the Human and Social Dimensions of Science & Technology program at Arizona State University. His work focused around his ancestral homelands at Gila River, and he's also interested in other indigenous spaces on the urban periphery. He's been delving into a lot of work around decolonizing employment, increasing Stueti is the co-founder and director of BlueKei Solutions with 12+ years of experience. She has led systems Engineering research and practices in the area of system dynamics modeling and simulation, system architecture analysis. Stueti studied Mechanical Engineering at BITS Pilani, Cornell University and also received formal certification in Systems Design and Management from Massachusetts Institute of Technology, USA. She has few publications in this area. Stueti was the immediate Past President of SWE Pune Affiliate. She is currently the President of International Council on Systems Engineering India Chaptersocial and economic mobility, and trying to find ways that indigenous nations can build social and economic resilience to the threats posed by increased automation and decreased worker power.

Position Paper

The Covid-19 Pandemic has been exceptionally damaging to Native American communities. Tribal governments have been working to contain Covid-19 with little federal support or funding while also facing massive economic uncertainty and near non-existent revenue. The health impacts of COVID have also disproportionately affected Native Americans. Native Americans face 5x the number of hospitalizations and 1.4x the number of deaths than their white counterparts.

The challenges created by the pandemic for on-reservation Native American people and their governments are also exacerbated by a low rate of broadband access, low data sovereignty, low or non-existent public health capacity, and pre-existing social issues.

The challenges facing Native Americans are similar to those faced by indigenous people all over the world and by many rural communities in the United States. Moving forward there is an opportunity for growth and policy changes that could help these communities weather the pandemic and build back better during COVID recovery.

In the summer of 2016 the UN declared through resolution that it considered the internet as a human right. The consequences of low or unreliable connectivity have been amplified during the pandemic. Many communities lost the ability to work, to socialize, to visit a doctor, and to receive important news and updates. The new methods of communicating and socializing have the internet at its foundation, and the shift may be here to stay. Conversations around the future after the pandemic also stress the need to have a reliable internet connection – society is not expected to return to “normal” for years, if ever. Data Sovereignty is also an important factor in fighting the pandemic and having the ability to advocate for change. In the United States there have been numerous misinformation campaigns to downplay the dangers and impacts of the pandemic. These campaigns were especially damaging to Native American communities who typically have little capacity to collect and analyze their own local data. This was especially true for the public health context. Many Native American communities (and rural communities) do not have high capacity and well-funded public health programs. A well-funded and high capacity public health program will be especially important during the pandemic and moving forward into the recovery period. Stopping the spread of the virus is made easier when local data is gathered and used to drive locally relevant policies.

Many pre-existing social issues also enhanced the impact of the pandemic for Native Americans. Many people and tribal communities already faced high poverty rates, low employment and labor force participation. Many were in low paying jobs that were not eligible for remote work, or in the occupations most affected by the pandemic such as leisure and hospitality, construction, education, and non-essential medical practices. The loss of income, the loss of housing, and the disruption to educational attainment will further damage communities that were already struggling.

This position seeks to explore these background issues and propose policy solutions that are relevant for

the Native American context, but can be used in a variety of indigenous communities.

Shamsnaz Bhada (Worcester Polytechnic Institute) - shamsv@gmail.com

Dr. Shamsnaz Virani Bhada; Assistant Professor of Systems Engineering at Worcester Polytechnic Institute, earned her Ph.D. in Industrial and Systems Engineering from The University of Alabama at Huntsville. Dr. Bhada's research interests include Policy Content Modeling and Human Diversity in Engineering. She serves as Empowering Women as Leaders in Systems Engineering (EWLSE) Lead for New Faculty Support for systems engineering faculty and PhD students. She is dedicated to increasing women and minority population in Engineering

Position Paper

Physical, digital and power connectivity equals access during the pandemic year of 2020. Access to healthcare, access to education and access to information. The Socio-technical issues such as digital divide are even more pronounced in rural United States than some of the developing nations. There is research in the areas of better equipment, or better data science or better community but there is no research at the intersection of public policy, community and complex engineered systems resulting in unsuccessful solutions

The underlying conflict between policy makers, complex system implementers and citizens have arisen due to lack of easily understandable and customized information rooted in factual content and not embellished, incomplete and inconsistent versions seen and heard by all stakeholders. Policy Content Model is inspired by Systems Architecture work used for successful complex system development and delivery by Department of Defense. I will discuss my research which not only uses the systems research but also social studies, economic analysis, data science to develop a trustworthy, independent source for policy development, debate, and deployment

Alex Agloro (Arizona State University) - alex.agloro@gmail.com

Alexandrina Agloro is a cultural technologist, community-based researcher, and doula who believes in the possibilities of the decolonial imaginary using ancestral technologies as liberatory tools. She is an Assistant Professor of Science, Technology, and Innovation in the Borderlands at the School for the Future of Innovation in Society at Arizona State University. Alexandrina utilizes principles of self-determination and relevant education in her teaching and research. She teaches at university and high school levels and specializes in interactive media skill building with young people of color. She is a Director of Situated Critical Race and Media (SCRAM), a multi-university collaborative feminist technology organization. She is the Futurist for the Latinx Pacific Archive. As a community-based researcher and participatory designer, her speculative work is anchored in lived experience. Alexandrina uses critical pedagogy and community-based research as platforms to work with institutions, community organizations, birthworkers, researchers, and artists. Her research addresses connections between reproductive justice; land, water, and internet sovereignty; and interactive media. Her research has received funding from the Ford Foundation, the National Science Foundation, the Andrew W. Mellon Foundation-John E. Sawyer Seminars, the Teagle Foundation, the Rhode Island Council of the Humanities, and the Voqal Fund.

Position Paper

Our research investigates technology usage in a community of birthworkers in Long Beach, CA imagining how smart technologies could improve the collection, quality and accuracy of data that is collected through the Los Angeles Mommy and Baby (LAMB) survey. This survey critically influences strategies addressing perinatal issues faced by different LA communities.

The LAMB survey is the only survey in Los Angeles County related to birthing outcomes, and its data influences the allocation of resources and informs strategies aimed at ameliorating perinatal issues including infant mortality, low birth weight, and preterm births. Unfortunately, the current survey results are more than two years out of date and fail to capture data from vulnerable populations, specifically, the African American population of Long Beach. We suspected that the method used to administer the survey - mailed paper survey packets and reminder postcards - may contribute to these dysfunctions. For example, it is likely that the time-consuming nature of manual data entry, required when survey results are collected via paper surveys, significantly reduces the pace that data can be turned around and increases the odds of inaccuracy from human error.

In addition to improving efficiency, our research examined how to improve the survey data capture for vulnerable populations. In partnership with Birthworkers of Color Collective, we explored how technology can aid in reaching African American birthing people in Long Beach, one of the most underreported demographics in LA County. The LAMB survey has only captured data from 6.8% of the 13.1% African American live births in Long Beach. This is in comparison to data capture from 18.6% of the 19.2% white live births was recorded. A result of this discrepancy is an underinvestment of infant support resources for the African American population in Long Beach and across LA County. A possible explanation for the low data collection rate is the reality of housing insecurity within the African American population in LA County. Data shows that while 9% of LA County is Black, they comprise 40% of people experiencing homelessness. This correlation, that Black new parents experience a higher level of housing insecurity, suggests that the LAMB surveys may not be able to arrive at a home address because a stable address where a survey could be mailed may not be possible. Our community partner, the doula network of BCC, primarily serves birthing people of color in Long Beach and are often the first line of contact with this underreported demographic. While conducting postpartum visits, we envisioned how a doula equipped

with smart survey technology could administer the survey and submit answers immediately. While paper mail may not be able to find a person with housing insecurity, a technology-equipped doula will already be in contact with the birthing person and know where the new parent is. If the technology can be designed to work for the most critical population, this technology has the potential to work for all birthworker-assisted births in LA County

Panel#7

Solving the Digital Engineering Information Exchange Challenge

Terri Chan (Boeing Commercial Airplanes) - chante82@gmail.com
Philomena Zimmerman (US DoD) - Philomena.m.zimmerman.civ@mail.mil
Celia Tseng (Raytheon) - celiastseng@gmail.com
Sean McGervey (John Hopkins University Applied Physics Laboratory) - Sean.McGervey@jhuapl.edu
Tamara Hambrick (Northrop Grumman) - Tamara.Hambrick@ngc.com

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Presented on: Tuesday, 15:10-16:35

Keywords. Digital Engineering;MBSE;Industry 4.0;Acquisition and/or Supply;System Science

Topics. 1.5. Systems Science; 20. Industry 4.0 & Society 5.0; 3.1. Acquisition and/or Supply; 5.3. MBSE & Digital Engineering; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. As more organizations and disciplines move toward a model-based engineering (MBE) approach, there is a growing need to share, cross-reference, integrate, reuse, and extend models to digitally represent a total system model. Industries and governments have a long history of using a document-based engineering exchange approach; they must now convert to model-based digital artifacts with their currently disjointed use of models. This panel discussion will focus on the challenges of digital artifact exchange, and key concepts and steps to facilitate exchange between disciplines and stakeholders throughout the engineering lifecycle.

Biography

Terri Chan (Boeing Commercial Airplanes) - chante82@gmail.com
Terri is a Sr. Systems Engineer in the Boeing Commercial Airplane Product Development organization, focusing on Architecture Integration across the lifecycle with dynamic functional modeling. She has over twenty years of experience, beginning at JPL on the Cassini: Mission to Saturn program and future network architecture integrator of the Air Force Satellite Control Network. Terri has worked across the product lifecycle on military programs from conceptual design through integration/testing and operations. She has also consulted executive leadership as a competitive intelligence analyst, where the benchmarking of model capabilities for the enterprise played a pivotal role in the current MBE transformation strategy.

Position Paper

Terri Chan is the moderator. Terri works on the commercial side of the Aerospace and Defense Industry, bringing an operation and sustainment perspective rather than product development.

Philomena Zimmerman (US DoD) - Philomena.m.zimmerman.civ@mail.mil

Ms. Philomena (Phil) Zimmerman is the Director for Engineering Tools and Environments within the Department of Defense Office of the Deputy Director for Engineering. Her portfolio includes Digital Engineering, Engineering Infrastructure, Chief Information Officer collaboration, and model and simulation technical leadership. She supports elements of the Office of the Under Secretary of Defense for Research and Engineering (OUSD(R&E)) related to policy, practice, and workforce development, as well as the R&E use of digital practices. She has a bachelor of science in Mathematics from St. John Fisher College, with an emphasis in Computer Science from Rochester Institute of Technology. She is DAWIA Level 3 certified in Engineering and Test and Evaluation.

Position Paper

Phil Zimmerman presents the challenges in implementing Digital Information Exchange from a Acquisition point of view (DoD).

Celia Tseng (Raytheon) - celiastseng@gmail.com

Celia is a systems engineer with 16 years of experience in missile defense, radar systems and command and control systems. She has a masters degree in systems engineering from Cornell University (2004) and is a certified systems engineering professional (INCOSE CSEP), certified system modeling professional (OMG OCSMP), and certified agile scrum master (SAFe). Celia had experience throughout the development lifecycle in the capacity of system qualification lead, system IPT lead, systems modeling lead, and cost account manager. Celia is also co-chair of the joint INCOSE/ NDIA Digital Engineering Information Exchange Working group and work across industries on MBSE adoption best practices. She is currently a systems engineer in Raytheon Technologies.

Position Paper

Celia Tseng discusses the need for standards to enable Digital Engineering Information Exchange. Discuss current applicable standards and gaps.

Sean McGervey (John Hopkins University Applied Physics Laboratory) - Sean.McGervey@jhuapl.edu

Sean McGervey is a Systems Engineer at the Johns Hopkins University Applied Physics Laboratory, where he was Architecture Lead on a Major Defense Acquisition Program (ACAT-1) for the US Navy and is a key contributor to efforts supporting the Digital Engineering Transformation of APL's DoD Sponsors. Sean founded and leads the APL MBSE Community of Practice, teaches three courses in MBSE at APL, and teaches an "Applied Analytics for MBSE" course for JHU's graduate program in Systems Engineering. Sean is also Chairperson of the INCOSE Digital Engineering Information Exchange Working Group (DEIXWG), a key element of the broader effort to drive forward OSD's Digital Engineering initiative. Prior to joining APL, Sean worked for 15 years in the Systems Engineering Department at Northrop Grumman Mission Systems in Baltimore, Maryland. While there, Sean practiced MBSE on multiple programs and founded the Northrop Grumman Corporate Model-Based Engineering (MBE) Community of Practice.

Position Paper

Sean McGervey addresses the lessons learned from the DEIX challenge, insights and future work. Focus is on stakeholder need analysis for information exchange pain points.

Tamara Hambrick (Northrop Grumman) - Tamara.Hambrick@ngc.com

Tamara Hambrick serves as Systems Engineering Control director within the Systems Engineering and Integration Integrated Product Team of GBSB for the Strategic Deterrent Systems Division of Northrop Grumman Space Systems. In this role, Hambrick is responsible for leading engineers and managers in the implementation of model-based systems engineering for architecture models, integration approach, readiness assessments, and product quality metrics development and monitoring. Hambrick is a leader in driving technical innovation, influencing change and developing the next generation of thought leaders, advocates and practitioners in model based systems engineering for the last 15 years. She has held model-based advisory and IPT leadership roles for radar, open electronic warfare, avionics, cyber, space, and missile defense programs. Hambrick holds a bachelor's degree in engineering science from Pennsylvania State University, as well as a master's certificate in systems engineering from Johns Hopkins University, and a graduate certificate in architecture and systems engineering from Massachusetts Institute of Technology.

Position Paper

Tamara Hambrick discusses the Digital Viewpoint Model as a framework for defining Digital Engineering Information Exchange. Discuss why DE exchange is still a challenge for user and industry.

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

Nick Lombardo (Pacific Northwest National Laboratory) - nick.lombardo@pnnl.gov
Heidi Ann Hahn (New Mexico Tech) - heidi.hahn@nmt.edu
Michael DiMario (Astrum Systems) - mjdimario@outlook.com
Ann Hodges (Sandia National Laboratories) - alhodge@sandia.gov
Frédéric Autran (Airbus Defence & Space) - frederic.autran@airbus.com

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Presented on: Monday, 10:00-11:25

Keywords. Early stage R&D; Early stage R&D frameworks; Systems Engineering in Early Stage R&D; System Engineering Management in Early Stage R&D

Topics. 1. Academia (curricula, course life cycle, etc.); 3.5. Technical Leadership; 3.7. Project Planning, Project Assessment, and/or Project Control; 5.10. Diversity (cultural boundaries, diverse engineering teams, training underserved groups, etc.); 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Early stage R&D (ESR&D) is one of the most crucial phases in the design process. It blends and blurs the lines between science and engineering. Because of the differences in the social context and culture between research and engineering, many scientists, leaders, and program managers resist including systems engineering at this delicate phase, fearful of overburdensome activities that add little or no value for their R&D pursuits. Systems engineering applied in a risk-based, graded approach supports credibility of research results and provides a foundation for further technology maturation. This panel explores principles and frameworks that tailor systems engineering for ESR&D. Common frameworks adopted across technical disciplines reduce risk, increase return on investment, and enhance the opportunities for cross-discipline R&D collaboration which is becoming more critical in contemporary R&D. While all of the frameworks that will be discussed are risk-based, they view the problem space from different perspectives.

Biography

Nick Lombardo (Pacific Northwest National Laboratory) - nick.lombardo@pnnl.gov
Nick Lombardo is a Principle Project Engineer at the Pacific Northwest National Laboratory (PNNL) with over two decades of systems engineering experience. Over his 40-year career, Nick has served as a technical contributor, project and program manager, line manager, key account manager, and commercialization manager. He also served as the Director of Business development for Phytagenics, a biotechnology company he helped co-found targeting the production of therapeutic proteins from plants. Nick had a major leadership role in growing PNNL's systems engineering capability and currently serves as a systems engineering subject matter expert for the National Security Directorate. He led PNNL's effort to formally define a systems engineering framework and developed a risk-based systems engineering tailoring strategy compatible with a R&D-based organization such as PNNL. He helped create and implement an INCOSE certification training program and has developed a number of systems engineering training modules for PNNL staff. Nick is an International Council on Systems Engineering (INCOSE)-Certified Systems Engineering Professional (ESEP) and has served as PNNL's INCOSE Corporate Advisory Board representative and as Secretary for the INCOSE's Cascade Chapter. He has a B.S and M. Eng from Rensselaer Polytechnic Institute.

Position Paper

It is important for an organization to have a framework for executing ESR&D. A framework is a collection of institutional and codified processes, tools, and training that support the repeatable execution of a highly tailored SE process. Development of codified processes relies on having a system lifecycle from which processes can be defined. Life cycles expressed in broad categories (e.g., concept, development, utilization) are less effective for ESR&D given that much of what needs to be addressed falls into the "development" stage. Greater granularity is needed to describe the system lifecycle to successfully implement SE in ESR&D. The concept of maturity levels (technical, manufacturing, etc.) provides additional granularity that can be exploited by ESR&D. Another concept that could provide additional

granularity is the concept of project types. SE activities and artifacts can be defined at each TRL level and for each project type. The question then becomes “What are the right activities?” that should be conducted for each TRL level or project type. Baseline activities can be assessed based on “system development risks” for that particular TRL level and/or project types (a hybrid of both concepts represents a third model and brings the advantage of each to the table). An example of a system development risk is the “strength of requirements,” defined as the level of requirements definition, analysis, and stakeholder approval available to support system development, verification, and validation. Using the TRL model, a system at the proof of concept stage (e.g., TRL 3) should have at a minimum KPPs defined in order to mitigate the strength of requirements risk; for a system approaching a prototype (e.g., TRL 5), the system should have generated documents such as a SRD developed in order to mitigate this risk. Using the project type framework, a project delivering a technology assessment would be expected to use system thinking to guide how the project might address requirements, whereas a technology development project would expect some level of requirements definition and analysis activities to take place. TRLs could be used to differentiate the activities for this type of project.

The concept of technical debt is useful to apply to ESR&D. Technical debt is a concept that reflects the implied cost of additional rework (or delayed work) caused by choosing an easy solution now instead of using a better/more complete approach that would take longer. The premise of ESR&D is that some level of SE technical debt is acceptable given the project’s fiscal, programmatic, technical, and/or technical risks as well as the organization’s risk profile. The art is to get the balance of technical debt right--which is what ESR&D’s mission is all about.

Heidi Ann Hahn (New Mexico Tech) - heidi.hahn@nmt.edu

Dr. Heidi Hahn recently retired from Los Alamos National Laboratory as Senior Executive Advisor to the Associate Laboratory Director for Weapons Engineering Sciences. She had responsibility for engineering capability development including development of processes and tools to promote engineering capability; professional development of R&D engineers and engineering technicians; and engineering capability assessment. Currently, Heidi serves as an adjunct faculty member in Engineering Management Department at New Mexico Tech teaching courses in project management and systems engineering. She holds a Ph. D. in Industrial Engineering and Operations Research (Human Factors Option) from Virginia Tech and is a certified Expert Systems Engineering Professional (ESEP) and a certified Project Management Professional (PMP). Heidi is Past President of the Enchantment Chapter and has served on the chapter’s Board of Directors since 2007. She also serves on INCOSE’s Certification Advisory Group and the PMI/INCOSE/MIT Alliance Team.

Position Paper

Early-Stage Research and Development (ESR&D) is one of the most crucial phases in the product development process. It blends and blurs the lines between science and engineering. It is argued that it requires a risk-based, graded approach to effectively manage scope, cost, and complexity. ESR&D is defined in terms of Technology Readiness Levels (TRLs) between 1 and 5. TRLs 1-2 define basic research and TRLs 3-5 define research to prove application feasibility.

The value proposition for applying systems engineering (SE), including systems engineering management, to the early stages of R&D is that the cost to extract defects rises exponentially throughout a project, increasing three to six times between the concept and design phases but up to a thousand times in the production/test phases (Walden et al. 2015).

This value proposition is unclear to many leaders, program managers, and scientists, who are seemingly unwilling to use SE practices because of the perception that they are heavily process oriented, add unnecessary costs, and should be applied only to mature technologies. One can argue that misapplication of systems engineering principles has led to these negative perceptions of SE for R&D. However, the failure to apply SE in ESR&D results in R&D efforts that may have solved the wrong problem, selected the wrong architecture, required technical rework, has difficulty transitioning to later maturity levels, and results in higher R&D costs, low return on investment, and extended development timelines.

A fundamental difference between R&D and more traditional SE activities depends upon the ability to decompose complex systems into fundamental components having manageable complexity, bounded development costs, and highly predictable completion schedules. Traditional SE then, especially as it is represented in the left side of the V-Model, is a “reductionist” activity, in which the goal is to reduce a “perceived complexity” by establishing shared and valid models of the system (Sillitto et al. 2019).

ESR&D, however, is radically different. Innovation does not happen by reduction processes. Innovation depends upon the creativity and discovery that leads to “expansionism,” which tends to increase complexity at the outset rather than reducing it.

Another key difference between SE and R&D involves “capabilities” versus “requirements.” Addressing a capability need is, by design, the focus of most ESR&D. Creating a point solution, while contending with the multitude of new discoveries that redirect or derail a research or technical investigation, is a large challenge. It calls for special discipline. Moving away from simply meeting a capability need and moving prematurely toward satisfying requirements or demonstrating a performance envelope too early in development creates big issues.

Today the lack of a commonly understood and accepted framework inhibits multi-disciplinary collaboration. What is needed is a common process framework that can be tailored and sustained for ESR&D, while enabling transition to TRLs 6 and higher. Several such frameworks are under consideration by members of the SE in ESR&D Working Group. These frameworks are the subject of this panel.

Michael DiMario (Astrum Systems) - mjdimario@outlook.com

Dr. Michael DiMario is the Founder and CEO of Astrum Systems, a global consulting venture focused on advancing process of innovation using a comprehensive systems approach. His corporate career began at General Electric Medical and progressed to Lucent Bell Laboratories, and Lockheed Martin. With a background in engineering, quality management and computer engineering, DiMario's career has spanned the leadership and management of numerous critical research and development projects and organizations. Dr. DiMario has five granted patents, numerous corporate trade secrets, a published book on systems engineering, a book chapter on systems engineering, and numerous peer reviewed papers in regard to systems engineering, innovation, and quality management. He has been interviewed and quoted in Wired Magazine, GPS World, Sifted, Financial Times, and the Smithsonian Air and Space. He holds a PhD in Systems Engineering, MBA in Management of Technology, MS in Computer Engineering, and significant course work in Space Science. He co-chairs the INCOSE Early Systems Engineering and Research Working Group. As a hobby note, he is an avid amateur astronomer and is acknowledged for the earliest pre-discovery of Pluto.

Position Paper

Early-stage low TRL R&D is a mixture of research and early engineering. In research and early development organizations, there are differing processes that constitute their particular framework that leads to success or failure. The organization's framework may be executed with first research followed by engineering, research only in support of engineering problems, or a cyclic iteration of research and engineering with varying degrees of success factors and exit strategies. Most, if not all, of these ventures result in low return on investment, high project failure rates, dead end research, research deliverables that cannot be engineered without starting over, and organizational social antagonism among researchers, engineers, and managers. In many cases, the research and subsequent engineering fails at TRL 5-6 whereby the project cannot cross the classic TRL Valley of Death. How could systems engineering be applied to reduce risk? A common framework of system engineering management can be developed to reduce risk, improve return on investment, and provide for greater collaboration among researchers, engineers and managers. To accomplish an organizational common framework, a process architecture and its requirements need to be established that initiates an executable framework and its associated processes.

The early-stage engineering environment needs to establish a holistic research and engineering approach recognizing that the execution of research is expansionist and systems engineering is reductionist. Researchers and early R&D engineers have typically not embraced systems engineering because of perceptions of process centric and rigid rules following established standards. Heuristics are required versus rules, standards, and checklists creating a capability and outcome-based research and engineering versus a compliance-based environment.

This panel member will be discussing a TRL based process architecture requirements that would lead to various frameworks to support the myriad of diverse R&D organizations.

Ann Hodges (Sandia National Laboratories) - alhodge@sandia.gov

Ann Hodges has worked over 45 years at Sandia National Laboratories and is a Distinguished Member of Technical Staff. She is the Mission Services Division's systems engineering lead for the systems engineering part of the Project and Product Delivery System (PPDS) framework at Sandia National Laboratories and is currently a project manager and systems engineer for a complex exploratory-phase project. She is a primary author of the PPDS framework, which is a risk-informed graded approach to the application of project management, systems engineering and quality management. She obtained a BBA and an MS in Computer Science from the University of NM, and holds CSEP, SAFe SPC4, and CMII certifications. Ann has held Leadership positions in the INCOSE Enchantment Chapter since 2011, as Director-at-Large, Past President and currently Secretary. She is the chair of the INCOSE Systems Engineering for Early Stage R&D working group. (SAND2020-12414C) Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

Position Paper

Sandia National Laboratories has implemented a risk-informed graded approach to the application of systems engineering (SE), project/program management (PM), and quality management (QM). Risk is the key factor in this framework. A challenge in the framework development was determining the core set of practices that every project is required to follow - from the small best-effort research efforts to large pathfinder operational systems. The set of practices need to be at the right level of rigor to provide research-oriented projects an efficient and solid foundation for growth - either for future research efforts or further development of the research results - without stifling creativity and exploration. Experienced systems engineers, program/project managers, and quality management subject matter experts with over 150 years of collective experience were involved in the definition of this framework.

The framework is applied early in the project creation phase using a rigor-level determination template, followed by the tailoring of a project and product plan template for the determined level of rigor. Rigor attributes consist of timing (how early, how often), scope (breadth and depth), and formality (form of artifacts, who has access). The technical project lead, supported by systems engineering, quality engineering, other specialty engineering, and project management subject matter experts, are involved in completing these templates for their project at the very beginning. The project and product plan templates are based on industry standards, lessons learned, and address the rigor attributes. The industry standards include PMBOK for PM, ISO 15288 for SE, and AS9100 for QM. Approximately 70% of Sandia projects are

low-category projects (e.g., R&D and studies) which typically equates to lower rigor across all three rigor attributes, and therefore Sandia is keenly interested in ESR&D. The low-category project/product plan template contains the minimal set of practices and information for artifacts that facilitate capturing enough information for future growth, thus providing a roadmap for researchers. These are the practices and artifacts that provide the most value: a charter (why and what), milestone list, WBS, budget, change tracking, requirements management approach, risk management approach, configuration management approach, and quality control. The category determination, thereby the applied rigor, is reviewed when the project scope changes or minimally yearly for required changes in rigor.

A second organizing principle is project type. We are currently developing project type category and subcategory templates for the risk-informed graded approach to increase efficiency and effectiveness. We are utilizing a scalable, participative method to introduce this project type approach as well as identify best practices and work products common to each project type. This will better equip technical and leads with enough systems engineering/project management/quality management knowledge to perform defensible research that positions the project for potential future growth.



Frédéric Autran (Airbus Defence & Space) - frederic.autran@airbus.com

Frédéric Autran is a Systems Engineering (SE) Senior Expert in Airbus Defense & Space. He has an engineering degree from Ecole Centrale de Paris (1984). He developed a Computer Aided Software Engineering environment used for the A320 aircraft, and then consulted for the French Ministry of Defense, contributing to building a semantic interoperability framework for various French Army C3I systems. He joined Aérospatiale in 1997 to set up management of systems interoperability in the new French Air Force command and control system, introducing SE principles in this programme. Since 2000, he is deploying SE in Airbus Defence and Space.

Corporately he chaired the "PLM4SE" group from 2011 to 2014 that defines the interface between SE activities and the Master Product Definition. He is a member of the Airbus group SE Steering Group. In INCOSE, he created and chaired the AFIS (French INCOSE chapter) SoS and Complex Systems working group from 2005 to 2009. He is the AFIS board associate director for certification. He chaired the Tool Vendor Challenge of the IS2012. He holds an Expert Systems Engineering Professional certification. He has participated in the INCOSE Certification Advisory Group 7/2014 to 7/2020, being the chair in 2017.

Position Paper

Unlike other panelists, I am not involved in research and technology development. But I deal with early stages of system development (aircrafts, satellite, command and control military systems etc.). And I wish there is a better coordination between system and technology development.

Early stage of system development is a challenge for systems engineers. I will define early stages as all what happens before development is actually planned and resources are allocated. It can be a bid phase, or a feasibility study, or even a proof of concept. We all know that the lack of proper systems engineering at that time is likely to provoke disaster during development. On the other hand, there is limited budget, because all what we do is at risk (risk of nogo decision). There is a tendency for discarding all SE activities that do not provide tangible marketing material. But we shall also remember that the goal of any commercial company is not only to get contract, but to have profitable contracts. This is what SE should support, by carefully analysing the problem and solution scope, identifying potential issues, and focusing the early engineering effort of the risky part of the development. This does not only addresses technical risks, but as well uncertainty on real operational needs, impact of the industrial organisation (e.g. multinational workshare - aka geographical or industrial return - decided by governments and not by engineers!). SE shall give inputs for an informed go-nogo decision.

Early stages of commercial products Systems Engineering often deals with two aspects of the system that seem to be completely disconnected, dealing with two extremes of the SE scope: defining a CONOPS and identifying the technologies. One may believe early stages should focus on CONOPS, technology will follow. The problem is that we need to setup innovative concepts, that are simply not feasible without the development of new technologies. Here is the link with laboratories (private or public). Early stage system development shall sketch a system/solution concept. The concepts may rely on low TRL technologies. Planning TRL increase shall be done in alignment with system development schedule. Thanks to appropriate SE techniques applied for technology development, it should be possible to evaluate the risks that the candidate technology is not mature enough when system realization begins. It should be a matter of classical risk management to decide to include or not this technology in the product to be developed. And maybe launch anyway the technology development so that it is available for the next generation system. To summarize my "commercial company" point of view, any technology development needs to be justified by a need regarding development of an end product, and systems engineering of this end product shall be used to set the targets of the technology R&D.

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

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Presented on: Wednesday, 10:00-11:25

Keywords. Artificial Intelligence; Machine Learning; MBSE; Modeling Simulation; Intelligent Systems

Topics. 1.2. Cybernetics; 14. Autonomous Systems; 2. Aerospace; 5.3. MBSE & Digital Engineering; 5.4. Modeling/Simulation/Analysis;

Abstract. It is well recognized that Systems Engineering is a transdisciplinary and integrative approach to enable the successful realization, use, and retirement of engineered systems. The importance of using systems principles and concepts, and scientific, technological, and management methods is core to systems engineering. Modern systems are subjected to an enhancing footprint of intelligence in product functionality and inter-connectivity. AI and other advanced technologies are increasingly popular among scientists and engineers to inculcate differentiating intelligence in modern systems. These systems are envisioned to emulate and simulate beyond human intelligence to achieve their goals and perform better than their "traditional" predecessors. They function in a completely different manner than their predecessors, and demand different approaches during its life cycle. In the current context of open communications, applications availability and big data, excessive emphasis on technology aspects and fading SE approaches would not be the answer support the design and management of complex intelligent systems. The answer has to come by achieving the following objectives: (a) Self-awareness, (b) Self-control, (c) Self-improvement through learning and (d) Machine-to-Machine & Machine-to-Environment Connectivity. An emerging view is that some of the prevailing SE approaches and tools don't accommodate system design life cycle that address such objectives that are necessary in the modelling of an intelligent system. The panel is designed to gather the industry and academia experts to share their research and knowledge where SE methodologies can be improved to meet the current era needs of AI and advanced technologies, with focus on (1) MBSE for AI applications (2) Potential SysML extensions for intelligent systems (3) Systems Engineering approaches for Intelligent system Applications (4) Lessons learned from implementing MBSE in AI applications

Biography



Ramakrishnan Raman (Honeywell) - ramakrishnan.raman@hotmail.co.uk
Dr. Ramakrishnan Raman received B.Tech and MS degrees from IIT Madras, and PhD from IIT-Bangalore. He is a certified Six Sigma Black Belt and is INCOSE certified Expert Systems Engineering Professional - ESEP. He has extensive systems and software engineering experience in domains of Building/ Industrial Automation, and Aerospace. He has been the Lead Systems Engineer and Architect for the design of many complex systems globally over the years. He is currently Principal Systems Engineer at Honeywell Technology Solutions, Bangalore. He has to his credit publications in refereed international conferences & journals, pertaining to complex systems architecture design, Artificial Intelligence - Machine Learning.

Position Paper

Modern systems are subjected to an enhancing footprint of intelligence in product functionality and inter-connectivity. AI and other advanced technologies are increasingly popular among scientists and engineers to inculcate differentiating intelligence in modern systems. These systems are envisioned to emulate and simulate beyond human intelligence to achieve their goals and perform better than their "traditional" predecessors. They function in a completely different manner than their predecessors, and demand different approaches during its life cycle. In the current context of open communications, applications availability and big data, excessive emphasis on technology aspects and fading SE

approaches would be detrimental towards robust design and management of complex intelligent systems. The need for increasing self-awareness, self-control and self-evolution requires enhancements in conventional systems approaches. An emerging view is that some of the prevailing SE approaches and tools don't accommodate system design life cycle that address such objectives that are necessary in the modelling of an intelligent system. Balancing the impulse for inculcating advanced intelligence against the imperative in ensuring robust intelligent systems with well understood behaviors and unintended consequences is required.

Stephen Piggott (Canadian Space Agency) - Stephen.Piggott@canada.ca

Stephen Piggott graduated from the University of Toronto with a BAsC and later earned an MASc at UofT's Institute for Aerospace Studies in aerospace control systems. In his 30+ years in the aerospace industry he has worked in controls, simulation and structures before becoming a Systems Engineer and the joining the Canadian Space Agency almost 20 years ago. Since then he has worked on programs at various stages of the life cycle including delivering parts of the Mobile Servicing System to the International Space Station, supporting its operational phase, preliminary design of Canada's contribution to the James Webb Space Telescope, and most recently as SE lead on Canadarm3 for the Lunar

Gateway. Mr. Piggott has been involved in a number of SE's subdomains but has taken a particular interest in MBSE and SysML including authoring a paper for INCOSE Symposium 2008. He has been leading and mentoring CSA and industry to encourage adoption of SysML and digital requirements management, which is bearing fruit as the Gateway partnership moves increasingly to integrate MBSE into its work practices. Canadarm3 is intended to work in a highly automated fashion which is pushing Mr. Piggott to learn more about AI

Position Paper

Human spaceflight is an enterprise fraught with considerable risk for the crew, which needs to be controlled through rigorous system design, safety analysis and verification to control all foreseeable hazards. The insertion of a self-learning system would create significant uncertainties that may not be acceptable without constraints, on top of which, the opportunities to train such a system are many orders of magnitude smaller than in the domains such as face recognition which have been successful. Consequently, the use of the type of AI discussed in many contexts is questionable in the space domain. However, there are several useful forms of AI, some of which are more predictable. For instance, knowledge bases and structured decision trees are more amenable to analysis. In addition, there are potentially many problems that can be solved by an AI and where the results can always be verified for safety, for example, robot path planning problems and optimal scheduling problems. In any case, MBSE can be used to construct models of any use of AI and make the process of development more predictable, consistent and reliable. Requirements can define the scope. Models can respond to the requirements with design concepts. Models can define the programming or training process. Models can describe how the results need to be verified. If the problem domain can be reasonably described mathematically, which is the case for significant areas of spaceflight engineering, these models can be automated and the design varied to find successful and optimal solutions. Even if it isn't, the well-known benefits of MBSE for structuring and communicating the approach and solution will help the AI development to a successful conclusion. SysML, since it is in widespread use and sanctioned by INCOSE, is suggested as a way to describe the requirements, design and verification for a problem in which AI may be the best solution.

Vincent Arnould (Hensoldt) - Vincent.Arnould@hensoldt.net

Vincent Arnould is a System Architect in the Defense domain currently working for HENSOLDT. He has been graduated in 2000 from the French Engineering School Centrale Marseille where he studied Mechanic and Acoustic. He has first worked as Software Developer at THALES, in the Paris area, in the field of Modeling and Simulation for SE, where he achieved several publications on Model Driven Engineering and participate in the definition of SysML at the OMG. After that, he has joined Naval Group in Toulon, where he has spent 15 years, dealing first with Combat Management Systems (CMS) as Software Architect, and as Industrial Bid Manager, then for the whole Combat System as System Engineering Manager and Combat System Architect, deploying industrially the MBSE approach, as for example on the GOWIND frigates. In 2018, he published two articles at the IEEE/INCOSE SoSE conference. The last two years he was part of the LEIDOS Team as Senior Architect on the Battle Management, Command, Control, Communication and Intelligence (BM3CI) Systems-of-Systems engineering, at the NATO Communication and Information Agency (NCIA) in The Hague, Netherlands.

Position Paper

I will try to bring an analysis on the positioning of MBSE in regards of AI. The MBSE approach should not be seen as a hindrance or an incompatible approach in regard of the advent of AI. On the contrary. Both disciplines are maturing and will emphasize each other in the future. First both MBSE and AI help to cope and deal with complexity. But their mutual integration will also be a source of huge opportunities, from both perspectives:

- MBSE can help the design of intelligent systems by formalizing the necessary split between the humans and the AI: what does the humans and what does the AI. A necessary work to understand how to capture the AI components into the architecture is still to be conducted.
- In the other way around, the AI is also able to help the design of system through integration of AI inside the MBSE tooling, for example enabling the automated exploration of the design space and optimum solution finding. Some existing tools already exists in this field, and many others should come in the future.

Juan Navas (Thales Group) - juan.navas@thalesgroup.com

Juan Navas is a Systems Architect with +10 years' experience on performing and implementing Systems Engineering practices. He has evolved on several industrial domains, developing complex modern systems. He has worked on the design and the procurement of instrumentation & control systems and simulation systems for petrochemical plants, nuclear fuel cycle plants and nuclear power plants. He has also lead projects to improve software and systems engineering performance following Model-Based Systems Engineering approaches. He currently leads the team at Thales Corporate Engineering that accompanies managers and architects implement MBSE approaches on operational projects, helping them define their engineering schemes, objectives, and guidelines. He holds a PhD on Computer Science, a MSc on control and computer science, and Electronics and Electrical Engineering Degrees.

Position Paper

In 5 years, the number of devices that can be connected to a network will be multiplied by four. More devices means more data being collected and being exploited. Data is and will be everywhere, which will lead to an exponential number of connections, and hence an exponential number of opportunities to arrange them on innovative ways and to provide new services. The orchestration of such devices to build up solutions that satisfy the expectations of our customers becomes a key expected competency of systems providers. Model-based Architecture Design, a subset of Model-Based Systems Engineering (MBSE), is what defines connections between building blocks, coordinating them so as to reach a common and shared purpose, which is the reason to exist of the system they make part of. MBSE has proven its effectiveness on designing, developing, integrating and validating complex systems. MBSE improves communication between technical and non-technical stakeholders, leads to securing the design and check its consistency, and enables the automatic production of engineering deliverables, to name a few its benefits. More and more of the components that will integrate our systems tomorrow will have some kind of intelligence, ranging from reactivity to self-awareness capabilities. In such a context, how MBSE and in particular Model-Based Architecture practices shall evolve to cope with these needs? One first illustration is the need to identify where the self-awareness, self-control and self-improvement capabilities shall be implemented. Here, a set of ordered and consistent practices enabling the characterization of the operational context and the elicitation of needs at the system-level, lead to the characterization of the required AI-related capabilities required from the components of the architecture.



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Hany Fawzy graduated from Electronics and Telecommunication Department, Faculty of Engineering, Cairo University in 1985. Following that, he continued his postgraduate studies in Computer Engineering and Computer Science in Egypt and France, where he obtained his Ph.D. degree from University of Nancy 1 (Lorraine University) in Artificial Intelligence in 1992. Following that, Dr. Fawzy continued his research in the domain of AI application in different fields such as telecommunications and health systems. Dr. Fawzy joined the industry in 1998, and worked for multiple companies such as Motorola and Harris in the fields of Systems Engineering and

Project Management. In 2005, Dr. Fawzy joined the Canadian Department of Defense as a Systems Engineer and participated in managing the System of Systems engineering cycle of the intelligent Land Command Support System. In 2011, Dr. Fawzy joined the Canadian Space Agency (CSA) as a Senior Systems Engineer, he worked as Lead Systems Engineer for RadarSat Constellation Mission Ground Segment. Currently he's a member of CSA Lunar Gateway Program Systems Engineering Team. In his function, he supports the different Artificial Intelligence activities within the gateway program as well other CSA AI scientific and industrial initiatives.

Position Paper

The world are on the footsteps of a time where the advances of technology supported by AI will force all stakeholders to re-examine their traditional methods for designing and engineering of all future intelligent and autonomous systems. During the panel, I will outline my thoughts and effort on going by me and my organization to provide with answers to the questions raised. Intelligent and autonomous systems would have the advantages of being self-awareness, self-control, self-improvement through learning and are self-sufficient. The current MBSE or system engineering methodologies and architecture approaches doesn't yet respond to those new features and how to address them in any modeling language. There are multiple challenges to System Engineering for such Intelligent and AI based systems such as Lack of human role to review and responsibility as well as public trust and users acceptance. Also, learning would require huge and continuous data and self improvement might require continuous source of huge amount of data, meta data and retraining needs of the release application in case of ML and deep learning applications. A new concept of self-awareness and situation awareness now appear, how we would handle the modeling such a concept. How we can manage the bias for deciding and make decisions. Add to all the previous, how the testing and validations requirements will be met in stochastic model. At the moment we will not address the cyber security aspects as we are not able to determine the increase threat surface of AI based system. In fact, coming to areas like aerospace industry, there are a lot of challenges would appear for certification where the bias need to be needed and trace for audit is required. AI and autonomous systems lifecycle management, what will be the future Engineering lifecycle and planning to migrate from and for traditional systems to intelligent and autonomous ones.



Tutorial

Tutorial#19

Applied Systems Theory to Enhance Systems Engineering Practice for Complex Systems

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Presented on: Sunday, 15:00-19:00

Keywords. Applied Systems Theory;Complexity;Systems Engineering

Topics. 1.1. Complexity; 1.5. Systems Science; 1.6. Systems Thinking; 19. Very Small Enterprises; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. This tutorial provides participants with a detailed examination of applied Systems Theory (ST) to enhance Systems Engineering practice. ST is presented as a set of propositions (principles, laws, and concepts) that provides a language to define the structure, behavior, and performance of all systems (natural and manmade). This ST language provides practitioners with knowledge that explains issues in complex system design, execution, and development from a different perspective. Emphasis is placed on using ST to change thinking (reframing how we understand and perceive complex systems), decision (expansion of alternatives in response to complex system issues), action (development of different responses to complex system issues), and interpretations (shifts in understanding provided by different explanations). Four objectives are pursued for the tutorial, including: (1) examination of complexity, complex systems, and the problem domain of future systems engineering, emphasizing limitations created by inaccurate framing of complex systems and problems (2) introduction of Systems Theory propositions and their role in determining the behavior, structure, and performance of systems, demonstrating how systems can be understood 'differently' through the lenses of ST, (3) application of the ST propositions in SE through a set of practice application exercises to demonstrate how ST can enhance SE practice, and (4) providing a set of practitioner guidance for application of ST to multiple SE problem domains to restructure understanding and create different conditions for alternative paths forward. At the conclusion of the tutorial, participants will be capable of applying ST to enhance understanding of complex systems and develop different response strategies.

The tutorial provides a clear explanation for four critical questions:

- (1) What is the Systems Engineering problem domain and how can Systems Theory help?
 - (2) What is Systems Theory and how can it support better Systems Engineering?
 - (3) How can Systems Theory be applied to advance the practice of Systems Engineering?
 - (4) What guidance can be provided for the deployment of Systems Theory across design, execution, and development in applied Systems Engineering settings?
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Artificial Intelligence for Systems Engineers: Going Deep With Machine Learning and Deep Neural Networks

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Presented on: Sunday, 08:00-12:00

Keywords. Artificial Intelligence;Systems Engineering;Machine Learning;Intelligent Systems

Topics. 14. Autonomous Systems; 2.4. System Architecture/Design Definition; 20. Industry 4.0 & Society 5.0; 5.11 Artificial Intelligence, Machine Learning;

Abstract. Deep Neural Networks have become the most powerful software development technique in recent years, leapfrogging other more established, but increasingly obsolete, artificial intelligence (AI) techniques. They are responsible for most of the recent wave of successful AI and Machine Learning (ML) applications for image and speech recognition, natural language, big data analytics and even deep fake videos. At the same time, over-anthropomorphized explanations invoke human notions of “learning” or “neurons” to try to explain the technology and lead to unfounded fears of synthetic intelligences running amok on our streets, in our homes and on our battlefields. Just as systems engineers need a sufficient understanding of electrical engineering, mechanical engineering and software engineering, they must come to understand AI/ML as a new engineering discipline. While many courses are available for AI specialists and programmers, this tutorial is designed for systems engineers and requires no programming background or specialized mathematical knowledge.

Part I of the tutorial provides an overview of the field of AI and ML. Part II focuses on deep neural networks, starting from first principles and showing how they work—taking all the mystery out of important concepts like multi-layered neural networks, forward and back propagation, hyperparameter tuning and training data. We will also cover applications like convolutional neural networks for image recognition, recurrent neural networks for machine translation, word embeddings for natural language processing, and reinforcement learning for physical systems control. Part III will focus on the relationship between artificial intelligence and systems engineering in practice.

From Operational Concept Development to Systems Architecture Definition with SysML and MBSE Grid approach

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Presented on: Sunday, 08:00-12:00

Keywords. Model-Based Systems Engineering (MBSE); SysML; MBSE Grid; Stakeholder Needs; System Requirements; System Model; Operational Analysis; Functional Analysis; Solution Architecture; System Configuration; Traceability; Trade-Off Analysis; System Context

Topics. 2. Aerospace; 2.4. System Architecture/Design Definition; 3. Automotive; 5.3. MBSE & Digital Engineering; 6. Defense;

Abstract. Model-based Systems Engineering is understood and applied differently by different communities, however there are fundamental principles and practices that are common to all. And none is possible without tool, language, method, and the harmony between the three.

This tutorial introduces one of the methods for MBSE, the MBSE Grid. It is used in combination with “vanilla” SysML and is tool-independent as long as that tool supports SysML.

The tutorial is intended to:

- Introduce MBSE
 - Reveal the motivation and benefits of using the MBSE Grid
 - Introduce the MBSE Grid cell by cell and disclose what SysML concepts and diagrams are used within each cell
 - Explain the modeling workflow and roles that are involved in developing different parts of the model
 - Show how the elements from different parts of the model and even from different layers of abstraction can be related together over traceability relationships
 - Share worldwide experience of building system models
 - Show a consistent modeling case study The PowerPoint presentation is attached.
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Handling Organizational Complexity

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Presented on: Sunday, 08:00-12:00

Keywords. Complexity;Organization;Systems;Difficulty Assessment Tools;Complex;Complicated

Topics. 1.1. Complexity; 2.1. Business or Mission Analysis; 3.5. Technical Leadership; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Recognizing that vast swathes of the world are increasingly complex, as opposed to complicated, is to accept that we need to change our approach to everything. The International Centre for Complex Project Management noted that the misunderstanding of the difference between 'complicated' and 'complex' projects is a major cause of difficulty and failure [Project Complexity Assessment, Cavanagh]. With organizational complexity only set to increase further, the need for the whole organization to start engaging and responding to complexity is becoming increasingly desperate.

Many academic works and consultancies propose methods for engaging with complexity based on their own or others' experiences and insights. However, as all experiences are different, especially in a complex world, and no community can experience everything, the suitability to your organization beyond the sales pitch might be poor, or worse, unknown.

The purpose of this workshop is to take a fresh approach to handling complexity, to empower you with the insights, tools, techniques and a lexicon, to help you develop an holistic organisational way forward based on your own unique culture and challenges.

This tutorial will lay the foundations for an understanding and exploration of complexity that can be tailored to your organisation. It will demonstrate how key techniques for handling complexity: assessing, mitigating and tailored improvement, can be created. It will provide generic working examples for all of these tools, that can be used and adapted according to your organisational needs, using the insights from the tutorial.

Introduction to Model Simulation and Engineering Analysis with SysML

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Presented on: Sunday, 08:00-12:00

Keywords. Simulation;SysML;MBSE;Executable models

Topics. 2. Aerospace; 2.1. Business or Mission Analysis; 2.6. Verification/Validation; 3. Automotive; 3.3. Decision Analysis and/or Decision Management; 5.3. MBSE & Digital Engineering; 5.4. Modeling/Simulation/Analysis; 5.7. Software-Intensive Systems; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 6. Defense;

Abstract. The tutorial provides a reusable typical system modelling patterns on how to create models in OMG standard SysML that can be executed as a single system. Model execution is performed based on other standards such as OMG fUML, SC XML. The tutorial is very practical - it is driven by a sequence of hands-on assignments based on an educational case study model used in multiple workshops and trainings. Tutorial explains SysML by simulating system model. We will explain how to model system structure as independent interconnected communicating components, we will add behavior models (state machines, activities), parametric analysis, Instances representing configurations, sequence capturing execution scenarios. Attendees will learn easy to follow modelling pattern suitable for any system simulation. Also will learn how executing models can help to better understand and communicate models, debug complex behavioral models, create functional system prototypes, verify requirements, and perform engineering analysis.

This tutorial is well balanced covering major capabilities enabling you to apply modelling and simulation pattern for any systems in the future. Tutorial is intense, but all participants will follow through. For the tutorial we will require Cameo Systems Modeler installed on your machine. To save time please download and install demo version from www.nomagic.com/products/cameo-systems-modeler in advance.

Tutorial#23

Leadership Skills for Systems Engineers

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Presented on: Sunday, 13:00-17:00

Keywords. leadership; soft skills; power; influencing; communication; decision making

Topics. 3.5. Technical Leadership; 3.7. Project Planning, Project Assessment, and/or Project Control; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Many of our Systems Engineering processes rightly discuss management (e.g., decision management, risk management, portfolio management, knowledge management), and these are all important. However, leadership is an equally important topic to Systems Engineers. Leadership is both an opportunity and a critical responsibility of the Systems Engineer. Soft skills play a critical role in your success as a Systems Engineer leader. This tutorial will introduce the participants to a set of soft skills in which every Systems Engineer leader should excel. Practical information and tools will be provided. The tutorial includes several in-class exercises to solidify the concepts being presented. The tutorial follows the terminology and conventions of the INCOSE Systems Engineering Handbook, ISO/IEC/IEEE 15288, and the Guide to the Systems Engineering Body of Knowledge (SEBoK). Each student will receive a complete set of lecture notes and an annotated bibliography.

Tutorial#24

Modeling and Analysis of Standard Operating Procedures

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Steven Dam (SPEC Innovations) - steven.dam@specinnovations.com

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Presented on: Saturday, 13:00-17:00

Keywords. Model-Based System Engineering; Standard Operating Procedures; Human Performance Analysis

Topics. 13. Maritime (surface and sub-surface); 2. Aerospace; 2.1. Business or Mission Analysis; 2.2. Manufacturing Systems and Operational Aspects; 3. Automotive; 4. Biomed/Healthcare/Social Services; 5.3. MBSE & Digital Engineering; 5.4. Modeling/Simulation/Analysis;

Abstract. Standard Operating Procedures (SOPs) are critical for the safe operations of complex, hazard-sensitive systems. The SOPs are particularly important for dealing with non-normal operations in which the human operator must intervene and/or provide instructions to the automation. The SOPs must be completed within an Allowable Operational Time Window (AOTW) to avert a hazardous outcome. In many cases, the AOTW is not fixed, but exhibits variance due to complex non-linear, plant dynamics. The Time on Procedure (ToP) is also subject to variability due to human factors such as experience, proficiency, fatigue, and the efficacy of the SOPs and the supporting automation user-interface. For this

reason, it is critical to evaluate the dynamic performance of the SOP in the context of the operations and determine the likelihood of the ToP exceeding the AOTW.

This tutorial describes how to model SOPs and perform SOP analysis using LML/SysML Action/Activity Diagrams that can be found in most Model-Based System Engineering (MBSE) tools. The method enables the SOP designer to assess the performance of the SOP by accounting for human factors and operation dynamics. The ability to test the procedures in a MBSE tool can inform the system design and verify the procedure design early in the development life-cycle.

Biography

Lance Sherry (Center for Air Transportation Systems Research at George Mason University) -
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Lance Sherry, is Associate Professor of Systems Engineering and Operations Research at George Mason University. Dr Sherry also serves as the Director of the Center for Air Transportation Systems Research at George Mason University. Dr. Sherry has over 30 years experience in the industry ranging from flight test, avionics design and certification, program management, strategic planning, and research. He has published over 100 papers and journal articles, holds several patents, and has received several awards for his work.

Steven Dam (SPEC Innovations) - steven.dam@specinnovations.com

Dr. Dam is the President and Founder of the Systems and Proposal Engineering Company (SPEC), based in Marshall, VA. He has been involved with structured analysis, software development, and system engineering for over 40 years. He participated in the development of C4ISR Architecture Framework and DoD Architecture Framework (DoDAF), the Defense Airborne Reconnaissance Office (DARO) Vision Architecture, the Business Enterprise Architecture (BEA), and NetCentric Enterprise Services (NCES) architecture. He currently is applying system engineering techniques to various DoD and DOE projects. Dr. Dam has been a member of INCOSE since the early 1990s.. Dr. Dam is the author of two systems engineering-based books: "DoD Architecture Framework: A Guide to Applying System Engineering to Develop Integrated, Executable Architectures;" and "Proposal Engineering: A Guide to Developing Winning, Cost-Effective Proposals Engineering."

Overview of the INCOSE SE Handbook Version 4.0

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Presented on: Sunday, 08:00-12:00

Keywords. INCOSE Systems Engineering Handbook;systems;complex systems;systems of systems;key SE terminology;principles;processes;tailoring;project success;organizational success;business success;mission success

Abstract. This tutorial provides an overview of the INCOSE SE Handbook V4.0 using key excerpts from the INCOSE Central Technical Product Tutorial of January 2020 that received the INCOSE 2020 Product of the Year Award in January 2021. Participants will benefit by learning how the Handbook can be used to apply the SE processes to realize systems, complex systems, and systems of systems, including key SE terminology, principles, processes, tailoring, what-to-do, and how-to-do SE to achieve project, organizational, and business success. The intended audience includes participants interested in learning and applying SE based on ISO/IEC/IEEE 15288, and who wish to increase their professional and/or personal value to their project and organization. Case studies, questions, answers, group exercises, and a discussion of how the Handbook relates to the SEBoK are included to help participants apply the concepts being presented. The tutorial also includes enhancements to the Handbook developed by creating additional figures using the information contained in this and prior Handbook versions.

The INCOSE Hampton Roads Area Chapter developed the tutorial, and the INCOSE Training Working Group presented and recorded the webinars. The complete tutorial and its webinar recordings are available via INCOSE Connect at <https://connect.incose.org/Library/Tutorials/training/SitePages/Home.aspx> for free electronic download by all INCOSE members, employees of INCOSE Corporate Advisory Board (CAB) members who become an INCOSE associate member, and employees and students of INCOSE Academic Council (a part of the CAB) members who become an INCOSE associate member.

Note: This tutorial does not include the level of detail typically presented in a Systems Engineering Professional (SEP) preparation course, but it will help a candidate get a good start toward becoming a SEP. A certificate of completion will be provided on request.

Systems Security Engineering: A Loss-Driven Focus

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Presented on: Sunday, 13:00-17:00

Keywords. Systems Security Engineering; Assurance; Trustworthy Systems; Loss Driven Engineering

Topics. 4.4. Resilience; 4.7. System Security (cyber-attack, anti-tamper, etc.);

Abstract. Systems security engineering (SSE), as an integral part of systems engineering, applies scientific, mathematical, engineering, and measurement principles, concepts, and methods to coordinate, orchestrate, and direct the activities of security and other contributing engineering specialties (e.g. reliability, safety and human factors) to deliver sufficiently secure systems. This tutorial provides an overview of SSE, its concepts, and the increasingly critical role of SSE as part of systems engineering. Loss-driven systems engineering provides a means to focus the tutorial; relating to loss driven concepts will be a key element.

Systems engineering is about meeting stakeholder needs within constraints of cost, schedule, and performance; integrating system security into systems engineering is about meeting the security protection needs derived from those stakeholder needs. SSE activities address system-of-interest loss concerns associated with the system throughout its life cycle, in consideration of adverse conditions resulting from threats, disruptions and hazards. The tutorial will offer a system-oriented framing of the security perspective with connections to the technical engineering and technical engineering management methods and activities employed as part of a systems engineering project to address stakeholder security concerns.

This tutorial targets the experienced systems engineer who is a novice in SSE as a specialty discipline of systems engineering

Biography



Mark Winstead (MITRE) - mwinstead@mitre.org

Mark had over twenty-five years' STEM experience before joining the MITRE Corporation in 2014, including stints as a cryptologic mathematician, software engineer, systems engineer, systems architect and systems engineer in addition to being a systems security engineer from time to time. He has worked for several defense contractors, an Environmental Protection Agency contractor, a Facebook-like startup, a fabless semi-conductor manufacturer of commercial security protocol acceleration solutions, and a network performance management solutions company.

Mark serves as the MITRE Systems Security Engineering Department Chief Engineer as well as works with various MITRE sponsors, helping programs with security engineering as well as teaming with others on integrating SSE into the acquisition systems engineering process. Additionally, Mark is currently co-authoring NIST SP 800-160 Volume 1 Revision 1 - the update to NIST SP 800-160 volume 1 - with Michael McEvelley and Ron Ross. Mark is a graduate of the University of Virginia (PhD, Mathematics) and Florida State University (BS & MS, Mathematics). He resides in Colorado Springs, CO.

Presentation

Presentation#13

6 Vs and 3 Ts of Systems Engineering

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Presented on: Wednesday, 15:10-15:50

Keywords. MBSE;Digital Engineering;Transformation

Topics. 5.3. MBSE & Digital Engineering;

Abstract. V may be the favorite letter of systems engineers. V&V (verification and validation) is the fundamental manner by which we confirm that we have delivered the right capability in the right way to address the business need. As we consider the alphabet, T may be our second favorite letter as it is often used to characterize the preferred “shape” of a systems engineer – someone with the required depth in one area and breadth across the technical and management domains necessary to successfully deliver a system.

In transforming our practices through model-based systems engineering (MBSE) and seeking to transform the greater enterprise through digital engineering, V and T become even more important. First, we must understand our heritage – the Vee diagram providing an idealized representation of how we progress through the engineering lifecycle. However, there is far more than one V in the Vee diagram. There is the V as commonly (mis)understood, the V as intended by Forsberg and Mooz, the V as executed in classical design, and the V as realized through traditional integration and test. Understanding those four Vs, we can look to the power of digital transformation and appreciate how the application of MBSE and digital engineering can transform the V and the greater engineering lifecycle to better meet 21st century needs.

But systems engineering is not done by process, method, or tool. Systems engineering is dependent upon the human, and that brings us to the T. First is the T-shaped individual and the competencies necessary to architect and engineer systems. Systems engineering is also dependent upon trust (our second T), a concept of growing importance as we leverage models and adopt MBSE.

What about the third T and the sixth V? They are perhaps the most important of all, and you will have to attend to learn what they are and the critical role they play in our future.

A Systems Theory Approach to Building Management

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Presented on: Tuesday, 15:10-15:50

Keywords. Buildings;Asset Management;Smart Building;Systems Theory;Systems Thinking;Asset Ikigai

Topics. 12. Infrastructure (construction, maintenance, etc.); 17. Sustainment (legacy systems, re-engineering, etc.); 3.9. Risk and Opportunity Management; 4.2. Life-Cycle Costing and/or Economic Evaluation; 4.3. Reliability, Availability, and/or Maintainability; 4.4. Resilience; 5. City Planning (smart cities, urban planning, etc.);

Abstract. Synopsis

“Smart cities” require “smart buildings.” Usually, both these terms are defined based solely on the technologies they incorporate. Little thought is given to the reductionist paradigm prevalent within the building management community, and the significant obstacle it poses to realize the full potential of smart cities and smart buildings. This paper will show how applying a systems theory approach to holistically blend the organizational and technological aspects of building management is needed to both improve building performance and speed acceptance of smart technologies within them. This paper will present one such approach, Asset IkigaiSM, that combines system thinking, data analytics, and cross-functional management processes to maximize the value a building owner can extract from the building asset portfolio.

Background

Almost universally, buildings are managed using a reductionist approach characterized by both organizational and technological “silos.” Organizationally, the result is the “silo effect” - the well-documented dysfunction characterized by the inability or unwillingness of functional silos to communicate and collaborate, to the detriment of the larger organization. Technology silos, also known as “point solutions,” or “data silos,” arise when each functional organization independently procures and configures the technologies it requires to fill its functional role, yielding a portfolio of narrowly focused, disconnected systems.

The reductionist approach exists even though building management activities are naturally interdependent. In contrast, systems theory holds that the success of an organization depends on recognizing functional interdependencies and interrelations, and managing to leverage the natural synergies between them. Buildings offer a textbook case of where systems theory can be applied to provide value to both building owners and society at large.

Why focus on buildings?

In fact, there are few applications of systems thinking that can have greater cost and environmental impacts than in buildings.

Consider that humans spend 90% of our time in buildings. There is a building type for nearly every human activity - homes, workplaces, manufacturing plants, research labs, restaurants, theaters, houses of worship, hotels, stores, schools; they are at the core of human experience. Buildings consume 40% of global energy use and contribute about the same percentage to the earth’s carbon footprint.

It is likely that the building economic ecosystem - building design, construction, operation, maintenance, and refurbishment; and the supply web of equipment, furniture, supplies, software, technology, financial, insurance, real estate, utility and service providers that supports it - consumes more human effort and resources than any other economic activity. Although detailed estimates of the global economic impact of buildings are hard to find, a 2019 study sponsored by NAIOP (the U.S. Commercial Real Estate Development Association) found that new and existing commercial buildings in the U.S. contributed approximately \$1 trillion to the US. Economy (about 5% of GDP), generated \$326 billion in personal earnings, and supported 8.3 million jobs.

Am i doing the right job and am i doing the job right?

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Presented on: Thursday, 14:15-14:55

Keywords. Systems Thinking;Efficiency and Effectiveness;Verification and Validation;Doing the job right and doing the right job

Topics. 1.6. Systems Thinking; 10. Environmental Systems; 2.6. Verification/Validation; 22. Social/Sociotechnical and Economic Systems; 4.4. Resilience; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. We humans love to take on tasks, jumping in with gusto where we believe we can contribute and make a difference, or reluctantly when we doubt our ability or suitability for the task at hand. Interestingly, no matter the motivation (enthusiasm or reluctance), the outcomes of our efforts, do not necessarily correlate with our opening intentions, but are always dependent on getting right, the answer to two key questions: did we do the right task and did we do the task right.

How do we know if we are taking on the right tasks or that tasks we take on are done right? Answering these two questions through a Systems lens is the prime motivation and focus of this presentation. A secondary intent is to highlight the universality and power of systems concepts that enable not just the engineering of complex systems, but help us better understand ourselves and the world around us, and through this awareness, catalyse the creation of a better, brighter, resilient and sustainable future.

This presentation will highlight how these two questions resonate all through our personal lives and professional careers. Every role we choose to take on, whether it be personal or professional in nature, comes with an associated set of tasks. Understanding and choosing the right role each time in the greater environmental context is key, as our chosen role then defines the tasks we, rightly or wrongly, assume responsibility for. When we understand and make the right role related choice, we then take on the right tasks, while also allowing others to take on their associated right-tasks applicable to their responsibilities. The suitability of the outcomes of our efforts is then a function of our ability (competency) to perform the applicable tasks. When we make the wrong choice of role, we inadvertently take on the wrong tasks, and no matter how competent we may be at performing the tasks, we (almost) always end up with dysfunctional outcomes, sometimes in the short term, but always in the longer term.

The presentation will define a four-systems context, within which to consider any initiative, in terms of the System-of-Interest (Sol), its Interfacing Systems and its Enabling Systems. It will identify foundational role-archetypes applicable within this four-systems context and how the tasks associated with role-archetypes are categorically different but complementary to achieving desired outcomes. It will highlight the implications of making the wrong choice with regards to role, and how to check to confirm the right role choice within any operational or environmental context.

It will describe a simplified tiered framework for how we as humans make sense of reality, transforming data, into information and then to knowledge. It will highlight the fundamental role of the environment that then catalyses the transformation of knowledge into wisdom through understanding. It will map this evolution in maturity from learning to knowledge and then through understanding to wisdom, to two foundational systemic concepts of efficiency and effectiveness. It will illustrate, and how these two concepts in turn align with the concepts of verification and validation in the engineering of systems.

It will conclude with integrating these systemic concepts into a foundational four-dimensional construct relating knowledge, wisdom, efficiency and effectiveness that provide us with a reference framework within which to answer the opening question - am i doing the right job and am i doing the job right.

Biography

Jawahar Bhalla (JB Engineering Systems) - jb@engineeringsystems.com.au

JB is a Systems professional with a wealth of experience over 30 years across multi-national organisations in technical and strategic leadership roles delivering complex capabilities across defence and civil sectors.

He is a passionate advocate and educator in the utilisation of Systems approaches, Modelling and Simulation as foundational pillars for understanding and resolving complexities in work and life and their application in the efficient and effective engineering of systems for a better and safer world.
He is the current Technical Director of SESA (INCOS's Australian Chapter), and an elected co-chair of the Australian Defence Force Synthetic Environment Working Group (SEWG). He was an elected member of the Simulation Australasia Board, a founding member and past Chair of SimAusts' Professional Development committee and was the Convenor of the SimAust SimTecT conferences from 2006 to 2008.
JB is currently casually contracting as Principal Systems Engineer to Shoal Group, while working towards a PhD at the University of Adelaide under an Australian Government Research Training Program Scholarship, with Shoal Group as the industry partner, focusing on the digital transformation of systems engineering.
He has a BE (Aerospace Engineering) and a BSc (Computer Science) from UNSW, and a Master's in Systems Engineering from UNSW@ADFA.

Presentation#14

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

Zane Scott (Vitech) - zscott@vitechcorp.com

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Presented on: Tuesday, 10:00-10:40

Keywords. Conflict management;Communication;Innovation;Technical Leadership

Topics. 18. Service Systems; 20. Industry 4.0 & Society 5.0; 22. Social/Sociotechnical and Economic Systems; 3.3. Decision Analysis and/or Decision Management; 3.5. Technical Leadership;

Abstract. Very often when we think of conflict in our work and personal life we think the answer to handling it is "resolution." But that is misleading. In reality, conflict is the engine that drives innovation and it should be constructively managed rather than "resolved." This presentation explores the value and role of conflict in a healthy organization and the key differences in managing and resolving it. Along the way there will be pointers to tools and techniques that systems engineers, whatever their organizational role, can use to harness the benefits of healthy conflict.

Defining a Measurement Framework for Digital Engineering

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Presented on: Wednesday, 10:00-10:40

Keywords. Digital Transformation; Digital Engineering; Measurement Framework

Topics. 20. Industry 4.0 & Society 5.0; 3.3. Decision Analysis and/or Decision Management; 3.6. Measurement and Metrics; 5.3. MBSE & Digital Engineering; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Many industries are undergoing profound transformational change from traditional engineering methods to a future based on digital models and cross-functional digital designs and solutions. As stated by the INCOSE Systems Engineering Vision 2035, "The future of Systems Engineering is Model Based". We are still in the early stages of this Digital Transformation, and our processes, tools, methods, and measures must mature to fully achieve the apparent benefits of applying digital engineering methods and models across the product life cycle.

Organizations must be able to measure the effectiveness and business impact of digital engineering relative to traditional engineering methods. Indeed, measures of effectiveness are key enablers for this digital transformation – but as evidenced by academic research including a SERC/INCOSE/NDIA survey of MBSE maturity and effectiveness, measurement of model-based practices and digital engineering implementations is one area of low maturity currently.

INCOSE is partnering with a broad set of stakeholders across industry, government, and academia to develop a proposed measurement framework for digital engineering, using a process based on Practical Software and Systems Measurement (PSM) to define measures aligned with business information needs. The objective of this working group is to help projects and enterprises establish an initial path toward transition and implementation of digital engineering methods and to be able to assess the effectiveness of their digital engineering transformation initiatives.

This presentation will provide an overview of the Digital Engineering Measurement working group, a summary of applicable studies from SERC and other researchers on digital engineering/MBSE measures and benefits, and an overview of the initial digital engineering measurement framework planned for publication in 2021.

Delighting your client as a Systems Engineering consultant

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Presented on: Thursday, 09:15-09:55

Keywords. Systems Engineering;Consultancy;Effectiveness

Topics. 3.1. Acquisition and/or Supply; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. There are a significant number of organisations that need to employ SE consultants to bolster their internal SE capability. Engaging effective SE consultants can lead to significant improvement in an organisations capability. Engaging less effective SE consultants can, however, lead to wasted time, money and significant disruption to the clients organisation.

This presentation will provide an overview of what these consultants need to do to ensure that they are effective.

Using real world examples the authors will share their insights as to what is needed to be an expert SE consultant . Whilst primarily aimed at SE consultants, it will give SE purchasers insights into the minds of their consultants!

It will cover:

- Developing a clear market offering that exploits your strengths as a Systems Engineer and consultant.
- A description of the common commercial models used to bring in SE expertise, including their strengths and weaknesses. For each of the three we will explore the commercial, organisational and technical challenges.
- How to understand your clients' stated and unstated needs as well as agree the requirements, deliverables and acceptance criteria for your work. We will explain the importance of understanding the benefits your client wishes to achieve by employing you and how that aligns with the different delivery models
- How to ensure that you get a reasonable return for the work you do. This will cover bidding for work, estimating effort and delivery risk.
- Understanding the client's operating environment, including their stakeholders, decision making culture, business and commercial practices – and how they align with the delivery model that you are using.
- Managing delivery. This will include managing scope creep, monitoring/reporting progress, use of intermediate deliverables and product descriptions to reduce risk.
- Building the win-win relationship with your client. This will include how to build rapport with clients, managing expectations, helping them manage their stakeholders and internal politics.
- Recognising when you need to 'say no' and how to say no in a way that both helps the client, maintains your credibility and future opportunities.
- Helping the client build their own capability to ensure the value of your work is sustained after you leave.

Finally we will present a list of warning signs that the consultancy engagement is having difficulties and advice about how to deal with them.

Designing Systems by Drawing Pictures and Telling Stories

Barclay Brown (Raytheon Technologies) - barclay@barclaybrown.com

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Presented on: Thursday, 11:15-11:55

Keywords. Use Cases; Timeboxes; MBSE; Business Processes; System Concept; System Design

Topics. 1.1. Complexity; 2. Aerospace; 2.3. Needs and Requirements Definition; 3. Automotive; 5.3. MBSE & Digital Engineering; 6. Defense;

Abstract. One of those most fundamental aspects of building systems is coming to full agreement with all stakeholders on what is to be built and how it is going to work for its users. Sounds simple enough, right? Long ago, the practice of writing lists of specific requirements was developed to capture user needs and describe system functionality. Lists of thousands of requirements though can fail to produce a complete picture of the system that is understandable to everyone, leading to unnecessary and resource-wasting change and rework throughout the systems development lifecycle.

In this presentation, we will focus on techniques useful in the early stages of any systems development project, whether it be designing a new home or building a spacecraft. The techniques are most valuable when the system has not yet been designed—when it's just an idea, or a need. Looking to stories, movies and visual art for inspiration, we'll explain several techniques for understanding, modeling and conveying the needs, functionality and performance of a new system.

Beginning with the familiar technique of developing use cases in the MBSE process, we will show how the idea of use cases can be expanded to larger scale systems and systems of systems. Expanding from the idea of individual use cases, we will introduce a way of combining more general business processes with use cases to produce a more flexible way of describing a system's use in an operational context. To that we will add the concept of timeboxes, which allow for the flexible modeling of loosely connected processes and systems.

Next, we'll explore the techniques professional storytellers and filmmakers use to create compelling stories, images and scenarios in very little time and with few words, including storyboards, movie trailers and recaps. Some insights from the science of the relative passage of time and even from time travel will be applied to help create compelling stories of the systems we seek to engineer.

Biography



Barclay Brown (Raytheon Technologies) - barclay@barclaybrown.com

Barclay R. Brown is an Engineering Fellow at Raytheon Technologies, focused on MBSE and artificial intelligence and machine learning in systems engineering. Before joining Raytheon, he was the Global Solution Executive for the Aerospace and Defense Industry at IBM, and lead systems engineer for some of IBM's largest development projects. Dr. Brown holds a bachelor's degree in Electrical Engineering, master's degrees in Psychology and Business and a PhD in Industrial and Systems Engineering. He has taught systems engineering and systems thinking at several universities, and is a certified Expert Systems Engineering Professional (ESEP),

certified Systems Engineering Quality Manager.

Economic Analysis of Unmanned Aerial Vehicle (UAV) Platform Options

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Presented on: Wednesday, 15:55-16:35

Keywords. engineering economic analysis; UAV platform; MBSE; FAA certification; civil air space; safety; cost effectiveness; market opportunities

Topics. 14. Autonomous Systems; 2. Aerospace; 3.3. Decision Analysis and/or Decision Management; 4.2. Life-Cycle Costing and/or Economic Evaluation; 5.1. Agile Systems Engineering; 6. Defense;

Abstract. The objective of this presentation is to help us learn how the economic analysis of Unmanned Aerial Vehicle (UAV) platform is conducted to select the best option for civil and military customers. The ideal UAV platform is selected based on a complexity of factors including safety, development, and flight capabilities for assigned tasks. The UAV platform is greatly beneficial for military, government, and civil applications.

The UAV platform reduces pilot workload (for non-autonomous) and increases maximum endurance for assigned missions which enhances the cost effectiveness and financial impact. The duration of training requirements for UAV is greatly reduced compared to military and commercial manned flight school training in thousands of costly hours flying. The UAV mission applications have multiple concerns to be addressed such as safety, cost effectiveness, and market opportunities. The UAV platform can create thousands of job opportunities for both military and commercial sectors which brings economic growth. The UAV platform brings enhanced opportunities for agriculture, delivery, public safety, public transportation, and environmental uses.

A Model Based Systems Engineering (MBSE) modeling tool should be used to identify the preferred design requirements given a range of performance and cost along with economic viability and technical aspects. This intended study ought to consider using both commercial-off-the-shelf (COTS) platform systems and emerging technologies that will meet performance and affordability requirements for specific customers. The study depends on current product line capability and leveraging existing MBSE modeling for implementation.

The challenge of UAV development lies in integrating the increasing scale of UAV and the complexity of its systems with air space and FAA regulations acceptance. The cost of UAV development and certification by the FAA and civil air space approval is billions of dollars. The cost to benefit ratio is rapidly increasing due to more efficiency from new technology and the ability to adapt to new circumstances. UAV development needs to balance between the economic consideration factors, production, military or commercial applications, product line capability, customer program configuration, security, safety, adaptability, maintainability, risk mitigation, and forecast revenue. Segregation of types of users and degree of complexity will be used to develop a projected revenue stream and cost estimate for each segment.

The UAV will change the world with greater flight capabilities, flexibility, and adaptability by being more convenient for pilots and users during all flight phases of missions. UAV demand is increasing for military, government, and civil applications due to lower purchase price, high flexibility and adaptability. The acceptance of UAVs operating in civil air space has been delayed for years due to obsolete FAA regulations that has an impact on financial growth to invest in UAV development.

From Systems to Silicon: MBSE-Enabled Digital Electronics Verification

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Presented on: Thursday, 14:15-14:55

Keywords. MBSE;EDA;Design Verification;Decomposition;Parameters;Simulation;Modeling;Requirements;Electronics Design;Systems of Systems;Systems Engineering

Topics. 14. Autonomous Systems; 2. Aerospace; 2.4. System Architecture/Design Definition; 2.6. Verification/Validation; 3. Automotive; 5.4. Modeling/Simulation/Analysis;

Abstract. Title: From Systems to Silicon: MBSE-Enabled Digital Electronics Verification

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Relevant Domains: Autonomous Systems; Industry 4.0; Sustainment

Industries Impacted: Aerospace; Automotive; Autonomous vehicles; Consumer Electronics; Cyber-Physical; Defense; Health/Medical Equipment; Smart Cities; Systems of Systems; Telecommunications

Problem and Motivation

It is rare today to find a system or product without numerous custom-designed electronic components. In many cases, insufficient performance or a violation of a constraint by one of these of electronic parts can result in system-level failure and associated risk and costs. Yet it remains challenging to achieve high levels of assurance that the electronic products perform as needed when integrated into a system product or a system of systems. Even before autonomous vehicles are a reality, there is reason to be concerned as automotive warranty issues for integrated electronic components in 2018 resulted in 6.3 million vehicles recalled – at 26%, the largest single category of recalls.[1]

While electronics manufacturers are making great progress toward 100% production output reliability, perfectly produced of electronic components that don't do what is needed for the system cannot be considered satisfactory. Certainly, design verification has been pursued, right? Indeed, digital verification of electronic designs is an important practice supported by powerful tools. But the disconnect between electronic component ("local") verification and the system ("global") verification is more consequential now as systems engineering pursues more dynamic modeling and simulations characterized by increased detail and complexity while electronics proliferate in our products.

State of Practice

Ironically, among engineering domains, electronics design has pioneered the use of extremely high-fidelity abstractions to represent localized behaviors and verify performance and compliance. For example, architecture exploration capabilities can connect black box functions to architecture tools to hardware and software co-simulations that assess expected bandwidth performance and CPU utilization. However, this increasingly detailed and focused path has led to an electronics verification activity chain that breaks connections to the system-level representations and emergent system-level behaviors.

This break happens substantially because to produce microelectronics requires design definitions in exquisite detail – detail not consumable by humans unaided – with design verification modeling and simulation motivated to meet downstream demands driven by tight production constraints. On its side, systems engineering has been comfortable treating electronic assemblies as if they were irreducible, as black box items if you will. From a systems verification perspective, these Integrated electronic

components may have been assessed only at the subsystem to which they belong, rather than to decomposed requirements used within electronics design activities. MBSE tools that cannot support rich functional tracing, partitioning, or continuous decomposition contribute to the gap.

From System to Silicon

Closing this gap can provide earlier and more complete identification of conflicts, disconnects, and emergent states. Our investigations show that it is key to have:

- Requirements mastered in an authoritative source and be parameterized with the parameters traceable and managed as instances (rather than attributes).
- Systems modeling capabilities that provide unlimited continuous decomposition of architecture with associated requirements and parameters.
- EDA models and simulations configured by these parameters, be well-formed, and be at needed levels of fidelity.
- Simulation results mapped to pre-defined targets that assert an unambiguous and traceable result.
- Verification of electronics managed as a part of an inclusive and comprehensive systems verification plan/event list accessible in a shared single source of truth.
- Subject matter experts should establish ground rules for the level of detailed (“local”) design verification and how to incorporate those results into systems models and simulations (“global”).

Exploiting recent advances to both EDA design verification and MBSE, we are on track to close this gap. We identify existing barriers and precursors to success. We also report on a pilot effort connecting Siemens EDA design verification and simulation tools to Siemens Teamcenter Systems Modeling Workbench using Capella MBSE tool and Teamcenter requirements, architecture, verification, and parameter management. We call this “From System to Silicon (and back again).”

Authors

From Siemens EDA (formerly Mentor Graphics): Mark Malinoski, MBSE Solutions Director and Ahmed Hamza, Applications Engineering Consultant. From Siemens Digital Industries Software: Shashank Alai, MBSE Solutions Architect and Lisa Murphy, Lifecycle Systems Technology Consultant.

Malinoski has a deep background in both MBSE and Electronic Design Automation (EDA) tools and practice; he participates in the OMG SysML V2 definition effort and works across multiple industries to understand how to make EDA more effective. Hamza’s sixteen years at Mentor/Siemens EDA includes roles supporting the architecting and deployment of electronics design solutions giving him unique insights into verification practices in EDA domain. Both are E/E engineers by training.

Alai is a hands-on MBSE consultant, an expert user of multiple MBSE tools, and a mechanical engineer, he focused on integrating MBSE with PLM while pursuing his master’s in systems engineering. Murphy’s forte is integrating engineering with enterprise needs; she serves as a digital thread expert for Aerospace and Defense; she has a doctorate in Information Systems from Indiana University.

These authors represent a diverse community inside Siemens DISW and Siemens EDA who are collaborating to build a true digital thread that connects multiple specialized engineering domains to and through systems engineering. This paper represents a progress report of sorts.

Note to reviewer: graphics will be used extensively in the presentation to illustrate the messages conveyed here.

References

[1] Steincamp, N., Levine, R. & R. Roth. 2019 Automotive Defect & Recall Report, 2020, p. 19. Accessed March, 2021 at <https://www.stout.com/en/insights/report/2020-automotive-defect-and-recall-report>.

Word Count: 888

Presentation#3

How do we know that we know? - A Model-Based-Knowledge-Management Concept supporting digital effectiveness

Robert Nilsson (Volvo Cars Corporation) - robert.nilsson.2@volvocars.com

Presented on: Monday, 15:10-15:50

Keywords. MBSE;Architecture;Ontology;System of Systems

Topics. 1.5. Systems Science; 2.4. System Architecture/Design Definition; 5.3. MBSE & Digital Engineering;

Abstract. The combination of computers getting smaller and increased amount of connectedness is one of the main contributors to amplified complexity in product development. The number of product nodes as well as connections between them is increasing at the same time as new feature is becoming a commodity at a higher speed. Product affordability by well-designed services as well as continuous adaptations and continuous improvements is becoming a natural part of expectancies on products and services.

In work with architectures the increased complexity challenges the task to create a wholeness (do the right thing) out of bits and pieces (do the thing right). In bigger complex systems this means that the number of potential solutions to a problem is increasing in the same time as we do not know the problem space itself well enough. This particular situation was e.g. found in a research project (called MAUS) dealing with business models and architecture patterns related to urban mobility in a system of system (SoS) context. As soon as the traditional world of architecture principles and potential business cases was entered the problem space literally exploded. After interviewing 10 other SoS related projects similar results were found. Working in a SoS context in a silo format is manageable and definitions and SoS types can be found and sometimes even applied. But, entering a world of common values, clear business cases and setting boundaries in a collaborative manner is still challenging. To handle the complex situation in MAUS a concept for Model-Based Knowledge Management (MBKM) inspired by the INCOSE Knowledge Management Working Group was tested.

This presentation will explain the basics of the MBKM-concept, anchor it in a systems science context and give an example of application. The scientific anchoring is enabled by the framework for organizing principles according to the Architecture of Systemology presented by Rousseau (2018). The Architecture of Systemology is used as the foundation for organising and defining a set of systemic principles which were identified as necessities for managing complexity (highly inspired by development of ISO/IEC/IEEE-42010). The set of principles are identified as enablers to tackle problems of applying abstractions, break-down structures and aspects in a consistent way. The principles are then in turn used to explain the framework defining the MBKM-concept. The framework enables a systematic approach to manage complex areas using taxonomy, ontology, architecture description and classical information modelling. As yet another attempt for scientific anchoring the presentation will also include results of comparing the MBKM-concept against the Architecture for System Science presented at International Society for Systems Sciences by Gary Smith (2021, ISSS, <https://vimeo.com/519125085>).

The MBKM-concept has potential for managing enterprise architectures covering both the organisational and business aspects as well as product architectures and tool meta-models. It is considered a vital part of the big task of untangling unknowns of what the connectedness of internet of things offers. If we want to understand dependencies in a cross-domain system of systems context a framework like the MBKM-concept is needed. As Volvo Cars entered a big scale agile set-up in 2017 several challenges for aligning companywide concerns has been under consideration and in this context the capability of dealing with knowledge management has shown to be vital. With a large scale agile set up and MAUS as a background knowledge management in a model-based fashion is considered an essential part to be able to digitalise and enter the future capabilities of industry 4.0.

The key take-away from this presentation is the MBKM-concept that can be applied for managing knowledge with hands on modelling. "Oh my"- with the MBKM-concept the confusions of taxonomy, ontologies and meta-models can be clarified and resolved. The concept can be applied wherever wanted and has no requirement of tools although graph-database technology is recommended. One example of application is definition of boundaries for SoS enabling architecture work which in turn can be worked on according principles of ISO/IEC/IEEE-42010, as in the research project MAUS. Another example of application is management of an organisations processes and tools. Organisations are traditionally highly dependent on tools provided by different vendors which all have unique strengths and boundaries. If these tools are to be used in an efficient manner, e.g. in a large agile context, it is of high importance to know what problem that is to be solved as well as the chosen approach and being able to continuously review the developing situation.

How to get the most out of your Systems Engineering consultants

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Presented on: Thursday, 13:30-14:10

Keywords. Systems Engineering;Consultancy;Effectiveness;Value for Money;Procurement

Topics. 3.1. Acquisition and/or Supply; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. There are a significant number of organisations that need to employ SE consultants to bolster their internal SE capability. Engaging effective SE consultants can lead to significant improvement in an organisations capability. Engaging less effective SE consultants can, however, lead to wasted time, money and significant disruption to the client's organisation.

This presentation will provide an overview of what the client needs to do to ensure that they get effective SE consultants. Using real world examples the authors will share their insights as to what is needed to be an expert purchaser of SE consultancy . Whilst primarily aimed at purchasers of SE, it will give SEs a good understanding of what is driving the mindsets of their better clients!

It will cover:

- How to understand/assess your internal capability and needs before engaging SE consultants. We will explain the importance of understanding what you need from an SE consultant, the challenges that you will face bringing them in and what you can, and cannot, expect them to achieve for you.
- The common commercial models used to bring in SE expertise including a review of their strengths and weaknesses. We will explore the three common models for consultancy delivery and outline the commercial, organisational and technical challenges of each. This will cover how to task SEs under the different models.
- How to achieve value for money form your SE consultants. This will cover the whole life costs of the SE consultants, advice on the right commercial approaches to contracting for SE and ensuring you are able to sustain the work the consultants have delivered after they have left.
- What does a good SE consultant look like, and how do you assess them before spending too much time and money on them. We will explore the basic technical competences, soft skills and systems thinking needed in different SE roles. We will explain the approaches we use to get the right SE consultants on task
- What you need to do to enable the SEs to succeed. We will explain the different roles that are needed inside the client organisation to ensure that the SEs can succeed.
- Recognising when you need to conclude an engagement with SE consultants and how to transition them out effectively. We will cover how to use the SE consultants to grow your internal capability and improving internal self-awareness of what you can deliver internally and when to buy in expertise.

Finally we will present a list of warning signs to consider when assessing or employing SE consultants and advice about how to deal with them.

Integrating MBSE and Product Lifecycle Management

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Presented on: Thursday, 12:00-12:40

Keywords. MBSE;PLM;MBE

Topics. 2. Aerospace; 2.3. Needs and Requirements Definition; 2.4. System Architecture/Design Definition; 2.5. System Integration; 3. Automotive; 6. Defense;

Abstract. Model-Based Engineering (MBE) is an “approach to engineering that uses models as an integral part of the technical baseline that includes the requirements, analysis, design, implementation, and verification of a capability, system, and/or product throughout the acquisition life cycle.” This includes system development from concept through to manufacturing and distribution. MBE is wide in scope in that it encompasses the entire lifecycle process as envisioned by the Digital Engineering Working Group (DEWG). This approach requires integrated digital engineering tools that provide traceability, interoperability and exchange throughout the development lifecycle including between systems engineering and Product Lifecycle Management (PLM).

During 1982-83, Rockwell International developed initial concepts of PDM and PLM for the B-1B bomber program. In 1985, American Motors was looking for a way to speed up its product development process to compete better against its larger competitors. The first part was computer-aided design (CAD) software system that made engineers more productive. The second part in this effort was the new communication system that allowed conflicts to be resolved faster, as well as reducing costly engineering changes because all drawings and documents were in a central database or PLM system. PLM has since expanded from its aerospace and automotive roots. PLM software helps companies of all sizes in the seamless management of their product development. Companies include a multitude of industry domains. PLM is used to manage the entire lifecycle of a product from inception, through engineering design and manufacture, to service and disposal of manufactured products. PLM integrates people, data, processes and business systems and provides a product information backbone for companies and their extended enterprise. The primary goal of Product Lifecycle Management (PLM) is to coordinate the information, processes and people associated with the lifecycle of a product. Doing so entails many benefits such as fewer production errors, fewer cycle iterations and, ultimately, increased speed to market.

Systems engineers typically use the Systems Modeling Language (SysML) as a means of modeling their systems. Models created in SysML include functional views such as use cases, state and activity diagram, and sequence diagrams. System structure is defined using block definition diagrams and internal block diagrams. These define the various components and assemblies of the system and system components. This includes details of the different components or parts in the system, the number of each part, and where it is included in the hierarchy. Other information modeled in value properties can include, size, weight, power, cost, etc. This is similar to what is known as a Bill of Materials or BOM in PLM. A BOM or product structure is a list of the raw materials, sub-assemblies, intermediate assemblies, sub-components, parts, and the quantities of each needed to manufacture an end product. A BOM may be used for communication between manufacturing partners or confined to a single manufacturing plant.

Capabilities of an integration between MBSE and PLM include:

- Auto-generation of PLM parts from Model System Blocks
- Auto-generation of PLM Options & Variants from Model Variation Points & Variants enabling Integrated product Line Engineering
- Bi-directional traceability to manage traceability links between PLM parts and Model System Blocks
- Reverse engineering of SysML block structure from PLM BOMs.

This will increase productivity by accelerating PLM product/project start-up using pre-populated BoMs & Options. It will improve product quality by avoiding the re-entry of data throughout the system & product lifecycle, enabling early impact analysis of system design changes and product part changes. Cost reduction by increasing reuse, considering product lines and product variation early system & product lifecycle

This presentation will examine the integration between the MBSE and PLM domains, using OSLC connectivity, and its benefits, initiatives taking place at the OMG and OASIS, and look at the future of integrated MBE in a wider scope.

Presentation#15

Making Your Case- Negotiation and persuasion for the systems engineer

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Presented on: Tuesday, 10:45-11:25

Keywords. Communication;Technical leadership;negotiation;persuasion;argument

Topics. 18. Service Systems; 20. Industry 4.0 & Society 5.0; 22. Social/Sociotechnical and Economic Systems;

Abstract. Did you know that INCOSE's Competency Model lists "negotiation" as a competency essential to requirements management, verification and validation, and acquisition and supply? Every day we all are placed in the position of persuading others and negotiating our way to the solution of shared problems. Sometimes this formal- involving presentations or papers. Often it is informal with a friendly- or not so friendly- give and take. At the heart of any negotiation is effective communication in the form of listening and expressing ourselves.

In all these situations, the fundamental structure of persuasion and our path of expression are the same. Learning the psychology of persuasion and negotiation helps us to understand what it takes to “make our case” and really hear and understand what others are saying. In this presentation, we will discuss the structure of persuasion and identify tools and techniques that will make us better communicators on both sides of the conversation- listening and expression.

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

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Presented on: Wednesday, 14:00-14:40

Keywords. MBSE;Model-Based Systems Engineering;SysML;supply chain;systems integration;component design;systems engineering education

Topics. 1. Academia (curricula, course life cycle, etc.); 2.4. System Architecture/Design Definition; 3. Automotive; 3.1. Acquisition and/or Supply; 5.9. Teaching and Training;

Abstract. Since 2019, the INCOSE Automotive Working Group has been running a small project to explore techniques for exchanging models between suppliers in the automotive supply chain, especially given that not all players use the same modelling tools. During Spring 2021 Semester, the Automotive Working Group has been running a Capstone project in conjunction with George Mason University. The students have been roll playing a vehicle manufacturer purchasing three major subsystems for an electric vehicle from three different suppliers. The students have intentionally been using different modelling tools and the guidelines for the roll play have been not to allow the students any more coordination of their modelling efforts than might be expected in the real automotive supply chain where competitive information is closely guarded. This presentation will review the experiences and learnings of the students as well as the path forward for the ongoing effort in the Automotive Working Group.

Practical demonstration of a highly functional system-centric digital thread

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Presented on: Thursday, 11:15-11:55

Keywords. Systems Modeling;Systems Engineering;Digital Thread;MBSE

Topics. 11. Information Technology/Telecommunication; 2.6. Verification/Validation; 20. Industry 4.0 & Society 5.0; 3.2. Configuration Management; 5.3. MBSE & Digital Engineering; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. There are many initiatives that companies across all industries embrace to better manage the exploding complexities of the connected products and systems being designed. These initiatives typically focus on the design data, processes, tools, methodologies, best practices, and organizational structure and personnel, since there is often little that can be done to decrease the complexities of the designs. The objective is always the same: minimize the risk of failures by understanding and mitigating emergent properties and behaviors. Most global enterprises are turning to digital transformation (transforming documents to structured data models), MBSE (systems modeling), ever-increasing reliance on simulation (democratizing its use and impact beyond the experts), and the creation of a digital thread (to link disconnected islands of digital data). While each of these areas is often discussed on its own merits, there is little discussion of the overall synergy between them or how to manage and optimize the various initiatives from a system perspective. The authors contend that making Systems Thinking a driving force behind it all provides the necessary holistic view required to achieve optimal results.

This presentation will demonstrate how making systems models a central part of the digital thread achieves long-term success in optimizing these moving targets across the enterprise. We will demonstrate a practical approach to establishing a custom digital thread that can expand and morph with the complexities of the products and systems that it represents. The digital thread provides access to the data authored in the best-of-class tools in the context of the tasks at hand (eliminating time-consuming searches for the relevant data) and automatically exposes functionality appropriate to the task at hand (instead of forcing the user to jump between separate tools), while maintaining traceability and the history of changes across the entire lifecycle. This digital thread is “live” and up to date, allowing distributed teams of engineers to work simultaneously, without stepping on each other’s toes. We believe that demonstrations like this one, based on commercially available low-code platforms, are critical in helping organizations understand how their teams can best experience the practical impact of these corporate initiatives in their daily work.

The presentation will show an existing implementation of a digital thread, encompassing high-level stakeholder requirements, functional and architectural systems models, breakdown of technical requirements, simulation and test data that verifies requirements and implementation domain details—all the way to digital twins and maintenance in the field. The implementation allows for creative flexibility during the what-if engineering process as well as for formal management of released results and structures. Finally, we will highlight the essential enabling platform characteristics that are required to support the rapid and flexible management of an ever-evolving digital thread.

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Presented on: Monday, 15:55-16:35

Keywords. Configuration Management;MBSE;Traceability

Topics. 3.2. Configuration Management; 5.1. Agile Systems Engineering; 5.3. MBSE & Digital Engineering;

Abstract. The focus of the presentation will be to present and start a discussion on the benefits of applying appropriate configuration management to the model based systems engineering approach. The presentation will first provide an insight into configuration management best practices by going through the five activities in configuration management:

- Configuration management planning
- Configuration Identification
- Configuration change management
- Configuration Status accounting
- Configuration Verification and audit

The presentation will then move to an exploration of the MBSE approach as well as the Digital twin and Digital System Model concepts.

We will then pursue to look at how appropriate CM is applied to the MBSE approach including the Digital twin alongside an example that was developed as a study by the Transportation Working Group. The aim will be to focus on Configuration Management advancements in the Software Engineering field (i.e. Git, CI/CD, DevSecOps, ...) and how they can benefit MBSE by providing truth, trust and traceability of data throughout the system lifecycle.

Finally the presentation will reflect on the state of the art and future axes of development.

Biography

Adriana D'Souza (Airbus) - adriana.dsouza@airbus.com

Adriana D'Souza (CSEP) is a Configuration Management Process Architect for Systems for Airbus, having previously worked as a Systems Architect and as a Design and Development Engineer on challenging and complex projects like large border security projects and air traffic management projects both at the subsystem, system and system of systems level in the Airbus. She was awarded an Honours M.Sc. in Computational Science and Engineering from the Technical University of Munich (Germany) and a B.Sc. in Mathematics and Computer Science from the Ovidius University of Constanta (Romania). Adriana is also a Certified Systems Engineering Professional with INCOSE.

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A. Larry Gurule is the President of CMPIC LLC, lead instructor, and author of CMPIC's course material. He has decades of experience in configuration management, including consulting, assessing, and teaching on the subject matter to a wide variety of organizations across the globe. Mr. Gurule is an active member in the CM community and part of the SAE G-33 committee.

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David Hetherington is a Principal at SSI with over thirty years of experience in Software and Systems Engineering in the Automotive, Semiconductor, Oil and Gas, Enterprise IT, Server Computer, Telecommunications, and Electronic Publishing sectors. David has experience in automotive radar design, software safety for offshore oil rigs, infotainment software design, and ISO 26262 functional safety for automotive "System on Chip" products. David is the author of the SysML for Beginners book series and speaks both Japanese and German fluently. David received a BA in Mathematics from the University of California San Diego and an MBA from the University of Texas McCombs School of Business.

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Safety Engineering of Semi-Autonomous Cars

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Presented on: Thursday, 09:15-09:55

Keywords. System Engineering; System Safety; Electric Vehicles; Functional Safety; Safety of the intended function

Topics. 14. Autonomous Systems; 2.4. System Architecture/Design Definition; 3. Automotive; 4.6. System Safety;

Abstract. This paper addresses the system safety of adaptive cruise control (ACC) on a passenger electric vehicle. Historically, a cruise control feature was introduced in the car to automatically control the speed of the vehicle without using the accelerator pedal. However, this feature did not have the intelligence to slow down when required e.g. during crossing pedestrian, speeding around curves, etc. These discrepancies were resolved when ACC was introduced in 1992 bringing in distance control along with the existing speed control. Moreover, if traditional cruise control were replaced with ACC, then it would mitigate front collisions caused due to driver negligence or fatigue. All these Advanced Driver-Assistance System (ADAS) features when implemented on the internal combustion engine (ICE) still caused energy loss and tailpipe emissions. For sustainable development, in the last few years, most of the automotive world started moving towards electrification, where the driving power source of these features would be replaced by a motor and energy source as a battery. One of the recent studies showed that if we combine the three trends of vehicle automation, vehicle electrification, and ridesharing, it will help with the traffic accident reduction by 30%, tail-pipe emission reduction by 80% worldwide, and transportation cost reduction by 40%. Along with its environmental and cost benefits, electric vehicle poses newer challenges for safety engineers such as safety hazards of higher torque characteristics of the motor, direct drive unit, etc. The authors of this paper will focus on two of these three important vehicle trends and their safety relevance identified during complex system development.

The ACC system captured in this paper consists of multiple sensing devices- camera and radar, which perceive environmental conditions for real-time decision making. The camera module's image processing algorithm would help with the correct identification of the object. The actual distance to the object will be known through radar's electromagnetic waves of 76.5 GHz. Because radar operates at wavelengths on the order of a few millimeters, they are pretty good at detecting objects that are several centimeters or larger. The sensor fusion is a critical step in the flow to combine inputs of the camera and radar. The sensor fusion and other vehicle longitudinal parameters are taken up by the vehicle supervisory control unit to decide on the distance and speed control. The action of acceleration and deceleration is performed by the motor control unit and braking control unit. During the application of ACC function, major sources of functional safety (FuSa) related failures include hardware, software, and communication at all levels (perception, decision, and action). Apart from E/E system failures, when using a sensor fusion system within a semi-autonomous and fully autonomous car, Safety of the Intended Function (SOTIF) related triggering events becomes relevant while analyzing hazards. Note, vehicle cyber-security vulnerabilities will be out of the scope of this paper.

Using a system safety engineering approach, the authors attempted to minimize safety issues throughout the planning and design of the ACC system. They identified and resolved: 1) the safety hazards of ACC using FuSa standard ISO 26262, and 2) the safety hazards of ACC resulting from functional insufficiencies of the intended functionality or by reasonably foreseeable misuse by persons using SOTIF specification ISO 21448, and 3) the derivation of safety measures for both these cases. Depending on the different use cases and frameworks, the complexity of the safety solution varies. Our framework involves the ACC implementation within the Electric Powertrain (EPT) System of Battery Electric Vehicle (BEV). The authors used the above safety standards and system architecture to derive unknown and unsafe scenarios within its functional and system specification. Using these pre-requisites, SOTIF-related hazard identification and

risk evaluation were performed. This activity complemented the results of FuSa's Hazards and risk assessment (HARA) activity. For SOTIF, based on deductive/inductive safety analysis, triggering events were identified and evaluated. The analysis included sensor's disturbances, algorithms, and actuator's limitations. To mitigate the risk of triggering events and other functional safety failures, functional modifications were recommended to the initial functional and system specification. In conclusion, using our ACC example within an electric powertrain, we intend to share the best practices which can be adopted for safer systems within diverse industries.

Presentation#20

System Holarchy Structures for Sustainable Development Goals

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Presented on: Tuesday, 12:30-13:10

Keywords. Holarchical structure; Sustainable Development Goals; Governance; Organisations; Systems Theory; Self-organisation

Topics. 1.1. Complexity; 1.5. Systems Science; 1.6. Systems Thinking; 2.4. System Architecture/Design Definition; 20. Industry 4.0 & Society 5.0; 22. Social/Sociotechnical and Economic Systems; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. We are living in a world comprising interconnected human and ecological systems that are continually self-organising. These self-organising systems are made up of dissipative processes that make use of the raw materials and information that are available in a particular physical environment and dissipate exergy. Through catalysis, the physical environment as well as the information present favours and enables some processes to the disadvantage of others. Over a period of time, given the availability of sufficient exergy for support, such processes manifest themselves as dissipative structures. These structures provide a new context, creating the necessary conditions for new processes to emerge. Examples of the structures in the ecological context are forest, the individuals of species, etc., while those of processes are reproduction, metabolism, etc. The context comprises a physical environment consisting of multiple energy sources and an available set of nutrients. The information comprises the biodiversity.

Arthur Koestler, through his work in systems theory 1967 onwards, described the relationships and the behaviour of observed biological and social systems, which self-organise and adapt to their complex changing environments. He formally introduced the concepts of "holon" and "holarchy", and defined them as:

A holon is an entity exhibiting a dual tendency:
To preserve and assert its individuality as a quasi autonomous whole; and
To simultaneously function as an integrated part of a larger whole

Holarchy is a hierarchy of self-regulating holons. In other words, a system of holons that cooperate to achieve a macro objective, form a holarchy

His successor, Ken Wilber undertook the study of metaphysics to describe the evolution of man towards a higher consciousness, and conceived of the "Kosmos", as a general cognitive holarchy consisting of four dimensions: interior & exterior and individual & collective. Some of the basic tenets of evolution as postulated by Wilber, in terms of the rules governing the functioning of holarchies are:

Holons appear spontaneously forming a chain of containing/contained relations and are holarchic in form. However, they emerge as compositions of structures having new and emergent properties, different from those contained by their subordinate holon, and not merely in the form of increasingly larger hierarchical structures

The holarchically-ordered Kosmos has a useful and obvious asymmetry, in that each superordinate level of

the holarchy comprises holons containing the subordinate holons in its own structure, but not vice-versa. A superordinate holon not only contains, but also regenerates and preserves its subordinate holons to ensure its own existence

Connected to these terms are those of holonic/fractal/bionic manufacturing systems, and holonic firm and enterprise, to name but a few. We looked into a couple of examples of holarchy structures to gain a better understanding of their spatial-temporal structures and functioning. We realised that the holonic nature of these structures is not so much a function of the processors i.e. either men or men-machine production units, as the subdivision of responsibilities they are required to pursue to achieve macro objectives (The Holonic View of Organizations, 2005).

Having understood the notion of holarchy from the perspective of manufacturing systems, we were keen to observe and interpret this idea from the perspective of an organisation. By organisation is meant a social system, which forms “when a group of individuals (the personnel structure), accept to be bound by stable, horizontal and vertical structural relations (the organizational relations), thus becoming organs, or components of organs of a larger structure, in order to achieve a common goal that cannot be attained by the single individuals or by their subsystems.” (The Holonic View of Organizations, 2005)

The organs/components can assume one of two forms within holonic organizations, depending on their capacity to have vital autonomy, irrespective of the existence of the organization or its cessation. They are:

as member holons within a top-down holarchical organization with reflex vitality, so that the breakup of the organization implies the cessation of member holons as well

as component holons that are able to survive as independent holons even if the organisation they belong to ceases to exist, owing to their autonomous vitality

Through this presentation we aim to examine the behaviour and properties of the second form of holonic organisations comprising of self-organising component holons for example: industry coalitions, while keeping our focus on The United Nations Sustainable Development Goals (SDGs), and explore the relevance of putting in place holarchy structures within such organisations for the overall implementation and governance of SDGs.

The implementation and governance of SDGs is presently overseen by a Global Monitoring Framework with key touch points at the national, regional as well as global scales, which largely follow a top-down hierarchical structure. However, most of the action with regards to implementation takes place at the state and local levels. The interlinkages between the SDGs and targets give rise to certain dynamic behaviour on ground that is not very evident at the national and global levels.

Hence, understanding the dynamics that emerge from the interactions between different SDGs and their targets at local levels is critical to identify enablers and inhibitors across component holons. This necessitates envisioning an alternate bottom-up governance structure, where the feedback caused by various enablers and inhibitors can be influenced in order to leverage emergence bottom-up.

Since the SDGs have already been classified into three pillars: Social, Economic and Environmental, we are keen to study the merits of developing holonic organisations considering these pillars also as component holons, within a local holarchical governance structure, each of them capable of surviving disturbances autonomously, as well as able to cooperate to form a more complex, stable system.

As we step into the “Decade of Action” for SDGs, understanding synergistic relations as well as possible trade-offs between SDGs is critical for achieving long-term sustainable development outcomes. A bottom-up holarchical governance structure can serve as a good starting point for various state & non-state actors and institutions that need to work in tandem towards coherent policy making, by identifying their priorities and designing strategies for collaborative implementation across SDG goals & targets, which can have an amplifying effect on each other.

Presentation#22

System of Systems Modeling to empower decision makers in drone based services - an application in Agriculture

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Presented on: Thursday, 08:30-09:10

Keywords. UAV;autonomous;multi-method model;aerial vehicles;agent based and discrete event simulation;system of systems model;Anylogic;SysML

Topics. 14. Autonomous Systems; 5.4. Modeling/Simulation/Analysis; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.);

Abstract. Application of drones or unmanned aerial vehicles (UAV) is becoming prevalent in various industry segments such as military, commercial, government & law enforcement, and consumer market. The UAV market is estimated at USD 19.3 billion in 2019 and is projected to reach USD 45.8 billion by 2025, at a CAGR of 15.5% from 2019 to 2025. The key drivers of growth are the rise in applications in defence forces along with commercial applications like monitoring, surveying, agriculture, remote sensing, and product delivery. Technology developments in the field of computer vision, communication, battery technology and machine learning will provide UAVs with the right capabilities to cater to features beyond data collection.

Drones or UAVs are expected to cater to multiple missions and thereby operate in varied areas such as inhabited areas, areas in conflict, busy urban areas, etc. Such systems must be designed to be robust to operate in a wide range of environmental conditions, adaptive to unexpected conditions, and capable of anticipating and recovering from failure conditions. These vehicles also need to integrate within existing air traffic environments. Much focus is given to control of these vehicles such as path planning, autonomy, control and sensing. It becomes pertinent to build a complete understanding of operational behavior and performance of these vehicles.

This presentation describes the modelling and simulation of drones for agriculture operation as an example. It has been forecasted that agricultural consumption would increase by 69% from 2010 to 2050 due to increase in population. The current technological trends in agricultural practices are not suitable for small land holdings that are a norm in developing countries. There are several uses of drones for precision agriculture such as soil, crop analysis via imaging, planting, spraying of pesticide or fertilizer, livestock management and many more. The drones thus allow farmers to increase efficiency of the farming process and the ability to maximize the yields.

There are several decisions a farmer or a contractor of agricultural jobs need to make for effective use of drones. Modelling and simulation of drones for a given set of fields can help make key decisions for both farmers and contractors such as, the number of drones required for various agricultural activities, sequence of operations, path planning within the given agriculture area, cost of operation, etc. The simulation can inform total time taken to complete all the jobs, utilization of drones, measure other performance parameters and also determine the collaborative behavior of these vehicles.

The presentation will share how Systems Thinking can be applied to such scenarios, by understanding the business problem first, defining the scope by understanding the ConOps and Context of the problem at hand, and building a high level System of Systems architecture for this example problem. The various artifacts leading up to the System of Systems architecture are modeled using SysML to bring consistency and concordance in communication amongst different stakeholders. We will then show how this conceptual architecture can be objectively verified using Agent Based Modeling and Simulation using a tool called Anylogic, by modeling the behavior of all entities of the architecture as agents. Entities such as the drone, drone carrier or transporters, customer enquiries, fields, operation center for drones, have their own behavior, and the resultant behavior of the System of Systems is an emergent behavior. All these agents will have their own parameters such as flying capacity for drones, fields have a GIS shape which determines its boundaries and size, speed of operation for drones etc. Such simulations also aid in visualization of the System of Systems and its behavior.

We will share how tweaking these systems parameters and various scenarios can be simulated and the results can be compared to enable both business and technical decisions. Such simulations can be very useful for any organization planning to implement a drone based service while in the business planning stage, or even during the day to day operations to plan how the day looks like. These simulations can also be referred to in various other drone applications as mentioned earlier in the abstract such as customer applications or military applications to analyze and plan missions, or take other key decisions.

Presentation#7

Systems Engineering Professional Certification Standard

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Presented on: Monday, 15:55-16:35

Keywords. Certification;Competency;Skills;Knowledge;Professional Engineer

Topics. 4.5. Competency/Resource Management; 5.5. Processes; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Because of the cross-domain nature of Systems Engineering, the skills and experience that professionals bring to the Systems Engineering area of practice vary considerably.

What then does it mean to be called a Systems Engineer?
What are the competencies that must be demonstrated in order to claim this title?

This presentation reveals the content of the ISO/IEC 24773 Certification of software and systems engineering professionals – Part 3: Systems engineering anticipated to be published and adopted as an Australian Standard in 2021.
It will describe a unifying set of certification requirements relating to Knowledge, Skills and Competencies that underpin the profession and provide a benchmark for Professional Certification bodies that claim to register Systems Engineers.

ISO/IEC 24773-3 leans heavily on INCOSE products viz:

- INCOSE SE Handbook as an encapsulation to SE Knowledge
- INCOSE CSEP functional areas to define a set of SE Skills
- INCOSE SE Competency Framework (ISECF) to define a set of SE Competencies.

This presentation further explains how this standard is implemented through a Mutual Recognition Agreement (MRA) between INCOSE and Engineers Australia that rationalises pathways to be Chartered as an Australian Systems Engineer (CASE). Under this CASE the technical competencies that are certified under CSEP are supplemented by the Chartered Professional Engineer (CPEng) certification that assesses the generic professional competencies described in the ISECF.

Presentation#25

Systems Engineering - A Matter of Perspectives

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Presented on: Tuesday, 12:30-13:10

Keywords. viewpoints;competency;soft skills;leadership

Topics. 3.5. Technical Leadership; 4.5. Competency/Resource Management;

Abstract. When Bandler and Grinder introduced the concept of perceptual positions in the 1970s, they did so in the context of neuro-linguistic programming – an approach to communication, personal

development, and psychotherapy. In discussing the three major perspectives from which things can be viewed – self, other, and observer – they sought to enhance individual flexibility, wisdom, and resourcefulness within the context of individual interactions and across the lifetime journey of self-discovery and improvement.

But the concept and value of perceptual positions is not limited to neuro-linguistic programming. Certainly systems engineers are familiar with perspectives as we study both problem and solution from different viewpoints while blending subject matter expertise to see the whole picture. The five perceptual positions identified by Koyen have special meaning to the systems engineer. While those with a systems perspective implicitly apply the concepts of perceptual positions, a more explicit consideration of the concepts can improve their application to the lives we lead and the systems we build.

The first position – self – is typically the easiest and most natural perceptual position for most to see and use. It is simply seeing the situation through my own eyes. While this position may be the easiest to see and the most common to use for most people, it is the perceptual position most easily overlooked by systems engineers. As we help others “see the big picture” and as we seek to elicit and connect other perspectives, we can forget our own. Given that most systems engineers have deep domain knowledge and broad experience, overlooking our perspective is an error we cannot afford. We cannot put self ahead of the other perceptual positions. Nor can we overlook it as we blend our perspective with others to study both problem and solution from diverse angles.

The second position – other – seeks to truly see, perceive, and understand from another individual’s viewpoint. As Koyen points out, it is not “how would I feel if I were him”. It is how he feels and what he sees. This is analogous to listening to respond versus listening to understand. Systems engineers should be well-versed in the second position as we thoughtfully elicit needs, approaches, and perspectives of the greater team, enabling the team to better see, perceive, and understand through multiple eyes. In serving as the technical connective tissue that binds the team together, the systems engineer often finds the second position to be the most natural. It is one with which we can never be casual or cavalier. If so, we will fail as we serve as the translator – of language, of concept, and of perspective – in our journey from problem to solution.

In the third position – objective observer – we watch ourselves in interaction with others. We are neutral observers, avoiding introducing bias through either the “self” lens or the “other” lens in order to view what is happening dispassionately. As systems engineers, this is where we begin to bring the individual perspectives together to see a more complete picture, but it goes beyond that. It goes to the critical skill of making tradeoffs to honor and balance diverse systems concerns. It includes facilitating team discussions, not only between the needs and perspectives of others but also with the insights of self. To truly serve the team and help bring together the diverse perspectives, systems engineers must be skilled in moving teams from positional dialog which often leads to entrenched stalemates to interest-based dialog which increases collective understanding and expands the trade space.

When Koyen introduced the fourth position – contextual observer – he differentiated it from the third position by introducing context. The fourth position elevates the perspective to a higher plane. While the second position is often the most natural for a systems engineering, the fourth position is where the systems engineer must live, “seeing the big picture”. This brings together the insights and interactions of the users, customers, and project team members within the greater context – of problem, solution, technology, environment, culture, and business need. Embracing the fourth position is what we speak of when we seek the systems perspective to see the whole picture, truly seeing all concerns, all possibilities, and all impacts as we deliver the desired business value and avoid unintended, unforeseen consequences.

The fifth position is difficult to perceive and, in the words of Koyen, is even paradoxical in nature. From a neuro-linguistic programming sense, the fifth position is “watching me being involved in the content of my life”, watching myself as if watching a movie. It is about being deeply self-aware informed by our principles, in the moment and from a distance. In one systems engineering sense, this is recognizing the lifecycle perspective of a system, considering all phases from operation to maintenance to evolution and ultimately retirement and disposal. In another sense, this is where we must embrace our systems engineering ethos. As Jack Ring reminds us, like physicians we must first do no harm – to our users, to our stakeholders, and to our environment. Leveraging the other positions, particularly the second position, gives us insights to these concerns. Applying the fifth position requires us to be true to the principles of our profession and our commitments to society.

Leveraging multiple perspectives and positions is nothing new for systems engineers. The fundamental concept of viewpoints and perspectives help us understand and assess both problem and solution in a more holistic manner. As we seek to continuously expand and diversify our viewpoints to gain ever-greater insight, we can also advance by embracing the deeper concepts of the five perceptual positions. We can learn by seeing how they instantiate within our systems engineering practice. And we can grow by seeking to understand their neuro-linguistic programming foundations and application. After all, soft skills are critical to the systems engineer. As we well know, mastering the soft skills is hard, but mastering the five perceptual positions is certainly worth the investment for any systems engineer.

Towards an Integrated Approach of Systems Behavior Modeling and Specification.

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Presented on: Thursday, 10:30-11:10

Keywords. Behavior modeling;ISO-42010;Ontology;OPM;PMM;MATLAB Simulink;SysML

Topics. 2. Aerospace; 2.3. Needs and Requirements Definition; 5.3. MBSE & Digital Engineering; 5.4. Modeling/Simulation/Analysis;

Abstract. As highlighted by the OPM standard, the architecture of systems can be addressed through 2 main perspectives: from a structural viewpoint and from a behavioral viewpoint. To deal with all aspects of systems behavior, people often have to consider many different kinds of methods, viewpoints, modeling languages and tools. The system behavior can be expressed in various ways: as sequences of events, from the viewpoint of states changes, as transfer functions, discrete or continuous, through time-based simulations, through mathematical equations resolution, or as requirements that formalize the system expected behavior. The modeled behavior that result can be prescriptive, representing how we expect the system to behave, or descriptive, representing or anticipating how the system would behave, considering how it is / will be implemented (e.g. represented laws of physics in an acausal way).

The goal of this presentation is to highlight an approach, under development within Airbus, to address systems behavior, through a set of integrated viewpoints and model kinds. This approach relies on the ISO-42010 principles and the elicitation of an ontology, formalizing clear semantic foundations for the description of the behavior of systems. The approach relies on the parallel use of a set of different views and viewpoints, managed in consistency, and that can be associated with different modeling tools and modeling languages. The implementation of the approach also relies on an extensive use of automated modeling and analysis features, to get maximum benefits from its application.

These automated features first aim to support automatic views generation. They aim to ensure the semantic consistency across views, whatever the model kind, tool or modeling language used. Goal is, for the system engineer, to only have to model the information once, and then, to be able to get the best of each generated view. For example, operational and functional scenarios can allow a simple modeling of the expected behavior, in a storytelling way, breaking the complexity, for each scenario, by focusing on only one use case, for a single set of conditions of operation. On the other hand, behavior modeling of functions in a functional architecture model, can allow to obtain a global structured description of the overall expected system behavior, whatever the use cases and conditions. In between, this behavior can also be modeled in the form of functional requirements, expressed as formal properties. They can allow to represent this behavior in an atomic, unambiguous, traceable and testable manner, supporting the overall requirements engineering and testing activities.

By modeling requirements as formal properties and using the Property Model Methodology (PMM), these automated features can also support the requirements validation and verification, using both formal proof analysis and factual testing by simulation. It allows to ensure the overall consistency of requirements, to ensure their attainability and to improve their completeness, ensuring that the overall scope of operation is addressed by at least one requirement. It also allows to validate the captured expected behavior that results, by running interactive simulations with stakeholders and to verify that it behaves as expected. Finally, it can also be used to support factual verification of both the design and the product, by automatically checking that the requirements are well respected, when doing automatic or interactive tests, by simulation or by testing the real product.

The presentation will first introduce the topic and describe associated needs. It will then be followed by a practical demonstration, presenting the approach, and highlighting resulting benefits. It will highlight an example of what can be achieved thanks to the extensive use of the modeling, analysis and automation features. This demonstration will be based on specific developments built upon the MATLAB-Simulink framework.

Following this practical demonstration, the presentation will detail underlying principles and the used

semantic reference. Presented principles will then be extended considering the SysML language, diagrams, and their implementation upon the CAMEO tool suite. The presentation will finally end with presenting the way forward and summarizing main benefits that can be expected from such an approach.

This presentation aims to show to the audience how an integrated approach of the systems behavior modeling and specification can provide significant enhancements of our workflows, methods and usage of modeling features. It aims to show how it can improve the usability of modeling capabilities, improving easiness and intuitiveness of use.

Goal is to demonstrate, on a practical example, how it can drastically improve efficiency of use of MBSE, thanks to an extensive application of automated modeling and analysis features, and by the way, to show how it allows to strongly improve the overall maturity of models and of the resulting architecture, design definition and specification (completeness, consistency and attainability).

Goal is also for the audience to get an understanding of key principles of the approach.

It will also allow both to share and discuss the used reference semantics and ontology, and to share the way forward.

Such a presentation also represents a mean for us to progressively share and extend the approach to our partners, supporting its use in extended enterprise, and to share foundation of the approach across the SE community, with other companies, tool vendors and academics.

Biography



Jean Duprez (Airbus Operations SAS) - jean.duprez@airbus.com

Jean Duprez works for Airbus since 2001. For the past 8 years, he has been in charge of developing future Airbus strategies about Modeling and Simulation of Aircraft Systems; studying various aspects of the MBSE deployment across the overall Airbus Systems Design Office. He is currently in charge of the study, definition and deployment of future SE processes, methods and tools for the Powerplant Center of Competence. Jean also co-chairs the INCOSE Knowledge Management and Ontology Working Group and is part of the TLI (Technical Leadership Institute) cohort 6.



Laurent Royer (The MathWorks) - lroyer@mathworks.com

Laurent Royer is a principal application engineer supporting users of MathWorks products on the customization and deployment of MBSE solutions. Prior to joining MathWorks in 2011, Laurent also accumulated 13 years of experience in Model-Based Design applied to powertrain control at Renault. Graduated in Control and Computer Science from Centrale Lyon, Laurent got a Ph.D. in Robotics at Paris VI.

Raphael Faudou (Samares Engineering) - raphael.faudou@samares-engineering.com

Raphael Faudou is the founder and CEO of Samares Engineering. Samares Engineering was founded with the main goal to focus on MBSE method definition and to support its deployment within industry. Raphael is currently supporting Airbus on DDMS project. He is also co-chair of MBSE technical committee for AFIS, the INCOSE French chapter.

Presentation#29

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

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Presented on: Wednesday, 10:45-11:25

Keywords. Product Line Engineering; System Family Engineering; Feature-based Product Line Engineering; ISO/IEC 26580

Topics. 2. Aerospace; 3. Automotive; 5.3. MBSE & Digital Engineering; 5.6. Product Line Engineering; 6.

Defense;

Abstract. Feature-based Product Line Engineering (PLE) is an approach to efficiently engineer a product line, which is a family of related, similar systems that differ in features and functions. Early generation approaches to PLE required each organization to devise their own tools and methods for managing commonality and variation across the system family engineering lifecycle. Feature-based PLE soon emerged as the de facto standard for PLE due to the availability of commercial off-the-shelf industrial-strength tools and technology, along with robust best practices for methods and processes, which together resulted in less upfront analysis, design, and implementation effort prior to gaining the benefits of PLE.

The INCOSE PLE international working group brought together expert PLE practitioners from around the globe to initiate a formal and official standardization effort, ISO/IEC 26580, entitled “Methods and Tools for the Feature-based Approach to Software and Systems Product Line Engineering.” INCOSE’s PLE Working Group also produced a Primer for Feature-based PLE that is available as a companion piece to the standard.

The 26580 standard will usher in a new era for widespread Feature-based PLE adoption by providing engineering organizations the confidence to embrace the new paradigm that now has international credibility, validation, and backing of organizations like INCOSE and ISO.

This presentation will provide an introduction and overview to this new ISO standard. In addition, it will describe how Feature-based PLE specializes and improves on previous approaches to PLE, give examples of where and how it is being used, and show the economic model behind its success.

Organizations utilizing Feature-based PLE adopt a PLE Factory metaphor to building their products. The factory is a conceptual construct in which a number of key aspects of Feature-based PLE interact:

- The Feature Catalogue captures the distinguishing characteristics of how the members of the product line differ from each other and provides a common language of variation throughout the organization.
- The features selected from the Feature Catalogue for each product in a product line portfolio are specified in a Bill-of-Features.
- Shared Asset Supersets are the engineering artifacts that support the creation, design, implementation, deployment, and operation of products. They contain variation points, which are pieces of content that can be included, omitted, generated, or transformed for a product instance, based on the features selected for that product.
- The PLE Factory Configurator is automation that applies a Bill-of-Features for a product to each variation point in the Shared Asset Supersets, to determine that variation point’s content for the product. The PLE Factory produces Product Asset Instances, each containing only the shared asset content suited for that one product in the product line.

Engineers now work on the Shared Asset Supersets, the Feature Catalogue, and the Bills-of-Features rather than the individual product instances. Once the PLE Factory is established, engineering assets for products are automatically instantiated rather than manually engineered. Feature-based PLE transforms the task of engineering a plethora of products into the much more efficient task of producing a single system: The PLE Factory itself. This consolidation also means that change management and configuration management are performed on the single PLE Factory rather than separately on each of the product instances.

For many organizations, Feature-based PLE represents a shift in engineering approach that requires organizational change along with commitment from engineering and business leadership to make that change. The return-on-investment (ROI) to justify the organizational change is in most cases compelling, based on the elimination of low-value, mundane, replicative work, with doubling, tripling and larger improvements in engineering metrics such as effort, cost, time, scale, and quality. In consideration of this ROI, the question to leadership is, “What if your engineers could do their normal day’s work before lunch; what would you have them do in the afternoon?” There are many answers to this question, all of them good.

After attending, participants should:

- Understand the concepts behind Feature-based Product Line Engineering and how it differs from less efficient forms of Product Line Engineering
- Understand the economic model behind Feature-based Product Line Engineering
- Know examples of where Feature-based Product Line Engineering is being applied in industry and some

of the savings being achieved as a result

- Understand the structure and content of ISO/IEC 26580

Presentation#1

Using Heuristics to Refine the System Physical Architecture

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Presented on: Thursday, 11:15-11:55

Keywords. Model-Based Systems Engineering; Heuristics; Quality Model; Nonfunctional requirements; Medical devices

Topics. 2.4. System Architecture/Design Definition; 4. Biomed/Healthcare/Social Services; 5.3. MBSE & Digital Engineering;

Abstract. One of the challenges systems engineers have to face is how to meet nonfunctional requirements when they developed the model of the system physical architecture. Unfortunately some of the most common MBSE (Model-Based Systems Engineering) methodologies do not provide specific guidance to deal with nonfunctional requirements or consider their implementation similar to the functional ones.

Here, we apply the MBSE methodology named ISE&PPOOA (Integrated Systems Engineering & Pipelines of Processes in Object Oriented Architectures) (Fernandez, 2019) to the development of an intravascular medical devices where some quality attributes such as safety and someilities (reliability and maintainability) are very important.

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

But the modular architecture alone does not meet nonfunctional requirements. To meet nonfunctional requirements two best practices are proposed. One is tradeoff assessment and the other is the use of heuristics. Here we use tradeoff to select the best technology for implementing some of the system core components based on tradeoff attributes obtained from some nonfunctional requirements. So, tradeoff is applied here at building elements level. Some nonfunctional requirements apply how the system is architected that is at connector’s level, so heuristics are the best practice recommended here to implement those nonfunctional requirements that influence on how the building elements are connected. Heuristics and tradeoff are two complementary best practices promoted by ISE&PPOOA methodology.

Heuristics use knowledge from various quality reasoning frameworks (such as efficiency, maintainability, safety or resilience engineering). The quality model we propose is used for classification of the heuristics we collected from diverse sources and to be applied for refining the solution architecture when using ISE&PPOOA.

The quality model (Fernandez, 2019), shows the quality characteristics and sub characteristics we consider more useful for the type of applications where ISE&PPOOA can be used.

A more general quality model is proposed by ISO/IEC 25010 (ISO, 2011), where they describe quality characteristics such as functional suitability, performance efficiency, compatibility, usability, reliability, security, maintainability and portability.

A recent collection of heuristics is proposed by the INCOSE heuristics group where they consider a wider application scope of heuristics and principles (Brook, 2021), some of them related what is so called “elegant design” (Griffin, 2010).

For us, maintainability is an issue for any product to be durable, and reliability is very important for the success of the mission. Safety is a concern in some regulated domains such as aerospace, automotive, medical appliances, and robotics. Resilience is related in this quality model to survivability, adaptation and gracefully degradation, which are very important for some autonomous systems mission fulfillment.

We will present some examples of the heuristics applied to develop the refined physical architecture of an intravascular medical device. This funded research aims to develop a micrometric-size robotic joint, enabling the creation of micro-robotic complex mechanisms for minimally invasive micro-surgery techniques and in-vivo health treatments. The robotic joint will contain a micro-motor connected to a new type of long-lasting gearbox. A very important issue is that it will be wireless powered, thus providing long endurance to any tool or micro-robot activated by it. Other approaches for micro energy harvesting can be found in the literature (Brand, 2015).

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Presentation#2

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

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Presented on: Thursday, 12:00-12:40

Keywords. systems engineering;human systems integration;standards development;risk and opportunity management;human readiness

Topics. 2. Aerospace; 3.6. Measurement and Metrics; 3.9. Risk and Opportunity Management; 4.1. Human-Systems Integration; 6. Defense;

Abstract. This presentation will describe the effort to create and benefits of using an upcoming standard, ANSI/HFES 400-2021 Human Readiness Level (HRL) Scale in the System Development Process. This standard is intended to be used by government and commercial systems engineering organizations, with the US DoD expected to be an early adopter. The presenter is part of the writing committee for this standard, has authored a journal article on the topic, and has given similar presentations at INCOSE and HFES chapter meetings.

In 1970, the US Army began developing the FIM-92 Stinger Man-Portable Air Defense System, a shoulder-mounted missile launcher for targeting incoming enemy aircraft. The system was required to hit the target at least 60% of the time, which it did in developmental testing. But in the hands of actual soldiers, it hit the target only 30% of the time. Though the technology was ready, the system lacked human readiness, resulting in delayed fielding and additional development costs to improve it. A retrospective analysis by the Army found a number of contributing issues: incomplete task analyses, poor usability of key functionality, no requirements for man-portability, and lack of consideration for the cognitive and physical capabilities of the users. In short: the technology was not ready for human use; engineers had not considered the impact of human performance to overall system performance.

Lack of human readiness continues to be a problem for the US Department of Defense (DoD). A 2003 Government Accountability Office analysis found that the Navy could significantly reduce lifecycle costs through the application of HSI, but that the service failed to apply it consistently. A 2020 National Commission on Military Aviation Safety found that 80% of military aviation mishaps are attributed to "human error", yet the recommendations in the Air Force Human Systems Guidebook are often overlooked during system development.

The positive alternative is a system with high human readiness, in which human capabilities are well-integrated throughout the design. This results in improved human and system performance as well as reduced operations and maintenance costs. High human readiness is achieved through systematic and holistic integration of technological and human aspects of the system. The INCOSE SE Handbook describes the systems engineering specialty of human systems integration (HSI), which integrates the domains of staffing levels, personnel, training, human factors engineering, environment, safety and occupational health, force protection and survivability, and habitability. HSI integrates these domains with each other, with the hardware and software components of the system, and with the organizational factors that affect the use of the system.

Though the application of HSI has been required by DoD acquisition regulations since 2007, there exists no structured and objective method for evaluating human engineering maturity. To address this, a cross-functional working group with representatives from government, industry, and academia authored ANSI/HFES 400-2021 Human Readiness Level (HRL) Scale in the System Development Process, which supports HSI practitioners in evaluating and communicating the degree to which human systems activities and processes have been completed for a relevant technology or system in order to achieve desired mission outcomes. The HRL scale is modeled after the Technology Readiness Level (TRL) scale and can complement the TRL scale or be used independently. The nine levels of the HRL scale cover the entire range of development from early basic research to full fielding, ensuring that the appropriate considerations are applied for any stage. They are also adaptable to the broadest definition of system from specific technological solutions to non-materiel and macroergonomic applications. During planning phases, this helps the team think critically about the types of HSI and HSI domain activities necessary for throughout the development effort. The resulting tailoring provides a roadmap of activities that support program startup, budgeting, and development of human engineering plans. Evaluating the HRL throughout the program helps to identify the risk of insufficiently mature human engineering and specific contributing factors which need to be addressed. As with any system deficiency, the sooner the issue is identified the easier and less costly it is to correct.

The Stinger example demonstrates the risk of immature HSI resulting in a system with technological maturity but significant operational issues. Considering human performance as a factor in system performance not only reduces this risk, it also identifies the most effective ways to harness human capabilities to enhance system performance.

Another essential purpose of the scale is to support communication of HSI status to program managers and leaders. TRL has become a useful shorthand across government and industry. Decision makers understand the implication of TRLs: low TRLs require investment and involve uncertainty in the development; middle TRLs must be achieved for key decision gates; high TRLs mean a lower-risk acquisition. HRLs are a similar method for communicating human-system maturity with very similar implications.

The HRL scale addresses a need in the DoD and commercial organizations for a metric to convey HSI maturity and related program risk. Programs with an existing HSI commitment will appreciate the HRL as a helpful guidance document to support development and provide confidence in the effectiveness of the HSI effort. For programs with uneven commitment, the HSI advocate can leverage the standard to demonstrate the importance of HSI investment, quantify the success of their efforts accurately and reliably, and gain leadership buy-in. In any case, the HRL scale is a valuable tool that can reduce risk, increase human system readiness, and result in a more effective solution for any industry or application.

The audience will learn what human readiness is, why it's important in systems engineering, how to utilize the HRL scale to evaluate and communicate human readiness, and potential pitfalls to be aware of when applying the HRL scale.



Invited Content

Invited Content#TechOps#3

S.O.S. for FSS: The need for Systems of Systems (SoS) Thinking per Financial Services Architectures, both Current and Emerging.

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Presented on: Monday, 13:15-13:55

Keywords. Agile Systems and Systems Engineering; Architecture; Complex Systems; Lean Systems Engineering; Requirements; Resilient Systems; System of Systems

Abstract. During the session we will review the natural evolution of the financial services industry with its current and evolving technology paradigm. With technology emergence and convergence, Financial Institutions have evolved both their business and technology models. As such, now more than ever, a systems-of-systems approach can support sound governance and overall competitiveness for firms and industry. We will justify the claims as we dive into a series of emerging patterns and use cases and map fundamental Systems Engineering practices.

Invited Content#Inv#2

DE meets SE: Building a Joint Culture

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Philomena Zimmerman - Philomena.m.zimmerman.civ@mail.mil

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Presented on: Tuesday, 12:30-14:40

Abstract. Systems Engineering is a relatively new and evolving discipline when compared to classical engineering disciplines. However, its application and importance in organizations continue to grow as systems become more complex, giving rise to Systems of Systems and new and evolving domains. Digital Engineering is an engineering strategy and implementation approach to all levels and types of engineering discipline that takes advantage of today's rapidly evolving digital ecosystem, including new tools, technologies, big data, tighter feedback mechanisms that speed the flow of information, and system innovation. This session will discuss the relationship between DE and SE and the synergistic effects and pitfalls of each practice and together. The session will explore the cultural implications of DE and SE implementation and the question: DE helps an organization develop or improve SE, or is it best if you already have a strong SE culture/process/etc.

Invited Content#TechOps#4

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

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Presented on: Monday, 14:00-14:40

Abstract. Come join us to hear about how INCOSE is leading the way in the area of diversity, equity, and inclusion (DEI) in systems engineering. We will cover a short history of events of the last several years that include both personal insights and turning points on a collaborative journey to creating a more inclusive INCOSE. The presentation will also cover methods, processes, and tools that members of the DEI task team have used to develop a way forward. And the audience will also hear from our newly appointed Associate Director of Diversity, Equity, and Inclusion. Please plan to attend to both be informed and inform the DEI team on DEI related opportunities, challenges, and recommendations.

Panel: The Journey from SysML 1.7 to 2.0

Daniel Siegl - Daniel.Siegl@lieberlieber.com

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Presented on: Monday, 15:10-16:35

Abstract. In this panel session, we will have various parties talk about their take on what will be required to make the transition from SysML 1.7 to 2.0 a success for the MBSE Community.

Questions we will discuss with the panelists:

- What are the biggest benefits for the Systems Engineer
- Will Systems Engineering change with SysML 2.0
- How will the Transition from 1.7 to 2.0 work in the real world?
- Will SysML 2.0 Tools be more interoperable than 1.X Tools?
- What is a realistic expectation on timelines - from when can I work with 2.0?
- Will it be easier to learn?

The objective for this session is to provide a forum to hear the opinions of various Systems Engineering experts! The desired outcome is that the attendees will come to a clearer understanding of what the release and commercial availability of SysML 2.0 tooling will affect their Systems Engineering efforts.

Biography



Hans Peter de Koning (DEKonsult, Amsterdam, The Netherlands) -

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Hans Peter retired from ESA (European Space Agency) end 2019, with more than 35 years of experience in modeling, analysis, design and verification of (mainly) space systems. The last 10 years at ESA he was the responsible systems engineer for methods, tools and standards for multi-disciplinary, model-based concurrent engineering. Since 2020 he has his own consultancy company focusing on standards for digital engineering. He is an active member of the SysML v2 Submission Team at OMG, working primarily on the supporting model libraries. In INCOSE his main contributions are to the MBSE Initiative and the INCOSE-NAFEMS Systems Modeling and Simulation WG.

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

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Presented on: Monday, 10:00-11:25

Abstract. This session takes the form of a debate with one side proposing the proposition and the other opposing it. The proposition of this debate is:
"The 'Vee' model has outlived its usefulness and serves as a barrier to achieving the SE Vision"
The objective for this session is to provide a forum for people to debate this proposition by airing their views on the "Vee" model and its role in systems engineering. It should be remembered that this is a debate and the presentations may or may not be reflect the actual views of the participants. The desired outcome is that the attendees will come to a clearer understanding of how to think about and use this abstraction in their Systems Engineering activities. Just as there is no single definition of "system" that works for everyone, it is not expected that there will be a single view of the "Vee" that fits all, rather this debate will provide a diversity of opposing views so that participants and attendees can decide for themselves how to consider the "Vee" in their work. This debate session will consist of five short presentations on the "V", one historical and two pro and two con, followed by two questions from each side, and then an open Q/A from the audience. The audience's opinion on the proposition will be polled at the beginning and end of the debate. The "winner" of the debate is the side whose position on the proposition gained the most points.

Invited Content#4

Spectacular Views of the City

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Presented on: Monday, 12:30-13:10

Keywords. Smart Cities; Smart Cities Initiative; Deloitte model; TUSS model; MBSE

Abstract. As the INCOSE Smart Cities Initiative prepares its first work products, it is finding seemingly diverse points of view in several practicing definitions of the Smart City. There is no right or wrong model. Each model has a spectacular view of the city, and each model can offer valuable information (from its limited viewpoint) on how the city operates and how it could improve. When modeling, analyzing and optimizing the operations of a complex system, it's important to model the system from various viewpoints. This, of course, is a lesson from the ancient fable of 'the blind men and the elephant'; that we cannot claim an absolute truth based on one true but limited viewpoint while ignoring other equally true but limited viewpoints. Models are used in MBSE to map and keep track of the myriad butterfly effects caused by design and operational changes in complex real systems. But a single model is only a limited viewpoint, for the very reason that the real system it attempts to model is so complex. Comparing the complex system from various MBSE modeling viewpoints can help bring clarity.

In this presentation, we compare the viewpoints of two prominent Smart City definitions; Deloitte's viewpoint based on the idea that Smart cities emerge as the result of many Smart Solutions across all sectors of society, and TUSS's viewpoint based on the idea that a Smart city is a city that has the ability to identify its problems and its root causes promptly and remove the root causes by generating, and processing engineered quality data in a continuous and inclusive manner.

A comparison graphic illustrates how these are just two of the many views of the same elephant.

Invited Content#Inv#4

The next Systems Challenge: Developing resilient, effective, inclusive, sustainable societal systems of systems

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Presented on: Thursday, 10:30-12:40

Abstract. The modern world has a range of interconnected challenges. Global peak population is expected to reach 9.7Bn in the next 40-50 years. Societies need to provide food, water, housing, healthcare and security at the same time as dealing with climate disruption, unprecedented technological change and ensuring all in society benefit.

We already have well established and complex systems (e.g., transport, information, power, and urban infrastructure). Each of these systems have clear supply chain networks, consumers, markets and

regulators. In modern societies each of these are, in themselves complex systems of systems, which in turn form part of a wider system of systems.

This complex, and undesigned, network of different systems faces specific challenges. It is inefficient, both financially and in terms of carbon consumption. It is fragile, with failures in one system threatening a cascade of failures across apparently unrelated systems. Finally, it is opaque, potentially disadvantaging some groups over others.

This interactive session will:

- Explore the nature of these systems we are seeking to develop, with panelists sharing tangible examples of system interdependencies, trade-offs and challenges to illuminate the increasing complexities between these nested systems of systems;
- Explore the transition to systemic approaches and the future Systems Engineering practices that must be taken to meet these challenges; and
- Engage delegates on a journey of collective exploration to experience the deepening complexities we as Systems practitioners must be prepared to navigate with others.

Biography

Anne O'Neil (Anne O'Neil Consultants) - systems.oneil@gmail.com

Anne O'Neil serves as a committed global catalyst for building Systems capability among mobility and infrastructure sectors. Her firm advises organizations seeking to adopt Systems practices and apply Systems Engineering capability to achieve and improve business outcomes. Anne counsels industry leaders from increasingly diverse sectors facing complexity and integration challenges. As founding Chief Systems Engineer for MTA New York City Transit (NYCT) 2005-2013, Anne established an SE capability to improve the agency's capital project delivery. This required developing systems engineering discipline expertise and modifying the agency's business processes. It also necessitated effecting change and building Systems awareness at an industry level – among peer transit properties, consultants, contractors and systems suppliers. Anne has long served as a systems champion within infrastructure sectors, raising Systems awareness as a global speaker and lecturer. Former Director of Industry Outreach, INCOSE Board of Directors; INCOSE Founder (2011); and current Industry Outreach Ambassador.

Jim Bentley (New South Wales (NSW) Water Sector, NSW Department of Planning, Industry and Environment)

Jim Bentley is Chief Executive Officer, New South Wales (NSW) Water Sector and Deputy Secretary of Water, NSW Department of Planning, Industry and Environment. He was formerly Managing Director of Hunter Water Corporation for Newcastle NSW [Australia]. Jim has extensive global experience in infrastructure services, particularly in the water industry, having spent 6+ years in executive roles in Australia, New Zealand; and 12 years with Thames Water, including six years in the international business mainly focused on Turkey and the Middle East. Jim is a Professor of Practice in Business Law at the University of Newcastle NSW and Visiting Professor in Engineering at University College London, UK. Jim is a senior executive with extensive experience, working across both the private and public sector. His deep knowledge of water utilities supports his current role where he oversees billion-dollar water infrastructure programs, the prioritisation of water projects and works closely with utility companies. Jim has a history of Systems Thinking, evidence-based decision making, with a background in infrastructure services consulting.

Dr. Kirsten MacAskill (University of Cambridge)

Kristen's professional interests are centred on disaster risk management, post-disaster reconstruction, sustainable development of cities and resilience in infrastructure development. This interest has spanned roles as a consulting engineer, as director of a professional-oriented master's programme, through her research and through her teaching at both undergraduate and postgraduate levels. She now specialises in using cross-disciplinary research methods to explore governance issues in the management of infrastructure and the delivery of major infrastructure projects

Dr. Catherine Tilley (King's College London)

Catherine brings extensive experience of working as a consultant and researcher examining complex organisational problems and the way people take decisions in these settings. She has worked as a consultant and researcher with engineering organisations, on topics including risk management, knowledge management and sustainability. More recent work has included analyses of systemic problems and organisational responses to these over time

Using Systems Thinking to Add Value in these Uncertain Times

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Presented on: Wednesday, 12:30-14:40

Abstract. The intersection of three global crises: Pandemic AND Climate Change AND Global Pollution, provides the opportunity for INCOSE to innovatively learn together. Culture develops through the network of conversations it stimulates. Emergence outcomes can spread globally at extraordinary rates and scales. These three crises can no longer be ignored because their impact is felt on a global scale. The buffers of time and space that our planet provides have been depleted so we are seeing the emergent effects in global crises. There is a growing need to focus not just on symptoms, but on underlying patterns, architectures and root causes; to understand mental models that drive these and thereby mitigate the dangers from unintended consequences and turn crises into opportunities. These are complex problems. Systemic frameworks have evolved heuristically to help people make sense of such complex problems. These include the “Systemic View of Complex Challenges” and Cynefin. When heuristics is placed in the context of the whole, the systems science framework gives deeper meaning. INCOSE, in collaboration with ISSS, has been working to create a holistic framework for systems science. Its purpose is to provide the means to organise the pursuit and practice of systems knowledge as a learning system. Systems engineering experience has played a vital role in shaping the framework and when our heuristics are placed in the context of the whole, new insights and connections emerge. With the application of these approaches, greater fidelity, and performance in our systems engineering discipline is anticipated. It is exciting that a framework now exists and it will be used as part of this learning experience. AND with the art of harmonisation, a systems approach can stimulate global collaborative actions that will modify behaviours and enable us to learn to mitigate the dangers. Crisis is thereby turned into opportunity.

Biography

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Solution Architect and Technical Manager. VP System Practice at the ISSS.
Senior Editor - System Engineering Body of Knowledge - Section 2: System Foundations
Main past experience :
Industrial Chemist, Relational Database Systems, Software and Systems Developer.
Engineering Development PM, Customer Contracts PM (telecoms infrastructure delivery),
Corporate Project Management. Technical Management of complex systems. Architect of
Systems of Systems and business transformation solutions.

Viewing Grand Challenges as a System

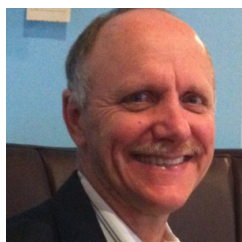
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Presented on: Monday, 12:30-14:40

Abstract. The National Academy of Engineering published a list of fourteen Grand Challenges which fall into four cross-cutting societal themes: sustainability, health, security, and joy of living. INCOSE's Vision 2025 describes a framework coupling societal needs to systems challenges, then to gaps in the capabilities of Systems Engineering. "Global trends include changes to both socioeconomic conditions and changes in our physical environment. These global changes impose new demands on the types of systems that are needed, yet are often impacted by the very technology and system developments meant to satisfy the human needs. For example, increased population growth and urbanization impose new challenges on transportation, health, and other modern infrastructures, while at the same time, systems solutions and technology itself can adversely impact air and water quality." Vision 2025 continues: "Large and often complex engineered systems are key to addressing the Grand Challenges and satisfying human and social needs that are physical, psychological, economic and cultural." Grand Challenge themes should address a scope which covers all aspects of the system outcomes whoever they are delivered by. Enterprises must consider the balance of finite resources and trade-offs across the full scope; how to set the necessary level of human and technical integration; and the need to remain viable within environmental factors and possible threats. All decisions must consider what is acceptable within the social context in which they sit. With this in mind, this panel will highlight the intersection of grand challenge areas, particularly with respect to human and social needs.

Biography



Bob Kenley (Purdue) - kenley@purdue.edu

C. Robert Kenley is a Professor of Engineering Practice in Purdue's School of Industrial Engineering, where he has been developing courses and curricula to support the educational objectives of the Purdue Systems Col-laboratory. He has over thirty years' experience in industry, academia, and government as a practitioner, consultant, and researcher in systems engineering at Lockheed, the Idaho National Lab, MIT, and Purdue. He has a Ph.D. and M.S. in Engineering-Economic Systems from Stanford, an M.S. in Statistics from Purdue, and an S.B. in Management from MIT. He has published papers on systems requirements, technology readiness assessment and forecasting,

Bayes nets, applied meteorology, the impacts of nuclear power plants on employment, and model-based systems engineering, and agent-based modeling for systems of systems. He is an expert system engineering professional (ESEP) and a Fellow of INCOSE.

Invited Content#WNB

Welcome New Member

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Presented on: Thursday, 14:30-15:30

Key Reserve Paper

Key Reserve Paper#104

A State-of-Practice Survey of the Automotive and Space Industry Product Development Strategies

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Keywords. Product Development; Systems Engineering; Space Systems; Automotive; Concurrent Engineering; Modular Architecture

Topics. 2. Aerospace; 2.2. Manufacturing Systems and Operational Aspects; 2.4. System Architecture/Design Definition; 3. Automotive; 5.6. Product Line Engineering; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Product Development is a process employed by all industries to support creating new opportunities. The approach to product development by the automotive industry is vastly different than the space industry. The methods of design, management and architecture are the topics reviewed in this work. From the background of these approaches, the analysis of trends in each of these industries suggest that the space industry is in the beginnings of an evolutionary change. Based on the trends for the space industry, there are possible product development management and architectural changes the automotive industry can pass along.

An Agile Systems Engineering Analysis of a University CubeSat Project Organization

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Keywords. agile;cubesat;academic;sociotechnical;knowledge management;space

Topics. 1. Academia (curricula, course life cycle, etc.); 2. Aerospace; 22. Social/Sociotechnical and Economic Systems; 3.7. Project Planning, Project Assessment, and/or Project Control; 5.1. Agile Systems Engineering;

Abstract. CubeSats are often built at universities for both educational and advanced scientific purposes. The challenges that CubeSat projects face include both technical and sociotechnical aspects, such as knowledge management and goal alignment. Universities, however, often lack systems for having effective project management or systems engineering which is beneficial to develop complex systems. An exploratory case study of a university CubeSat team developing their first CubeSat is the basis of this paper. The Agile Decision Guidance method was applied to pinpoint parts of the project organization which could benefit from agile methods. The specific spaces looked at were the: customer problem space, solution space, and product development space. The parts identified are related to the university context and its constraints. The factors that could benefit from an agile approach include stakeholder management, knowledge and information management, and the support environment. We outline some of the plans to move forward and how the team responded to the analysis. We also discuss if the method was appropriate for academic small satellite organizations and what possibilities there are for applying agile in academic CubeSat teams.

Architecture Analysis Methods

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Keywords. Architecture;Architecting;Architecture analysis;Architecture evaluation;Architecture characteristics;Architecture evaluation methods

Topics. 1.6. Systems Thinking; 11. Information Technology/Telecommunication; 2.4. System Architecture/Design Definition; 5.5. Processes; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Architecture as a discipline is gaining prominence in dealing with the size, sophistication and complexity of human-made entities. Organizations evaluate architectures to determine: fitness for purpose; presence or absence of characteristics; satisfaction of requirements; goodness, completeness and consistency; effectiveness and suitability; coping with change; stakeholder concerns are addressed adequately and so on. Organizations find it difficult to evaluate architectures as there are few publicly known architecture analysis methods, most of the methods are proprietary, architecture descriptions use different terminologies, architecture/system characteristics are wide and varying in nature and there is considerable manual skill and effort involved. In this paper, a few architecture analysis methods that can be codified and used to evaluate a wide variety of architectures across different domains are presented. Further, the efficacy of these analysis methods is illustrated with appropriate examples.

Architecture Literacy

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Keywords. Architecture;Architecting;Architecture decisions;Architectural Intervention;Architecture Literacy;Fundamental Concepts;Essential Principles and Properties

Topics. 1.6. Systems Thinking; 11. Information Technology/Telecommunication; 18. Service Systems; 2.4. System Architecture/Design Definition; 5.9. Teaching and Training; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Architecture as a discipline is gaining prominence in dealing with the size, sophistication and complexity of human-made entities. The architectures of these entities are expressed by architecture descriptions that depict how stakeholder concerns are addressed. Often, many stakeholders find it difficult to understand the underlying architectural concepts, properties and principles even though they are aware of the context of use and make decisions without understanding the consequences of their actions. Organizations often deal with the ripple effects of these uninformed decisions. In this paper, a few fundamental architecture concepts, principles and properties are presented with the expectation that it will help individuals understand and make better architecture related decisions

Automated trade study analysis based on dynamic requirements verification in the model-based system engineering

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Keywords. Trade Study;Trade-Off;Requirement verification

Topics. 2.6. Verification/Validation; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. In this complex world, where evolving systems communicate independently to achieve a common goal, the ability for an engineer to develop systems with traceability to requirements, using one integrated architecture model that enables all types of automated analysis (e.g., impact analysis, gap analysis, trade study analysis, and simulation) is becoming more and more vital. Today, the core enabler for automated analysis is the application of model-based systems engineering practices. Model-based systems engineering is used to capture system or systems of systems architecture as descriptive and analytical system models, which relate text-based requirements to the architecture and provide an infrastructure to support trade study analysis. One of the core techniques to perform such analysis is requirements verification. This paper proposes an approach for an automated trade study analysis based on dynamic requirements verification in the model-based systems engineering environment, with a goal to support trade of analysis both in the system of systems and systems engineering domains.

Broadening the Definition of Breadth in Systems Engineering

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Keywords. Expertise development;competency;Systems

Topics. 1. Academia (curricula, course life cycle, etc.); 1.6. Systems Thinking; 3.5. Technical Leadership; 5.9. Teaching and Training;

Abstract. Breadth versus depth is an aspect of systems engineering that is often referred to but seldom fully defined. This paper presents results of recent research that defines multiple aspects of depth that should be considered and discusses their value.

Conceptualizing the Lessons Learned Process in Delivery Projects: Detecting Knowledge Flow Barriers

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Keywords. Knowledge Management; lessons learned; Root cause analysis

Topics. 13. Maritime (surface and sub-surface); 3.4. Information Management Process; 3.5. Technical Leadership; 5.2. Lean Systems Engineering; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Knowledge is vital intellectual property and is one of the most significant assets of an organization. Notably, it needs to be highly prioritized and managed strategically to enhance continuous improvement by capturing and reusing knowledge. Technology enterprises are associated with innovation, productivity, a collaboration of multidisciplinary professionals, tight budgets, and challenging time-schedules. These factors combined are often what leads to challenges with knowledge management. Frequent disappointments with past knowledge management initiatives have motivated organizations to gain a new understanding of the complex mechanism of knowledge, which governs the effectiveness of an enterprise. This study elaborated on identifying knowledge flow barriers and handling knowledge by lessons learned (LL) practice in a case company and identify changes to ameliorate the flow. Albeit, the observations revealed that the difficulties related to finding LL documents were not the main issue, it was the contribution of the leaders. The case company demonstrated a discrepancy between what they said they do, and what they actually do. Besides these barriers, the research also detected divergence in the fundamental understanding of the theoretical aspects within knowledge management and LL, which indicates confusion and absence of awareness for the project managers and the leaders. Implementation of Systems Engineering (SE) methods, such as Communities of Practice (CoP) or triple loop lessons learned may fill both the gaps in the company but also in the literature when it comes to improving knowledge flow in large-sized delivery projects.

MBSE Enabled Trade-Off Analyses

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Keywords. MBSE;Trade-Off Analyses;Tradespace;Decision Analysis

Topics. 1. Academia (curricula, course life cycle, etc.); 3.3. Decision Analysis and/or Decision Management; 5.3. MBSE;

Abstract. This paper examines the potential to use Model-Based Systems Engineering (MBSE) tools to perform trade-off analysis of alternative systems decisions in the system life cycle from the concept stage to the retirement stage. Specially, we seek integrated models that automate the simultaneous evaluation of the performance, effectiveness, stakeholder value, and cost of multiple alternative system designs. We used the Web of Science to perform a literature search to identify published papers that describe the use of MBSE tools to support automated analysis of alternatives and trade-off analyses. We found very few papers that claimed to use MBSE to provide analysis of design alternatives or tradespace exploration. Based on the literature search insights, we identify and describe the required and desired capabilities to perform automated trade-off analyses of performance, effectiveness, stakeholder value, and cost for multiple system design alternatives using integrated models.

Model of Models Methodology: Reuse Your Architectural Data

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Keywords. MBSE;Systems Engineering;Digital;Methodology;Reuse

Topics. 2. Aerospace; 2.4. System Architecture/Design Definition; 3. Automotive; 5.3. MBSE; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 6. Defense;

Abstract. One of the primary and underutilized benefits of Model Based Systems Engineering is reuse. Most users of Model Based Systems Engineering lack the understanding of the process involved to develop a project tree that enables use of projects in other projects to facilitate that multi-dimensional reuse. Although, the benefits speak for themselves, few practitioners fully grasp the modeling techniques, and rigor, necessary to facilitate a model that is fully traced, modular, and reusable. The Model of Models methodology satisfies these needs, accomplishing the Digital Engineering needs on the project as well as enabling significant time and cost savings.

OMG RAAML standard for model-based Fault Tree Analysis

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Keywords. Safety and Reliability Profile; SysML; Fault Tree Analysis; Model Based Safety Assessment

Topics. 14. Autonomous Systems; 2. Aerospace; 3. Automotive; 4.3. Reliability, Availability, and/or Maintainability; 5.3. MBSE;

Abstract. Fault tree analysis (FTA) is a top-down method for identifying the discrete primary failure events that lead to system failures (top level events), and the means for determining the probability of the top-level events if the probabilities of primary discrete failure events are known. Fault tree models document the logical combination of events that support fault tree analysis. This paper presents part of a forthcoming OMG standard “Risk Analysis Modeling Language” (RAML) that defines a UML library and profile for fault tree modeling that can be used alongside the OMG ModelBased Systems Engineering language, SysML. This enables fault trees to be co-modeled with the system models with all the benefits of direct inter-model linkage, versioning, and change-impact analysis.

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

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Keywords. Digital transformation; Organizational redesign; Systems approach; Systems engineering; Human-centered design

Topics. 19. Very Small Enterprises; 3.4. Information Management Process; 3.7. Project Planning, Project Assessment, and/or Project Control; 4. Biomed/Healthcare/Social Services; 5.5. Processes;

Abstract. In the process of developing novel drugs to treat diseases, including COVID-19, companies consistently face challenges of budget and schedule overruns. Most R&D contractors involved have their own execution model in handling systems complexity, however a traditional way of executing the projects may not be sustainable for the growth and competitiveness. The case study discussed is a life-science company performing structure-based drug design research services. The shift of organizational execution model is enabled by the digital assistance and associated with the recent organizational structure change from hierarchy-based to matrix-based. We focus on the redesign of working process in organizational execution, which is the key determinant for project productivity and quality. However, there is no official international standard regarding organizational interface management. Using human-centered design and systems engineering methodology as well as the best practices from the case study, this study presents an approach to enable a digital transformation of such an organizational re-design with improved performance.

Overview of the Revised Standard on Architecture Description - ISO/IEC 42010

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Keywords. architecture; architecture description; architecture framework; architecture modeling; architecture views; architecture viewpoints; standard

Topics. 2. Aerospace; 2.4. System Architecture/Design Definition; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. An updated version of the international standard for Architecture Description is expected to be published in 2021 as the new version of ISO/IEC/IEEE 42010. This paper provides an overview of the key concepts defined by this standard and the rationale for them. In particular, it describes the key new concepts such as aspects and perspectives that were incorporated to bring this into alignment with current architecting and MBSE practices. These concepts are used as the basis for architecture description templates and guidelines contained in methodology documents and in architecture modeling tools.

Using Digital Viewpoint Concept Model for Defining Digital Engineering Information Exchange

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Keywords. Systems Science;Acquisition and/or Supply;MBSE;Digital Engineering

Topics. 1.5. Systems Science; 20. Industry 4.0 & Society 5.0; 3.1. Acquisition and/or Supply; 5.3. MBSE; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. The Digital Engineering Information Exchange Working Group (DEIXWG) is a collaboration between the International Council of Systems Engineers (INCOSE), the National Defense Industry Association (NDIA) Modeling and Simulation (M&S) Subcommittee, and the Department of Defense, Office of the Under Secretary for Research and Engineering (DoD/OUSE (R&E)). DEIX WG supports the strategic objective to accelerate the digital engineering transformation by evolving the characterization of the content and relationships involved in the exchange of digital artifacts between disciplines and stakeholders throughout the engineering lifecycle. The DEIXWG aspires to ensure that digital artifacts are transferable within industries developing complex systems. To address the challenges of digital artifact exchange, the DEIXWG created a Digital Viewpoint Model (DVM) Concept Model to define key concepts of exchange.

Workforce and Evaluation and Training for Digital Engineering in the US Department of Defense

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Keywords. digital engineering;workforce development;training;defense

Topics. 1. Academia (curricula, course life cycle, etc.); 5.3. MBSE; 6. Defense;

Abstract. Digital engineering (DE) is “an integrated digital approach that uses authoritative sources of systems’ data and models as a continuum across disciplines to support lifecycle activities from concept through disposal. A DE ecosystem is an interconnected infrastructure, environment, and methodology that enables the exchange of digital artifacts from an authoritative source of truth.” Digital transformation is fundamentally changing the way acquisition and engineering are performed across a wide range of government agencies, industries, and academia and is characterized by the integration of digital technology into all areas of a business, changing fundamental operations and how results are delivered in terms of new value to customers. It includes cultural change centered on alignment across leadership, strategy, customers, operations, and workforce evolution. In 2020, the [ORGANIZATION] developed a Digital Engineering Competency Framework (DECF) to support the US Department of Defense (DoD). The [ORGANIZATION] is mapping existing DoD training resources against the DECF to identify gaps and create recommendations on how to build the digital engineering competency of the DoD workforce.
