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Plenary featuring Keynotes

Plenary featuring Keynote#K3

AI in Action: Current Applications Transforming the World and Their Unintended Consequences

Mark Kelly (President of AI Ireland)

Biography

Mark Kelly (President of AI Ireland)
Mark Kelly, author of "AI Unleashed" and "AI Essentials," is a leading AI authority known for his engaging TEDx talks. As the founder of AI Ireland and a key figure in AI staffing, Mark has driven global AI adoption strategies.
His approach combines deep industry insights from over 500 AI applications and 600 leader interviews with practical, solution-focused methodologies.
Regularly featured in international media and as a television correspondent, Mark advises top organisations on AI integration.
His extensive social media following and popular newsletter further amplify his influence. Connect with Mark on LinkedIn, Twitter, or YouTube, and visit his website for more on his work and publications.

Engineering Tomorrow: Navigating Pathways to Industry 5.0

Kathryn Cormican (University of Galway)

Biography

Kathryn Cormican (University of Galway)
Kathryn Cormican is a Professor of Systems Engineering and Director of the Enterprise Research Centre in the School of Engineering at the University of Galway in Ireland and a funded investigator in Lero – The Irish Software Research Centre. She leads a large multidisciplinary research team. Her work focuses on the design, development, and validation of novel processes and information systems to enable smarter user-centred solutions. She is currently leading three EU-funded projects comprising researchers and practitioners. She is internationally recognised for her contribution to research and has won many prestigious best-paper awards including the European Academy of Management best paper award in 2023. She has delivered several keynote addresses at international conferences and has published extensively in high-impact journals in her field. Kathryn directs an award-winning MSc programme specifically designed to equip graduates with the requisite skills needed for employment in the high-tech industry. She received the President's Award for teaching excellence in 2018 and was awarded Female Entrepreneurial Leader of the Year in 2022 by the Accreditation Council for Entrepreneurial and Engaged Universities.

Risk, uncertainty and complexity

Dave Snowden (The Cynefin Center)

Topics. #TechnicalLeadership

Biography

Dave Snowden (The Cynefin Center)

Dave is the creator of the Cynefin Framework and originated the design of SenseMaker®, the world's first distributed ethnography tool. He is the lead author of Managing complexity (and chaos) in times of crisis: A field guide for decision-makers, a shared effort between the Joint Research Centre (JRC), the European Commission's science and knowledge service, and the Cynefin Centre.

He divides his time between two roles: founder and Chief Scientific Officer of The Cynefin Company and the founder and Director of the Cynefin Centre. His work is international in nature and covers government and industry looking at complex issues relating to strategy and organisational decision-making. He has pioneered a science-based approach to organisations drawing on anthropology, neuroscience, and complex adaptive systems theory. Using natural science as a constraint on the understanding of social systems avoids many of the issues associated with inductive or case-based approaches to research. He is a popular and passionate keynote speaker on a range of subjects and is well known for his pragmatic cynicism and iconoclastic style.

Dave holds positions as an extraordinary Professor at the Universities of Pretoria and Stellenbosch as well as visiting Professor at the University of Hull. He has held similar positions at Bangor University, Hong Kong Polytechnic University, Canberra University, the University of Warwick and The University of Surrey. He held the position of senior fellow at the Institute of Defence and Strategic Studies at Nanyang University and the Civil Service College in Singapore during a sabbatical period in Nanyang.

His paper with Boone on Leadership was the cover article for the Harvard Business Review in November 2007 and won the Academy of Management award for the best practitioner paper in the same year. He has previously won a special award from the Academy for originality in his work on knowledge management. He is an editorial board member of several academic and practitioner journals in the field of knowledge management and is an Editor in Chief of E:CO. In 2006 he was Director of the EPSRC (UK) research programme on emergence and in 2007 was appointed to an NSF (US) review panel on complexity science research.

He previously worked for IBM where he was a Director of the Institution for Knowledge Management and founded the Cynefin Centre for Organisational Complexity; during that period, he was selected by IBM as one of six on-demand thinkers for a worldwide advertising campaign. Prior to that, he worked in a range of strategic and management roles in the service sector.

Systemic leadership in a TUNA world

Professor Brian Collins (University College London)

Biography

Professor Brian Collins (University College London)

Professor Brian Collins took up the role of Professor of Engineering Policy at UCL on 1st August 2011 retiring as emeritus in 2020. He led the creation of a £278M capital investment programme in 14 Universities in the UK, UKCRIC, which he launched in 2017 which enables the UK to have a robust and innovative research and analysis base for informing the £700B estimated spend in Infrastructure in the UK in the next few decades. He is also currently vice chair of the National Preparedness Commission, whose mission is to help the UK be better prepared for an uncertain future. https://nationalpreparednesscommission.uk/

Prior to joining UCL he was the Department for Transport's (DfT) Chief Scientific Adviser (DCSA) from October 2006 and DCSA for the Department for Business Innovation and Skills (BIS) from March 2009 after being DCSA in Department for Business, Enterprise and Regulatory Reform (BERR) from May 2008, during which time Energy policy was in his remit. During that time with GCSA, he led the creation of the network of CSAs, and was involved in the studies that created the DCSA for national security. He left both DCSA positions at the end of June 2011.

He has contributed to many committees and boards; Safer Complex Systems as part of Engineering X at RAEng, Science as an Open Enterprise at Royal Society, Cybertrust and Crime Prevention Foresight study, CST report 'A National Infrastructure fit for 21st Century, RAEng Trustee Board, EPSRC Council, Vice President on the Trustee Board of IET.

He was Professor of Information Systems at Cranfield University from August 2003 to 2011.

Prior to these activities he was Global CIO for Clifford Chance, IT Director for the Wellcome Trust, Chief Scientist for all UK Intelligence Services and Director of Technology at GCHQ at the end of the 1980s. He was Deputy Director at RSRE just prior to privatisation into now what is Qinetiq and DSTL.

He was bestowed by Her Majesty the Queen the Honour of Companion of the Bath (CB) in the 2011 New Years Honours list. He was elected a Fellow of the Royal Academy of Engineering in 2009

He holds a visiting Professorship at Southampton University and Honorary Doctorates at Kingston and City of London Universities.

He has an MA in Physics and a D.Phil in Astrophysics both from Oxford University.

Papers

Paper#331

A Case Study of AI Usage within the INCOSE Technical Process

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Keywords. Artificial Intelligence;Product Development Process;INCOSE Technical Process;Customer Need Identification;Architecture Definition

Topics. 2.4. System Architecture/Design Definition; 5.11. Artificial Intelligence, Machine Learning; #AI

Abstract. The purpose of the research described herein is to analyze the use of AI platforms by a user implementing a generic Product Development Process (PDP) mapped onto the INCOSE Technical Process (ITP) and to identify the advantages and disadvantages.

A Classical Modernization of the V-Model

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Keywords. Digital Engineering;V-Model;Systems Engineering;Modernization;Test and Evaluation

Topics. 1. Academia (curricula, course life cycle, etc.); 1.5. Systems Science; 5.3. MBSE; 5.5. Processes; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. This paper provides new iconography for the Systems Engineering "V-Model". The "Arch Model" resets and refreshes the original iterative intent of the "V-Model" in a modern context integrated with digital engineering (DE). We will highlight common misperceptions that reduced the efficacy of the "V-Model" and explore how a "classical Roman engineering" metaphor can inspire a modern view of systems development based on historically successful, foundational engineering.

A Method for Human Systems Integration Requirements within Model Based Systems Engineering

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Keywords. MBSE;SysML;human factors;design;Vee-model;requirements engineering

Topics. 13. Maritime (surface and sub-surface); 2. Aerospace; 2.3. Needs and Requirements Definition; 4.1. Human-Systems Integration; 5.3. MBSE; 6. Defense;

Abstract. The Department of Defense (DoD) is no stranger to human factors requirements, but our revolutionary approach addresses the unique challenges faced by special operations in unconventional warfare scenarios. Introducing the Relational and Technological Capstone (RTC), a novel framework designed to expand Human Systems Integration (HSI) requirements, elevating the consideration of human factors while supporting cross-cooperation with other nations in optimizing special operation acquisitions.

Paper#563

A Model Based System Engineering Approach for Trucking Fleet Replacement

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Keywords. transportation;heavy vehicle;fleet management;environment;model-based systems engineering;sustainability

Topics. 17. Sustainment (legacy systems, re-engineering, etc.); 21. Urban Transportation Systems; 3. Automotive; 3.1. Acquisition and/or Supply; 4.2. Life-Cycle Costing and/or Economic Evaluation;

Abstract. Heavy vehicles operating for less than truckload (LTL) carriers are utilized to the maximum extent possible for the operator to maximize vehicle return on investment. However, the decision to purchase new vehicles, reallocate the vehicle, or retire the vehicle is based on complex and interacting factors like performance degradation, total cost of ownership, new regulatory pressures, and maintenance costs. The problem of optimizing fleet capacity is well suited to a model-based systems engineering approach. Using SysML as the language and MagicGrid as the method, a model for fleet vehicle replacement and utilization was built to understand the best way to maximize and grow shipping capacity. The process started with identifying stakeholders and their needs and ended with system parametric models capable of computing costs. This model has the potential to optimize operating costs for fleets and maximize the use of the vehicle assets. Not only do these optimizations improve company financial performance, they reduce the need to unnecessarily replace expensive equipment, which is a more sustainable business practice.

A Model for Cybersecurity Education through Challenge Events

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Keywords. Cybersecurity;Education;Competence;Cyber-physical System Security;Model-based Systems Engineering (MBSE)

Topics. 1. Academia (curricula, course life cycle, etc.); 11. Information Technology/Telecommunication; 3. Automotive; 4.7. System Security (cyber-attack, anti-tamper, etc.); 5.9. Teaching and Training;

Abstract. The INCOSE Vision 2035 sets an important Cybersecurity goal: "Cybersecurity will be as foundational a perspective in systems design as system performance and safety are today". A critical enabler of achieving this vision is educating cyber informed engineers and professionals. Across industries, the demand for talented cybersecurity professionals is high, which means the personnel and students need inspirational education and training to fill these opportunities. This is particularly the case for complex systems in transportation, maritime, agriculture, aerospace, energy, and industries that rely on operational technology implemented with embedded systems. This broad category of sectors need talent and community to address cybersecurity concerns. Often these economic sectors have systems with long lifecycles, regulations, market forces, or other constraints that preclude security solutions envisioned for information technologies. To address the needs for cybersecurity personnel for these industries, a model for developing talent and building community is explained in general terms with specific examples as it relates to automotive, heavy duty, maritime, and agriculture. The model de-scribes the CyberX Challenge, where X is an industry sector, such as the CyberAuto Challenge, CyberTruck Challenge, CyberBoat Challenge, and CyberTractor Challenge. These Challenge Events are described in detail with a focus on the characteristics of what makes those successful or difficult. The successful events have strong industry support, elite instructors, and motivated students. The model for the event is described in detail, with the intention that other industry verticals may inspire additional students and further build communities able to address cyberthreats to our modern way of life. This work directly contributes solutions to addressing the needed foundational concept of Security Education and Competency development as highlighted by the INCOSE FuSE working group.

Paper#376

A Model for Trust and Distrust: The Systems Dynamics Approach

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Keywords. Trust;Systems Thinking;System Dynamics;Causal loop;AI

Topics. 1.4. Systems Dynamics; 1.6. Systems Thinking; 4.1. Human-Systems Integration; #TechnicalLeadership

Abstract. The dynamics of trust have evolved from a reliance on human interactions to a newfound dependence on the seamless integration of automation and Artificial Intelligence (AI) in relationships. Because trust is still treated as elusive in prior research, in this study, we consider a society that utilizes trust as a system and present a panoramic perspective of trust in social systems using the causal loop of systems thinking. The perspective of systems thinking is holistic (integrative) and focuses on the interrelationships among components rather than on the components of the system itself. Thus, the architecture was presented by integrating the trust and distrust models identified in previous studies. To overcome the challenges presented in previous studies, a model for trust and distrust was developed using a system dynamics approach. By using systems thinking, the dynamics of trust are clearly illustrated among individuals, between individuals and automation, and between individuals and AI. In addition, it will allow for a perspective on the dynamic relationship between trust, reliance, and dependability, which is being studied in "Humans" and "Automation and AI," and will contribute to Trust research.

A New Horizon for Healthcare Delivery: A System of Systems Perspective and Governing Proposition

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Keywords. Healthcare Delivery System;Systems of Systems;Fragmentation;Reform;Governance

Topics. 1.5. Systems Science; 1.6. Systems Thinking; 3.3. Decision Analysis and/or Decision Management; 4. Biomed/Healthcare/Social Services; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.);

Abstract. The healthcare system is grappling with inherent challenges, functioning akin to a fragmented cottage-like industry, leading to significant cost implications and compromised care quality. This paper employs a systematic approach to scrutinize the Healthcare Delivery System (HDS) comprehensively, categorizing it as a Collaborative System of Systems (SoS), where multiple independent systems operate collectively, maintaining individual autonomy. Through a detailed examination, we identify the Collaborative SoS nature of the current healthcare system as the primary cause of its fragmentation. We address a gap in the current literature on the characteristics of SoS, focusing on the often-overlooked aspect of dependence and exploring why constituent systems collaborate to achieve common objectives. Then, we propose a hybrid SoS model where an external governing entity at the national level assumes the authority to determine objectives and drivers for the healthcare SoS. We contend that effective SoS governance is indispensable for addressing systemic issues, providing necessary coordination, allocating resources, establishing policies, fostering sustainable change, and ensuring a well-organized and efficient healthcare system.

A Proposal for Model-Based Systems Engineering Method for Creating Secure Cyber-Physical Systems

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Keywords. Security;Modeling;Cyber-physical systems;System threats;Vulnerabilities

Topics. 2. Aerospace; 21. Urban Transportation Systems; 4.6. System Safety; 4.7. System Security (cyber-attack, anti-tamper, etc.); 5.3. MBSE; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); #MBSE-DE;

Abstract. Rising levels of risk as cyber-attackers look to exploit system vulnerabilities threatens the Air Traffic Control industry. Attacks on Air Navigation Service Providers' communications systems may lead to airspace closure and even cause safety issues. This paper presents a novel Model-Based Systems Engineering method that enables systems engineers, in collaboration with system security and software engineers, to perform threat-modeling analysis of cyber-physical systems early in the system development process and incorporate mitigation strategies into the system design. The proposed model-based method covers few security concepts, including misuse cases, system assets, threats, risks, vulnerabilities, and security control identification. The study found that the proposed method is suitable for conducting security analysis for complex cyber-physical systems early in the system development process.

Paper#194

A System Dynamics Model of Organizational Resilience

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Keywords. modeling and simulation;Systems Dynamics;resilience;adaptability;recruiting

Topics. 1.4. Systems Dynamics; 1.6. Systems Thinking; 22. Social/Sociotechnical and Economic Systems; #TechnicalLeadership

Abstract. We look at organizational resilience using a case study. The organization we examined has suffered from a series of scandals, which has damaged its reputation as an inclusive organization. This manifests itself in problems with recruiting and retaining employees.We look at several policies to return the organization's reputation to a high level. These policies will impact all levels of the organization but must be led by the leadership's commitment to change the organization's culture.

Paper#474

A Systematic Literature Review of Policy Analysis and Modeling in Systems Engineering

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Keywords. Model Based Systems Engineering;policy modeling;systematic review;systems approach;United Nations Sustainable Development Goals

Topics. 1. Academia (curricula, course life cycle, etc.); 22. Social/Sociotechnical and Economic Systems; 4.1. Human-Systems Integration; 5.3. MBSE; 5.9. Teaching and Training;

Abstract. The International Council on Systems Engineering (INCOSE) defines systems engineering as "a transdisciplinary and integrative approach to enable the successful realization, use, and retirement of engineered systems, using systems principles and concepts, and scientific, technological, and management methods." The evolution of engineering practices requires new research in the disciplinary intersections of scientific, technological, and management methods, especially when considering the INCOSE System Engineering Vision of 2035, which identified political, economic, social, technical, environmental, and legal factors as becoming modern tenets of system engineering success. Because vast amounts of research have been performed in multidisciplinary engineering areas, this paper ex-amines the research landscape at the intersection of policy modeling and systems engineering by providing a systematic review of the literature to help guide future research based on trends and various guiding considerations. The results of this study will help identify gaps in the field while clarifying future research needs. We have applied the preferred reporting items for systematic reviews and meta-analyses (PRISMA) protocol, which yielded 38 peer-reviewed papers related to policy model-ing and systems engineering.

A Systems Engineering Methodology for Manufacturing Enterprises Planning and Design

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Keywords. Manufacturing Enterprise;Enterprise Architecture;Systems Engineering

Topics. 2.2. Manufacturing Systems and Operational Aspects; 20. Industry 4.0 & Society 5.0; 5.3. MBSE; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Manufacturing enterprises nowadays face increasing complexity challenges in terms of net-work-wide collaboration, inner business integration as well as rapid technology adoption. Previous studies have shown that systems engineering is promising for managing such complexity, there is still a need for a systems engineering methodology that support manufacturing enterprises planning and design taking into consideration the complexity challenges. This paper pro-poses such a methodology based on model-based systems engineering and enterprise architecture principles. An application ontology is first built to formalize core concepts in manufacturing enterprises planning and design. An architecture-centric approach is then developed to coordinate model-based planning and design activities. An integrated digital framework is further envisioned as critical infrastructure for implementing the proposed methodology. Use of the methodology facilitates concepts exploration and evaluation in integrated planning and design of future manufacturing enterprises.

A Systems Perspective on the Public Perception of Wind Power in Norway

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Abstract. The Sustainable Development Goals, a set of ambitious targets embraced by United Nations member states, are designed to meet global challenges head-on while shaping a sustainable future. Of these, Goal 7, in particular, focuses on the critical need for affordable, reliable, sustainable, and modern energy for all. Wind energy holds a significant potential in fulfilling Goal 7 of the sustainable development goals.In Norway, there exists a unique scenario, where nearly 98% of electricity is generated from renewable resources. However, a deficit in power is projected by 2027 according to a short-term market analysis by Statnett, without a subsequent increase in power production. To prevent this, it is imperative to increase the production of electricity from wind. However, in recent years, there has been a significant rise in opposition towards wind power projects in Norway. Some of the wind power projects have even been put on hold because of the increase in protests.In light of this, we apply systems thinking methodologies to improve our understanding of this complex problem. Initially, we identify the stakeholders in our system of interest and categorize them through stakeholder salience analysis framework. Then, we developed a systemigram to graphically represent the system of interest. Finally, we carry out causal loop analysis to find causal loops in our system of interest. Our primary focus with this work is to better understand the factors shaping public perception of wind power projects in Norway. By gaining a deeper understanding about the factors influencing public per-ception of wind power projects in Norway, we aim to find better solutions to improve the social acceptance of these initiatives in Norway in future works.

Paper#269

Accelerating Digital Transformation through MBSE, Multi-physics Simulation and Digital Twin in Industry

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Keywords. MBSE;Digital Twin;Digital Transformation

Topics. 2. Aerospace; #MBSE-DE;

Abstract. Many Aerospace Industries engages in digital transformation, where the adoption of Model-Based Systems Engineering (MBSE) stands as a pivotal game changer. MBSE is not merely an approach but a significant shift in aerospaces industries, empowering industrials with a collaborative systems engineering process that amalgamates key activities in requirements engi-neering . We dissect the influence of Model-Based Design (MBD) on design processes and introducing the concept of a digital twin.

Paper#562

AI Systems Modeling Enhancer (AI-SME): Initial Investigations into a ChatGPT-enabled MBSE Modeling Assistant

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Keywords. AI;AI-integration;ChatGPT;GPT-4;MBSE;SysML;Systems Modeling;Modeling Assistant

Topics. 1. Academia (curricula, course life cycle, etc.); 11. Information Technology/Telecommunication; 5.11. Artificial Intelligence, Machine Learning; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 6. Defense; #AI

Abstract. As artificial intelligence (AI) becomes integral across industries, there is a growing opportunity to transform the generation of models for systems engineering. This research investigates the integration of OpenAI's GPT-4 Turbo into CATIA Magic for Model-Based Systems Engineering (MBSE), resulting in the creation of AI Systems Modeling Enhancer (AI-SME). This study explores the comparison between models generated by AI, specifically OpenAI's GPT, and those crafted by human systems engineers. While recognizing challenges in AI-generated models, this research underscores the potential of AI assistants to enhance the speed and accuracy of SysML model creation. Results demonstrate AI-SME's successes in generating requirements, block definition diagrams, and internal block diagrams. Despite identified limitations such as redundancy and lack of cohesiveness in AI-generated models, the study concludes that AI-SME represents a notable advancement in AI-assisted systems engineering.

Paper#473

Aligning technical and project management through participatory approaches: An industrial case study

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Keywords. Systems engineering;Project Management;Participatory Approaches;Human-Centered Design;Action Research;Co-design;Complexity management

Topics. 3.5. Technical Leadership; 3.6. Measurement and Metrics; 3.7. Project Planning, Project Assessment, and/or Project Control; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. The importance of managing complexity is clear, however the question remains: how can this be accomplished? Although there have been answers to this question, the practical alignment of process (project management) and system (technical management) viewpoints remains understudied. We responded to this challenge with an in-depth case study in high-tech industry. In this paper we applied Human Centered Design (HCD) and Action Research (AR) principles in a novel context, namely systems engineering.

Paper#332

An Agent-Based Ontology to Support Modeling of Socio-Technical Systems-of-Systems

Jakob Axelsson (Mälardalen University) - jakob.axelsson@mdu.se

Abstract. Systems-of-systems are characterized by the independence of their constituent elements. Those elements are usually socio-technical, comprising technology, humans, and organizations. To capture their independence, they need to be viewed as intelligent agents that rely on internal models of the world for their decision-making. Hence, a system-of-systems model will include agents that inside themselves contain other models of the same system-of-systems. Describing these overlapping subjective models and their usage by the agents is essential to properly understand the resulting behavior of the overall system-of-systems. Current modeling practices are not well suited for dealing with this, and the paper therefore outlines an ontology that makes the agents and their internal models more explicit. The paper also discusses the implications such models have on sys-tems engineering practices and how they address known system-of-systems engineering pain points.

Application of the ARCADIA Method on a Bulk Carrier Vessel Equipped with a Wind-assistance Device

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Keywords. Capella;Arcadia;Model-based Systems Engineering;Vessel;Wind-assistance Device

Topics. 13. Maritime (surface and sub-surface); 2.4. System Architecture/Design Definition; 5.3. MBSE;

Abstract. The maritime industry is undergoing a major transformation to achieve reduction of greenhouse gas emissions. Many new options such as alternative propulsion systems and fuels, optimized routes, or auxiliary propulsion systems such as wind-assistance devices have to be integrated and aligned within a wide network of different stakeholders. New ways are necessary to work with and manage the increasing complexity in the maritime industry. Model-based systems engi-neering approaches are a promising strategy to get a better understanding of the as-is situation and to develop advanced solutions. This paper shows the application of the ARCADIA method for the maritime industry with the target of integrating wind-assistance devices to vessels using the Capella modeling language and tool.

Application of the System-Theoretic Process Analysis (STPA) technique to enabling systems in the rail industry

John Slowey (Think Systems) - john.s@thinksystems.com.au

Keywords. Rail Safety;enabling systems;STPA;STAMP

Topics. 16. Rail; 4.6. System Safety;

Abstract. Exploration of whether the application of a systems thinking approach to hazard analysis could have predicted a major rail incident in Australia.

Architecture of Nature-Based Smart City Introducing BaaS by Utilizing UAF

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Keywords. biophilia;nature-based smart city (NBSC);system of systems;systems engineering;unified architecture framework (UAF)

Topics. 10. Environmental Systems & Sustainability; 5. City Planning (smart cities, urban planning, etc.); 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.);

Abstract. Smart cities collaborate with various technological systems, including Internet of Things (IoT), artificial intelligence (AI), and drones, to fulfil the expectations of stakeholders and the needs of individuals and society. However, the use of such advanced technological systems imposes a burden on the natural environment, posing a risk to the sustainability of nature. Considering that people are a crucial element of smart cities, failing to incorporate a connection with nature could pose challenges to sustainable human well-being. Thus, future smart cities need to be a socio-technical system that not only provides convenience through the utilization of advanced technology but also maintains the relationship between humans and nature. This will enable the achievement of human well-being and sustainable natural environment. The concept of biophilia as a service (BaaS) has been introduced as a system of systems (SoS). BaaS is a service that contributes to human well-being and the sustainability of nature by emphasizing the relationship between humans and nature, promoting actions that safeguard nature, and collaborating with various organizations. In this paper, a smart, sustainable, and resilient city in harmony with nature is referred to as a nature-based smart city (NBSC). This study introduced BaaS to smart cities to contribute to the realization of NBSC as a socio-technical system. We defined the architecture of NBSC introducing BaaS using the Unified Architecture Framework (UAF). Furthermore, we illustrated the significance of introducing BaaS to NBSC to present a comprehensive picture of the realization of human and nature well-being by promoting actions that safeguard nature.

Automating Rule-Checking to Identify SysML Modeling Errors: A Preliminary Study in a Classroom Environment

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Keywords. Model-Based Systems Engineering (MBSE);System Modeling Language (SysML);verification and validation;systems engineering education

Topics. 1. Academia (curricula, course life cycle, etc.); 2.6. Verification/Validation; 5.3. MBSE; 5.9. Teaching and Training;

Abstract. This paper provides an empirical insight into this benefit through a study of models developed by students in a graduate MBSE course. The study shows that the term project models resulted in nearly zero latent errors when non-stylistic rules are concerned, with most of the latent errors categorized stylistic rather than fundamental violations.

Black Hole Cinema: Application of Systems Engineering Methods to Expand and Enhance an Earth-sized Telescope

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Keywords. black hole;EHT;astronomy;system of systems

Topics. 2.3. Needs and Requirements Definition; 5.3. MBSE; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); #MBSE-DE;

Abstract. This paper discusses how the next-generation Event Horizon Telescope (ngEHT) Project has created and implemented a systems engineering process, team, and culture to help deliver the next transformational result in black hole imaging.

Paper#465

Building a Scientific Foundation for Security: Multilayer Network Model Insights for System Security Engineering

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Keywords. Security;systems security engineering;network models;Trustworthiness;Loss-Driven;Capabilities-Based

Topics. 22. Social/Sociotechnical and Economic Systems; 4.7. System Security (cyber-attack, anti-tamper, etc.); 6. Defense; 8. Energy (renewable, nuclear, etc.); #FuSE

Abstract. To help incorporate security into INCOSE's Systems Engineering Vision 2035, the INCOSE systems security engineering working group endorses a paradigmatic shift to reframe systems security in terms of being trustworthy, loss-driven, and capabilities-based. Similar research out of Organization A has explored cutting-edge approaches to systems security for national security applications. Taken together, these efforts both highlight to need for—and a path toward—a scientific foundation for security. Leveraging underlying tenets of systems theory, observed security heuristics, and the concepts emerging from INCOSE's SSE working helps triangulate a set of "first principles" as part of a scientific foundation for security consistent with the (often ignored) interactions between physical security designs, cyber security architectures, and personnel security programs. These first principles, in turn, are the basis for a set of derived systems security performance axioms that support current INCOSE SSE working efforts. The logic and designability benefits of this approach is demonstrated with a multilayer network model-based approach for systems security. The structure of this scientific foundation for security offers additional, innovative opportunities to achieve desired levels of trustworthiness, creative mechanisms to meet needs, innovative loss-driven approaches, and enhanced capabilities—all aimed to at producing more efficient and effective systems security solutions against current and emerging threats, uncertainties, and complexities.

Case Studies for Complexity Pattern Identification

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Keywords. Complex;Complicated;Chaotic;Heuristic;Assessment;Pattern

Topics. 1.1. Complexity; 1.5. Systems Science; 17. Sustainment (legacy systems, re-engineering, etc.); 2. Aerospace; 3.7. Project Planning, Project Assessment, and/or Project Control; 9. Enterprise SE (organization, policies, knowledge, etc.); #FuSE

Abstract. Increase the use of the Difficulty Assessment Tool and of Systems Engineering Principles and Heuristics, and to gain feedback from users on the relevance and value of these for Projects both in the planning phase and after execution.

Concept Design Failure Modes and Effects Analysis Using System Level Assessment

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Keywords. Concept FMEA; DFMEA; Concept Selection; Architecture;

Topics. 10. Environmental Systems & Sustainability; 2.4. System Architecture/Design Definition; 3. Automotive; 3.9. Risk and Opportunity Management; 5.2. Lean Systems Engineering; #FuSE;

Abstract. Concept DFMEAs for complex systems can be large, complicated, and mired in component level details. The Concept DFMEA approach using System Level Assessment Methodology offers a fast, practical, and effective way to identify and mitigate design risks at the system level. This approach provides a streamlined requirements-led structure for mitigating risk in the earliest phases of the design process (or when working within "left wing of the vee-diagram"). The approach has been validated for automotive and energy systems and is more effective and efficient than traditional concept DFMEA approaches.

Conceptual Modeling for Early-Phase Decision-Making in the Maritime Industry: A Case Study of Power Generation System Concept Selection

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Keywords. Conceptual Modeling;Decision Making;Early Phase;Maritime Domain

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

Abstract. This paper showcase the value of conceptual modeling in early phase decision making. The authors have applied an approach for using conceptual models in system level decision making in an actual case in the maritime industry. The paper evaluate the benefits and pitfalls with using such models and how they are perceived by industry practitioners.

Paper#367

Contemporary Systems Engineering for the UN SDGs and NAE Grand Challenges

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Keywords. Social Systems Engineering;Public Policy;Systems Engineering Education

Topics. 1. Academia (curricula, course life cycle, etc.); 22. Social/Sociotechnical and Economic Systems; 4.1. Human-Systems Integration; 5.9. Teaching and Training;

Abstract. Systems engineering programs at US universities have been focusing more on sustainability, but systems approaches to sustainability are found in programs outside of a systems engineering context. Transdisciplinary collaboration has been emphasized to make progress toward the United Nations' Sustainable Development Goals (SDGs), requiring new approaches to collaborative understanding on the student and faculty levels in academic environments. This paper provides a qualitative network analysis of systems approaches to sustainability across disciplines using a US university as a case study. The analysis mapped systems approaches at Worchester Polytechnic Institute (WPI) within and outside of WPI's Systems Engineering Program. We specifically focused on thematic areas regarding systems in social science domains pertaining to the SDGs, which need to be brought into a systems engineering context. This paper aims to identify potential areas of collaboration to accelerate progress toward the SDGs using systems approaches.

Darth Vader's Secret Weapon: Implementing Mission Engineering with UAF

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Keywords. Mission Engineering;UAF;Enterprise Architecture;Acquisition;Mission Architecture;Mission Modeling

Topics. 2.1. Business or Mission Analysis; 2.4. System Architecture/Design Definition; 5.3. MBSE; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. The paper "Implementing Mission Engineering with UAF" was presented at a previous conference. This paper will expand on that presentation and will discuss additional work that has been accomplished since then. This paper will explore some of necessary modeling features and constructs extensions for ME using the Battle of Hoth from Star Wars as a proof of concept for these modeling extensions using the process and mission engineering concepts defined in the Mission Engineering Guide (MEG).

Design Basis Model for Hosting Small Modular Reactors

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Keywords. Nuclear Energy;Design Basis;Model-Based Systems Engineering;Nuclear Reactor Infrastructure

Topics. 19. Very Small Enterprises; 2.4. System Architecture/Design Definition; 3.9. Risk and Opportunity Management; 5.12. Automation; 8. Energy (renewable, nuclear, etc.);

Abstract. To provide energy security and head off further increases in global temperatures, an aggressive transition from fossil fuels to other types of energy implies the need to construct hundreds of nuclear power plants in the near future. However, the real and perceived risks of nuclear energy remain a significant impediment to this transition. This paper describes a comprehensive work process that combines the rigor of model-based systems engineering (MBSE) with 1) the Idaho National Laboratory's (INL) decades of experience with small reactors and with 2) modern project delivery processes. The objective is to reduce the risks of building new facilities or converting existing facilities to nuclear power generation.

Paper#216

Design Thinking in a Systems Engineering World, within a Governmental Context

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Keywords. Systems engineering;systems thinking;design thinking;government;DoD;concept development

Topics. 1.6. Systems Thinking; 2. Aerospace; 2.3. Needs and Requirements Definition; 4.1. Human-Systems Integration; 6. Defense; Other domain;

Abstract. Systems engineering evolution has been an incredible asset to innovation. This is particularly true in industries that drive its academic advancement and maturity. In these industries, systems engineering is a proven approach to developing a program from conception through retirement. Design thinking is a design methodology and separate from systems engineering/ thinking; it is defined by its intensely human-centered approach. This report hypothesizes that design thinking processes used during the concept development phase of the systems engineering process enables a more comprehensive view of key challenges due to the inclusion of more contextual stakeholder information, particularly in a government context. A mixed methods approach using 35 surveys and 11 interviews of subject matter experts, project managers, and innovation challenge participants was used to test the hypothesis. Interviewees disagreed on the impact that design thinking processes ultimately have on stakeholder information. There was a common consensus that the process yields key beneficiaries. The quantitative data showed a shift in familiarity with design thinking principles during the innovation challenge as a result of design thinking teaching modules. The increase in familiarity correlated with an increased likelihood to use various design thinking processes during concept development, and stronger agreement that design thinking affected understanding the stakeholders, key beneficiaries, and comprehension of the challenge space. Together, the qualitative and quantitative data agreement on the addition of key beneficiaries is evidence in support of design thinking processes affecting the context of stakeholder information. Embracing more contextual stakeholder information results in designers seeking a more comprehensive view of the challenge space. Additionally, analogous research can have a significant effect on comprehension of the challenge space but there is a higher barrier to entry for new practitioners.

Developing an Integrated Mission Simulation to Evaluate Technology Impact on Military Scenarios

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Keywords. MBSE;Model Based Systems Engineering;Military Mission;Modeling and Simulation

Topics. 1.6. Systems Thinking; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 6. Defense; #MBSE-DE;

Abstract. Evolving technologies have resulted in new capabilities being implemented across the defense sector. While these new capabilities are often beneficial, they can sometimes beget unforeseen consequences. Thus it is important for the military to understand how new technologies can impact its missions. To address this, we developed an Integrated Mission Simulation (IMS) to assess the potential impact different technologies may have on a given mission.

Early Validation of SysML Architectures by Extending MBSE with Co-Simulation using FMI and SSP

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Keywords. MBSE;System Architecture;Simulation;Co-simulation;SysML;FMI;SSP

Topics. 2.4. System Architecture/Design Definition; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis;

Abstract. In this paper we discuss the current status of Co-simulation in MBSE and how we might extend the current capabilities using the SSP standard.

Paper#266

Early Validation using Architectural Overviews (A3AO) a Case Study in an IoT Consultancy

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Keywords. A3 Architectural Overviews;Early Validation;A3AO

Topics. 1. Academia (curricula, course life cycle, etc.); 2.3. Needs and Requirements Definition; 2.4. System Architecture/Design Definition; 2.6. Verification/Validation; 3.7. Project Planning, Project Assessment, and/or Project Control; 5.9. Teaching and Training;

Abstract. This paper focuses on the use of A3 Architectural Overviews (A3AO) for early validation of stake-holder needs and system concept as part of a tender proposal in an IoT consultancy. Tender proposals are an essential part of communication between most companies working in the engineering field. Often with high-tech companies, a technical knowledge gap exists between the different stakeholders reading tender proposals. This knowledge gap increases the risk of miscommunication and wasteful work. A real-life case from an IoT consultancy tendering an IoT concept for a processing facility forms the basis for the research. Applying an action research approach, the researchers tailored the A3AO framework to fit within the consultancy's workflow and developed an A3AO describing the tendered system concept. The customer received and later accepted the tender proposal including the A3AO containing the stakeholders' problems and needs, a concept solution, and a roadmap detailing further work. In this study, we collected data from observations, semi-structured interviews, surveys, and a follow-up questionnaire to the customer. The study found that the A3AO functions as a tool for early validation and that it helped bridge the knowledge gap between the consultancy and customer. The study also raises questions and criticism regarding cost and complexity. The consultancy later decided to implement A3AOs in future proceedings.

Paper#453

Empowering Model-Based Systems Engineering Through Metamodeling

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Keywords. Model-Based Systems Engineering;Digital Engineering;Metamodeling;System Modeling;Model Validation;Model Analysis

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

Abstract. MBSE and DE require coherent and consistent system models, typically facilitated through non-standard profiles, style guides, reference models, and low fidelity metamodels. These approaches are insufficient for robust, automated verification and model analysis. The Best Fit (R2) Metamodeling Approach enables the creation of precise, machine-interpretable metamodels with numerous applications that reduce overall system model development time and maximize system model utility.

Enable Effective Digital Engineering Information Exchange using Digital Viewpoint Model (DVM) Framework

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Keywords. Digital Engineering;Digital Information Exchange;Digital View;Digital Viewpoint;Stakeholder Analysis;Digital Artifacts

Topics. 2. Aerospace; 2.3. Needs and Requirements Definition; 3.1. Acquisition and/or Supply; 5.3. MBSE; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. The objective of the Digital Viewpoint Model (DVM) framework is to characterize the content and relationships involved in the exchange of digital artifacts and its curation for stakeholder use and consumption. The DVM Framework structures the characterizations in four inter-related ontological concepts – Stakeholder, Digital View, Digital Artifact and Process. The Stakeholder concept focuses on the definition of stakeholder needs in terms of perspectives. The Digital View concept focuses on the construction of views that relate inter-disciplinary data that conforms to stakeholder needs and constraints. The Digital Artifact concept focuses on ensuring the quality and trustworthiness of data being used to construct the digital views. The process concepts provide a construct to define necessary work activities to extract data to use. Applications of the DVM Framework are described in the form of use cases to demonstrate their utility in facilitating effective digital engineering information exchange.

Enabling Digital Engineering with Federated PLM – Experiences from the Heliple-2 Project

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Keywords. Federated Product Lifecycle Management;OSLC;Service oriented federation

Topics. 2.5. System Integration; 3.2. Configuration Management; 5.3. MBSE; #MBSE-DE;

Abstract. Federated PLM enabled by OSLC - Experiences from the Heliple-2 project activities for building federated and integrated development environments at low cost.

Enabling FuSE Security Objectives through Cyber Survivability Methods

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Keywords. Cybersecurity;FuSE Security;Cyber Survivability;Mission Based Cybersecurity Analysis MBSE

Topics. 11. Information Technology/Telecommunication; 2.4. System Architecture/Design Definition; 3. Automotive; 4.7. System Security (cyber-attack, anti-tamper, etc.); 5.3. MBSE; 6. Defense; #FuSE

Abstract. The importance of system security, especially cybersecurity, continues to grow as systems become more complex, more connected, and more vulnerable. The INCOSE Vision 2035 sets goals for systems engineering (SE) as a discipline in enabling engineering solutions for a better world: "Cybersecurity will be as foundational a perspective in systems design as system performance and safety are today". A key objective of the INCOSE Future of Systems Engineering (FuSE) Security Foundations Roadmap is to recognize cybersecurity as a fundamental part of the mission, integrated into the system architecture, and not "bolted-on" as a separate subsystem or set of features in the detailed design. To achieve this, systems engineering must address cybersecurity early in the system lifecycle, during the mission analysis and concept development phase. Cybersecurity needs must be treated as fundamental system capability. The INCOSE FuSE Security foundations roadmap identifies six (6) objectives and eleven (11) foundational concepts necessary to achieve the FuSE vision for cybersecurity. Five of the objectives and five of the foundational concepts are directly related to systems acquisition and engineering lifecycle processes. The five objectives are: Stakeholder Alignment, Security as a Capability, Security as a Functional Requirement, Loss Driven Engineering and Modeled Trustworthiness. This paper examines these foundational concepts in comparison to several directives and publications addressing cybersecurity analysis from a specific organizational or engineering perspective. For each publication, we examine the methods used to support cybersecurity and the benefits the method can bring to a holistic cybersecurity analysis approach.The Cyber Test and Evaluation community has extensive cyber assessment and execution processes mandated through numerous Department of Defense (DoD) and individual service policies and directives. While cybersecurity affects both the commercial industry as well as defense programs, DoD methods and processes are more mature, better documented, and largely accessible. Each of the examined DoD-based documents includes processes and methods that directly support or enable the five FuSE foundation concepts related to system acquisition and systems engineering. This paper studies several of the cybersecurity assessment and process guidebooks, analyzing the processes and methods to identify areas where systems engineering should be responsible, and which SE activities and outputs are needed to enable the requirements of each guidebook. Next, the paper proposes a set of common activities represented across the various guides and explains how these commonalities enable the FuSE security objectives. This paper propositions an initial ontology to be examined by the system engineering community to enable a thorough definition and analysis of cyber survivability across the system design lifecycle.

Paper#262

Enterprise: Exploration of Concepts, Perspectives and Implications for Systems Engineering

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Keywords. Enterprise;Systems Engineering;Bibliometric Analysis

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

Abstract. The purpose of this paper is to explore the concept of 'enterprise' in the context of Systems Engineering (SE). The term 'enterprise' has been used extensively to generally describe large complex entities that have an extensive scope of operations. However, a deeper examination of 'enterprise' significance for SE can provide insights as our challenges continue with increasingly complex, uncertain, ambiguous, and integrated entities struggling to thrive into the future. The paper explores three central topics. First, the concept of enterprise is introduced as a central aspect of the future focus for SE as recognized in the INCOSE SE Vision 2035. Second, a more detailed examination of the enterprise concept is developed in relationship to SE. The thrust of this examination is to understand the nature and role of 'enterprise' across a broad spectrum of literature and knowledge, ultimately providing a more informed perspective of enterprise. As part of this exploration, a bibliometric analysis of the term 'enterprise' is performed. This exploration extracts key themes (clusters) in the 'enterprise' literature. Third, challenges for further development and inculcation of 'enterprise' within the SE discipline and the SE 2035 Vision are suggested. These challenges point out the need to 'think differently' about 'enterprise' within the SE context. 'Enterprise' is proposed as a central, albeit different, perspective for the SE discipline. The paper closes with a first-generation perspective for 'enterprise' in pursuit of the SE Vision 2035.

Evaluating the Eco-Efficiency of Urban Air Mobility: Understanding Environmental and Social Impacts for Informed Passenger Choices

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Keywords. Urban air mobility (UAM);sustainability;eco-efficiency;unified architecture framework (UAF);causal loop analysis;mobility-as-a-system (MaaS)

Topics. 1.6. Systems Thinking; 10. Environmental Systems & Sustainability; 2. Aerospace; 5. City Planning (smart cities, urban planning, etc.); 5.4. Modeling/Simulation/Analysis; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.);

Abstract. CO2 emissions during operations are zero for full electric aircraft and are considered a potential solution for the Fly Net Zero by 2050, a commitment proposed by the International Air Transport Association (IATA). In this sense, Urban Air Mobility (UAM) expects to offer an environmentally friendly alternative through electric Vertical Takeoff and Landing (eVTOL) aircraft. While eVTOLs produce no greenhouse gas emissions, the comprehensive eco-efficiency of UAM goes beyond the flight phase. This paper delves into evaluating UAM operation's environmental and social impacts, considering the urban space, public perception, operational profiles, and power consumption. Employing causal loop analysis, we uncover the relationships that add value or increase impact, assessing UAM passenger transportation's eco-efficiency. Furthermore, we use the Unified Architecture Framework to model the UAM ecosystem and to propose strategies to balance values and impacts in achieving eco-efficiency. By shedding light on the sustainability viewpoint, this paper aims to emphasize the importance of holistically understanding UAM's operational impact and empowering users to make eco-efficient choices when opting for UAM transportation. Finally, we discuss an integrated platform's role in providing sustainability awareness to the user.

Paper#554

Evaluating the Scalability and Combinatorial Effectiveness of Design-for-Resilience Heuristics

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Keywords. Systems of Systems;Ecological Network Analysis;Graph Theory;Design-for-Resilience

Topics. 1.3. Natural Systems; 12. Infrastructure (construction, maintenance, etc.); 22. Social/Sociotechnical and Economic Systems; 4.4. Resilience; 5. City Planning (smart cities, urban planning, etc.); 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.);

Abstract. Recent advances in design-for-resilience of Systems of Systems has proposed using Ecological Network Analysis (a type of graph theory) as a design tool. Some studies have developed heuristics that leverage graph analysis of low-fidelity architecture to inform design decisions. This paper builds on these previous works by testing the heuristics across multiple sizes of networks as well as testing them in combination. The result is new early stage design tools for SoS architecting.

Evaluation of Visual ConOps in Early Solution Validation in a Small and Medium-sized Enterprise

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Keywords. Visual ConOps;Early Validation;Need elicitation

Topics. 1.5. Systems Science; 19. Very Small Enterprises; 2.6. Verification/Validation; 3.7. Project Planning, Project Assessment, and/or Project Control; 4.3. Reliability, Availability, and/or Maintainability; 5.4. Modeling/Simulation/Analysis;

Abstract. This paper focuses on the design, implementation, and assessment of the visual Conceptof Operations (ConOps) as an informal visualization technique employed for early solution validationin Small and medium-sized enterprises (SMEs). SMEs face significant challenges in early solutionvalidation due to the complex nature of modern systems and the constantly changing market demands. These challenges may be further intensified by immature leadership and ineffective communication within the organization. By applying an industry-as-laboratory approach in an SME industrycase, this study aims to reduce the negative impacts of miscommunication between internal andexternal stakeholders and contribute to needs elicitation and system validation process. The resultsshow that visual ConOps can effectively support the need elicitation process, which is crucial forearly validation, however, it may not independently serve as a comprehensive communication toolbetween the developer team and stakeholders. It is essential to supplement visual ConOps withcomplementary tools to effectively convey stakeholder input to the developer team.

Evolving Roles in Systems Engineering — Insights from Germany's Mechanical and Plant Engineering Sector

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Keywords. Systems Engineering Roles;German Industry;Role Evolution;Competencies;Job postings;Literature Review

Topics. 1. Academia (curricula, course life cycle, etc.); 5.5. Processes; 5.9. Teaching and Training; 9.

Enterprise SE (organization, policies, knowledge, etc.); Other domain; #TechnicalLeadership

Abstract. Systems Engineering is developing differently in each sector and region. In German industry, especially in mechanical and plant engineering, Systems Engineering is of major importance. During the introduction of Systems Engineering, the question arises as to which roles and competencies are required. This article examines the evolution of roles in Systems Engineering from a German perspective. Based on a literature review, the evolution of the identified Systems Engineering roles over time, starting with the seminal publication by Sheard in 1996, is shown. It points out that only minimal adjustments and occasional role renaming have occurred. However, the review shows a common understanding of essential areas of responsibility within the SE and changes over time. The next step is to examine the current comprehension of Systems Engineering roles in the industry. A quantitative analysis of job postings in Germany reveals a diverse interpretation of the term 'Systems Engineer; more than half of the positions cannot be categorized according to INCOSE definitions. The job postings are used to determine which tasks are associated with it, how often they occur, and in what combination. The primary responsibilities of system engineers include creating and managing requirements, architecture processes, validation and verification processes, and coordinating with customers and stakeholders. Finally, three representative companies from the mechanical and plant engineering sector were selected to analyze existing roles and tasks. From this, a common understanding of tasks and responsibilities is combined and organized in clusters. These serve the companies to locate and thus derive their roles. This results in an integrative approach that enables companies, especially in the midsize and medium sectors, to design the introduction in line with stakeholder demands. In summary, the industry's ongoing adaptation necessitates the evolution of Systems Engineering roles and competencies for successful and sustainable implementation of Systems Engineering.

Biography

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Prof. Dr.-Ing. Lydia Kaiser is the Head of the Digital Engineering 4.0 department at Technische Universität Berlin and the Einstein Center Digital Future. She teaches and conducts research in the field of digital engineering. She earned her degree in Physics from Paderborn University and completed her Ph.D. in 2013 in the field of Model-Based Systems Engineering. As a researcher, Lydia Kaiser worked with different industrial partners on research projects and developed new approaches to enable engineers to deal with complexity and interdisciplinarity. She trains engineers in various career steps in systems engineering and awakens enthusiasm for Model-Based Systems Engineering.

Felix Förster (Institute of Smart Engineering and Machine Elements — Hamburg University of Technology) - felix.foerster@tuhh.de
Felix Förster, a Research Associate at the Institute of Smart Engineering and Machine Elements at the Hamburg University of Technology, undertook his master's degree at Technische Universität Berlin with a specialization in Systems Engineering. In his Master´s Theses he worked on a comparable description of MBSE-Methods.

Excuse me Sir/Madam, which Model?

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Keywords. MBSE;Modelling and Simulation;Systems Architecting;Virtual integration

Topics. 2. Aerospace; 2.4. System Architecture/Design Definition; 5.3. MBSE; #MBSE-DE;

Abstract. Transitioning to large scale MBSE is an industry-wide challenge, not the least for the multitude of models that will be managed. This paper presents a model structure and classification scheme adapted for iterative systems development. Examples illustrating real world applications are provided.

Biography

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Extending Systems Engineering for Safety-Critical Defence Applications

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Keywords. systems safety;systems engineering;standards;IEC 63187;IEC 61508;ISO/IEC/IEEE 15288

Topics. 4.6. System Safety; 6. Defense; #MBSE-DE;

Abstract. Defence sector applications are often characterized by a high level of complexity. ISO/IEC/IEEE 15288 provides a common set of life cycle processes and terminology for engineering complex systems but its generic approach does not directly address the needs of safety-critical systems. In contrast, safety-specific standards like for example IEC 61508 provides a framework for functional safety, but does not address the complexity found in defence systems.

Paper#184

How Systems Thinking Provides the Foundation for A W-Shaped Model of an Effective Technical Leader

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Abstract. Technical Leadership is a relatively new subject that has not been adequately addressed inliterature. Behaviors and skills ofeffective technical individuals and leaders are defined and citedoften, including various shape models of individuals. However, a SystemsThinking approach for combining these two mindsets has not been documented.This paper's goal is to provide a background on effective technical andleadership behaviors and skills, relate them to the various shape-based modelsof individuals, and ultimately present a novel W-shaped model describing aneffective Technical Leader whose foundation is a Systems Thinking mindset.

Biography

Michael Wozniak (Self) - michael.v.wozniak@gmail.com
An INCOSE Certified Systems Engineering Professional (CSEP) who has been working in the aerospace defense industry for eleven years with experience providing integrated Systems Engineering solutions for designs in traditional and Agile programs. He is a member of INCOSE's Technical Leadership Institute Cohort 6 with aspirations to get into high-level technical leadership. He hopes to continue advancing Systems Engineering concepts in theory and practice while mentoring and leading others to achieve their goals.

Paper#434

How the INCOSE Model-Based Capability Matrix has Steered Model-Based Systems Engineering Transformation at NASA

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Keywords. MBSE;digital engineering;MBCA;MBCM

Topics. 2. Aerospace; 3.6. Measurement and Metrics; 5.3. MBSE; 9. Enterprise SE (organization, policies, knowledge, etc.); #MBSE-DE;

Abstract. The National Aeronautics and Space Administration (NASA) is embarking on new, complex, and diverse missions to accomplish its scientific and exploration objectives, and it views digital trans-formation as a key enabler for those missions. The NASA Model-Based Systems Engineering (MBSE) Leadership Team (MLT) is leading the charge in the digital transformation of the systems engineering domain at NASA, and it is using the INCOSE Model-Based Capability Matrix (MBCM) as a roadmap. This paper discusses the modifications and tailoring of the INCOSE MBCM (Hale & Hoheb, 2020) for use at NASA, the process the team has taken on multiple rounds of assessment, findings to date, and work products that have been generated as a result of the assessment. The paper will also discuss findings and potential changes that should be made to the original product.

Paper#160

Human Frailties: Springboard to Increased Systems Engineering Influence

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Keywords. Leveraging human frailties;systems engineering influence;strategies;tactics;case studies

Topics. 20. Industry 4.0 & Society 5.0; 3.3. Decision Analysis and/or Decision Management; 3.5. Technical Leadership; 3.9. Risk and Opportunity Management; 9. Enterprise SE (organization, policies, knowledge, etc.); #FuSE

Abstract. Come hear how you, as a systems engineer, can increase your influence on decision-makers and thus decrease risks and improve the chances of project success.

Paper#371

Human-centered Smart Cities: an evaluation of a small community using the Smart Cities Initiative framework

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Keywords. Smart Cities;Domain application of SE;Infrastructure

Topics. 1.6. Systems Thinking; 12. Infrastructure (construction, maintenance, etc.); 2.1. Business or Mission Analysis; 22. Social/Sociotechnical and Economic Systems; 5. City Planning (smart cities, urban planning, etc.); 5.10. Diversity (cultural boundaries, diverse engineering teams, training underserved groups, etc.); #FuSE

Abstract. In September 2023, the INCOSE Smart Cities Initiative released a framework to evaluate and define smart city systems. It includes a human-centered definition of a smart city and offers metrics of a smart city. The framework allows consistent evaluation of city that focuses on providing for fundamental human needs. This case study is a qualitative analysis to apply the definition and framework. It provides an opportunity to evaluate the strengths and weaknesses of the new INCOSE framework.

Paper#545

Hyundai's Modular MBSE Approach to 'Purpose Built Vehicle' Architecture Development

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Keywords. system architecture;modularization;automotive;system of systems;PBV

Topics. 2.4. System Architecture/Design Definition; 2.6. Verification/Validation; 3. Automotive; 5.3. MBSE; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.);

Abstract. This presentation describes the modular MBSE approach applied to vehicle performance development at Hyundai. Hyundai Motor Group aspires to transition to a smart mobility paradigm where the boundaries between systems blur. The paper describes a MBSE approach applied in the context of smart mobility system of systems that can be incorporated to efficiently develop modular systems together with the automotive supply chain.

Identifying Reference Architecture Types for Stakeholder Groups in Industry 4.0

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Keywords. Reference architecture;Industry 4.0;RAMI 4.0;Model-based systems engineering

Topics. 14. Autonomous Systems; 2.2. Manufacturing Systems and Operational Aspects; 2.4. System Architecture/Design Definition; 20. Industry 4.0 & Society 5.0; 5.3. MBSE;

Abstract. New developments in the area of the Industrial Internet-of-Things (IIoT) and Industry 4.0 offer huge potential for a more efficient and flexible industrial production, but are also accompanied by rising system complexity. Consequently, to deal with the increased system complexity, novel methods in systems engineering are emerging. However, most of these novel methods are not yet mature and rather theoretical than ready-to-use. Thus, companies need to be provided with frameworks that actively support the transformation of their systems towards Industry 4.0. One of those approaches has been introduced with Reference Architecture Model Industry 4.0 (RAMI 4.0), which counteracts the men-tioned complexity and can be used for various use cases. However, as most of its concepts are too general to be applied directly to actual systems, the need for directly applicable reference architectures emerges. Therefore, this paper proposes a method to derive more detailed reference architectures based on RAMI 4.0 by making use of model-based systems engineering (MBSE), which target single manufacturing domains rather than the whole industry. Therefore, relevant stakeholders are analyzed and different types of reference architectures targeting their concerns are identified. The resulting reference architectures should be ready-to-use for interested manufacturers and thus, enhance the acceptance of RAMI 4.0 as well as improve systems engineering in industrial manufacturing. Finally, the developed reference architecture is evaluated in a real-world case study of a flexible production system.

Paper#273

Implications of Cultural Differences in the Systems Engineering Professional Competencies

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Keywords. Professional competencies;Cultural differences;Organizational implications

Topics. 22. Social/Sociotechnical and Economic Systems; 4.5. Competency/Resource Management; 5.10. Diversity (cultural boundaries, diverse engineering teams, training underserved groups, etc.); 9. Enterprise SE (organization, policies, knowledge, etc.); #TechnicalLeadership

Abstract. This presentation addresses the implications of cultural differences in the INCOSE Professional Competencies to systems teams. Specifically, conclusions are drawn as to the importance of improving competence in the Professional Competencies and of how to use them in selecting systems engineers, forming and developing systems teams, and making culturally sensitive design decisions based on the intended user population.

Paper#37

INCOSE Systems Engineering Competency Assessment Guide Systems Modeling Language (SysML) Model Description

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Keywords. Systems Engineering Competency Model;Competency;Competence;Model Based Systems Engineering (MBSE);Systems Modeling Language (SysML)

Topics. 1. Academia (curricula, course life cycle, etc.); 4.5. Competency/Resource Management; 5.3. MBSE; 9. Enterprise SE (organization, policies, knowledge, etc.); Other domain;

Abstract. The INCOSE Systems Engineering Competency Framework and INCOSE Systems Engineering Competency Assessment Guide provide a requirement definition for 37 systems engineering competencies across 5 different proficiency levels and sample evidence against each of these indicator requirements. This paper describes the development of a Systems Modeling Language (SysML) model that provides a digital representation of the architecture framework and associated requirement and evidence entry databases.

Paper#25

Innovation Ecosystem Dynamics, Value and Learning I: What Can Hamilton Tell Us?

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Abstract. IS2024 in Dublin invites a refresh on contributions to SE by Ireland's greatest mathematician, William Hamilton. Supporting theory and practice, they intersect Foundations and Applications streams of INCOSE's FuSE program. Strikingly, key aspects apply to systems of all types, including socio-technical and information systems. Applied to the INCOSE Innovation Ecosystem Pattern, this suggests an architecture for integration of the digital thread and machine learning in innovation enterprises.

Paper#312

Institute for Convergent Systems Engineering: A Strategic Plan for Ethical Sustainability

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Keywords. Convergent systems engineering;ethical sustainability;value supply chains;research institutes;strategic plans

Topics. 1.6. Systems Thinking; 10. Environmental Systems & Sustainability; 20. Industry 4.0 & Society 5.0; 22. Social/Sociotechnical and Economic Systems; 4.1. Human-Systems Integration; 5.4. Modeling/Simulation/Analysis;

Abstract. The last few years have made it clear that the world is entering a new phase in which sustainability is of paramount importance to the survival and well-being of our global societies. This paper describes the strategic plan for the Institute for Convergent Systems Engineering which is addressing the challenge of ethical sustainability in which social, environmental, and economic implications are carefully considered and balanced. Included is a discussion of the criticality of convergent systems engineering and its values and principles. The paper also presents a three part strategy for sustainability at the macro, meso, and micro levels entailing the consideration of end to end global value supply chains. The foundational pillars of research, education, and collaboration are also described.

Integrating AI with MBSE for Data Extraction from Medical Standards

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Keywords. Model-Based Systems Engineering;Artificial Intelligence;Digitization;Norm Compliance;Large Language Model;Classification

Topics. 4. Biomed/Healthcare/Social Services; 5.11. Artificial Intelligence, Machine Learning; 5.3. MBSE; #AI; #MBSE-DE

Abstract. The growing adoption of Model-Based Systems Engineering (MBSE) in the medical sector has prompted a significant emphasis on the digitization of medical standards into norm models aiming to improve data efficiency and establish traceability between norm data from medical standards and other model data, such as SysML models. Despite these efforts, the current digitization activities heavily rely on manual extraction and transformation, particularly from PDF documents into SysML models. Concurrently, the proliferation of Artificial Intelligence (AI) applications in recent years presents an opportunity to enhance these digitization activities. This paper contributes to the integration of AI with MBSE, focusing on automating and optimizing the digitization of medical standards. It explores the initial outcomes of augmenting data extraction from medical standards using advanced AI technologies and integrating them into MBSE practices. The evaluation involves two approaches, an open-source multimodal classifier model and a proprietary large language model. The study assesses these approaches on a medical standard and outlines future work, including the introduction of a third approach.

Integrating IoT Technology with a Systems Engineering Approach to Improve the GHG Emission Accounting in the Waste Management Industry

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Keywords. Waste Management Industry;IoT;GHG emissions accounting

Topics. 10. Environmental Systems & Sustainability; 11. Information Technology/Telecommunication; 3.4. Information Management Process; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.);

Abstract. This work presents how to automate emission accounting and analysis in the waste management industry. The methodology adopted is based on the combined use of Internet of Things (IoT) technology and a Systems Engineering approach. The presented methodology has been tested in an industrial case. In the case, there were multiple systems available to collect environmental data. However, the ac-cessibility and the interpretability of this environmental data were observed as a challenge. After gathering the data in a centralized database, the automation of the Green House Gasses (GHG) emission management and accounting was performed. Findings show that the operational emissions of the industry partner mainly occur from energy and fuel consumption. By measuring and categorizing energy usage, the industry partner identified several potential improvements for reducing emissions. Lowering energy usage can consequently decrease the associated carbon footprint. Finally, the authors suggest some useful insights for companies with the aim of improving the effectiveness and efficiency of industrial GHG emissions accounting.

Integrating STPA Extended for Coordination into SysML Using RAAML

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Keywords. Model-Based Systems Engineering;system safety;STPA;coordination;RAAML

Topics. 2. Aerospace; 4.6. System Safety; 5.3. MBSE; 6. Defense;

Abstract. As Model-Based Systems Engineering (MBSE) becomes prevalent in engineering practice, the Department of Defense (DoD) requires a consistent methodology to conduct and record system safety analyses in the system model. Systems Theoretic Process Analysis (STPA) is a relatively new safety and hazard analysis method that utilizes the principles of Systems Theory and abstraction to analyze today's complex systems. Systems Theoretic Process Analysis Extended for Coordination (STPA-Coord) provides a framework to design safe coordination among a system-of-systems architecture, which is needed for next-generation integrated military systems. This research presents results from conducting an STPA-Coord in Systems Modeling Language (SysML) using Risk Analysis and Assessment Modeling Language (RAAML), a recent extension to SysML that provides tools and guidance for multiple safety analyses. Results describe deviations from the RAAML standard and suggest extensions to RAAML for STPA-Coord. Results include qualitative and quantitative observations conducting an STPA-Coord using SysML, including time required for the effort and perceived benefit over document-based methodologies.

IT/OT Integration by Design

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Keywords. IT/OT integration;Digital Twin;MBSE;BPMN;RAMI4.0

Topics. 11. Information Technology/Telecommunication; 14. Autonomous Systems; 2.5. System Integration; 20. Industry 4.0 & Society 5.0; 5.3. MBSE; 5.5. Processes;

Abstract. The four Industry 4.0 design principles information transparency, technical assistance, interconnection, and decentralized decisions pose challenges in integrating information technology (IT) and operational technology (OT) solutions in industrial systems. These different solutions have conflicting requirements, making interfaces between them problematic for both systems and organizations. An Industrial Business Process Twin (IBPT) entity, acting as an intermediary between the realms of IT and OT, has been proposed in a previous work, to effectively reduce the amount of required IT/OT interfaces in an attempt of overcoming this situation. In this work, we investigate the effects of this approach during the design phase. We argue that, by eliminating interfaces between IT and OT components in the system design, this approach is therefore eliminating conflicting communication channels within the organization's communication structure. In order to verify our argument, we develop a model of our IBPT concept according to the Reference Architecture Model Industrie 4.0 (RAMI4.0) using an Industry 4.0 scenario addressing the four essential Industry 4.0 design principles. Results show that the IBPT approach indeed eliminates potentially conflicting IT/OT interfaces during the system design phase.

Lifecycle of Accident Pathogens: Common Systemic Factors in Construction System Accidents

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Keywords. construction system accident;temporary multi-organization;systemic factors;accident pathogen;system safety

Topics. 12. Infrastructure (construction, maintenance, etc.); 22. Social/Sociotechnical and Economic Systems; 3.7. Project Planning, Project Assessment, and/or Project Control; 4.3. Reliability, Availability, and/or Maintainability; 4.6. System Safety; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Construction system accidents are accidents due to defects embedded in the constructed systems (e.g., buildings, bridges, and other infrastructures) originating from failures in construction systems, which we can consider as temporary multi-organizations (TMOs) that are organic and ephemeral in nature. Understanding the mechanisms of such accidents in transient and multi-organizational systems requires a system-wide perspective and consideration of the temporary aspect. This paper examines six accident cases using the framed-and-layered accident pathogen propagation (FLAPP) model—an accident model we specifically developed to capture system-wide factors and the time dimension—and identifies five types of pathogen threads and eight types of thread elements, which contribute to the propagation of latent failures and defects, i.e., accident pathogens. With concrete reference to the processes and products found in accident cases, the concept of pathogen thread provides an explicit structure to the classic metaphor of pathogens that the safety literature has been using to describe latent failures. This paper further proposes the concepts of pathogen susceptibility and transmissibility to explain the mechanisms and dynamics that drive the generation and propagation of accident pathogens. Acknowledging the limitations of the modeling framework, this paper concludes with a discussion of the directions for future work to ensure system safety in the construction of future systems in various domains.

Paper#79

Long Term Trends in Security Threats and an Ap-proach for Integrating Them into System Architecture and Design

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Keywords. architecture;system security;trends;design;agile

Topics. 2.4. System Architecture/Design Definition; 4.7. System Security (cyber-attack, anti-tamper, etc.); 5.1. Agile Systems Engineering;

Abstract. Cyber security is an evolving consideration for design of current and future systems. A literature review of cyber challenges across a range of industries reveals a set of recurring long-term trends. These trends suggest challenges to security capabilities in the future. In this paper, we summarize and analyze these trends and propose an approach for addressing them using modern methods in architecture and design activities.

Paper#254

Mean dependency length – a new metric for requirements quality

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Keywords. Requirements quality metrics;Natural language requirements;Dependency grammar

Topics. 2.3. Needs and Requirements Definition; 3.6. Measurement and Metrics; Other domain;

Abstract. According to the authors, a linguistic feature based on dependency grammar, called mean dependency length (MDL), can be used as a metric to measure the quality of natural language requirements. They conducted statistical tests on over 1700 sentences, taken from 249 requirements that were rewritten using five different patterns. The results indicated that MDL is responsive to the application of pattern rules, aligned with users' values, and it can be automatically quantified.

MissionML: A Mission Architecture Modeling Language based on Unified Architecture Framework

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Keywords. UAF;Mission Architecture;UAF profile.

Topics. 2. Aerospace; 2.1. Business or Mission Analysis; 21. Urban Transportation Systems; 5.3. MBSE; 7. Emergency Management Systems; #MBSE-DE;

Abstract. The missions of complex systems, organizations, or groups can be identified through careful requirements and domain analysis. Mission architecture modeling is a crucial step for enterprise modeling and design. However, the concept of mission modeling is absent from the Unified Architecture Framework (UAF), in which the system engineers have to specify and model from the sketch. In this paper, we propose a Mission Architecture Modeling Language (MissionML), a two-layer architecture language that generalizes the general common knowledge and special knowledge from five typical missions as a shared layer and specific characteristic layer. Moreover, MissionML is implemented as a UAF profile, incorporating numerous domain concepts in its syntax and semantics for mission modeling. Finally, we use five public case studies to demonstrate the learnability and extensibility from the view of system engineers.

Paper#472

Model-Based Architectural Patterns for Teaching Systems Engineering

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Keywords. model-based patterns;pattern language;pattern library;SysML patterns

Topics. 1. Academia (curricula, course life cycle, etc.); 2. Aerospace; 2.4. System Architecture/Design Definition; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 5.9. Teaching and Training;

Abstract. This paper presents an incremental addition to the existing published work by the authors and describes an extended novel application of space-based pattern library and architectural patterns for teaching systems engineering in the classroom. This paper addresses the use of an applicable MBSE based pattern library, and its concepts, appear useful in teaching systems architecting.

Paper#264

Model-Based Decision Support using Test and Evaluation: A Lightweight Architecture Approach

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Keywords. Digital Engineering;MBSE;Decision Support;IDSK;Reference Architecture;Test and Evaluation;DOT&E

Topics. 1.6. Systems Thinking; 2. Aerospace; 2.4. System Architecture/Design Definition; 3.3. Decision Analysis and/or Decision Management; 5.3. MBSE; 6. Defense;

Abstract. A standardized decision support tool to support test prioritization and decision-making is a prerequisite to achieving on-time delivery of weapon systems that are adequately tested and vetted by decision makers within distributed organization such as the defense industrial base. To address this need, a model-based reference architecture for the standardization of the Integrated Decision Support Key (IDSK) data and decision formats is presented in this paper.

Paper#77

Model-Based Systems Engineering (MBSE) Application in Nuclear Power Plants (NPP)

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Keywords. MBSE;SysML;Nuclear;Impact Analysis;Lifecycle;Maintenance;Safety;Reliability

Topics. 2.4. System Architecture/Design Definition; 5.3. MBSE; 8. Energy (renewable, nuclear, etc.);

Abstract. Companies in the nuclear power sector are constantly being challenged to improve their safety and reliability due to increasing complexity arise from evolving safety regulations, long production life, interdisciplinary collaboration, and the need for analyzing the impact of the changes in an operational life cycle. Recognizing these challenges, the paper proposes a transition to Model-Based Systems Engineering (MBSE) as a transformative solution to improve the management of such complex systems. With this objective, this paper presents a workflow implementation that demonstrates the MBSE methodologies to define a concept model, system architecture, impact analysis, safety and reliability analysis, and operational decision-making of Nuclear Power Plants (NPP). The paper concludes that MBSE provides a potent approach to managing NPP by employing graphical models to develop interrelated systems that has strong adaptability to heterogeneous environments and regulatory changes. The simulation results demonstrated an NPP life cycle, impact analysis, and a test case for model-based safety and reliability analysis for regulatory compliance, operational efficiency, balance safety, and informed decision-making in NPP. The study also leads to a number of interesting directions of future work such as synchronization through Product Lifecycle Management, integration with Building Information Modeling, Model-Based Commissioning/Decommissioning, and Model-Based Cyber System Security tailored for nuclear power systems.

Paper#412

Model-Based Systems Engineering (MBSE) Methodology for Integrating Autonomy into a System of Systems Using the Unified Architecture Framework

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Abstract. Many stakeholders of existing Systems of Systems (SoSs) are interested in leveraging the new ca-pabilities provided by autonomous systems empowered by Artificial Intelligence (AI). This requires the integration of these systems into SoSs, resulting in Systems of Autonomous Systems (SoASs). SoAS architecting is different from SoS as the architecting challenges are exacerbated by the Level of Autonomy (LoA). An autonomous system has various LoAs depending on its AI advancement and the capabilities it provides. Each LoA impacts the managerial and technical challenges for SoAS architecting in a different manner. The managerial aspect covers concerns such as policies and agreements, whereas the technical aspect highlights issues such as compatibility between autonomous systems and legacy systems. Failure to address the LoA impact on these factors in the architecting phase results in an ineffective integration. In this paper, we propose a methodology that follows the SoS hierarchical lexicon, builds upon the standard steps of the Object-Oriented Systems Engineering Method (OOSEM), and leverages the Unified Architecture Framework (UAF) for modeling autonomy integration. The proposed methodology adds detailed sub-steps to OOSEM, where we introduce the required UAF views for modeling each aspect of the SoAS architecture. This methodology lays the foundation for the trade study analysis that helps stakeholders decide on suitable LoAs for SoAS. We also present an illustrative example to demonstrate the implementation and effectiveness of the proposed methodology.

Modeling Cybersecurity Operations to Improve Resilience

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Abstract. This paper explores the concept of a computer system's operational resilience, focusing on a cybersecurity team's processes. The computer system under examination has faced a cyberattack. The organization's reputation is damaged temporarily but can be restored if the cybersecurity team can quickly restore the system's capability. We examine the processes for restoring the system's capability with a balanced and adaptive personnel assignment policy.

Modeling NASA's Procedural Requirement Processes - Implications for Digital Future

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Topics. 2. Aerospace; 2.1. Business or Mission Analysis; 3.5. Technical Leadership; 5.3. MBSE; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. The National Aeronautics and Space Administration (NASA) has an ongoing Digital Transformation effort and to leverage and showcase the power of Digital Transformation, an effort is underway to develop an integrated, datacentric, model representing NASA's key process requirements. The task was divided into three phases: As Is modeling, Analysis, and To Be Planning. As part of this effort, a team has completed the first Phase I of the modeling task and is nearing completion of the second phase. This effort will capture the key elements as requirements, responsibilities, allocations, roles, products and associated lifecycle ele-ments. The scope of modeling included NASA's NPR 7120.5 (Project and Program Management), NPR 7123.1 (Systems Engineering) and NPRs 8705.2 (Risk classification for Robotic Missions) and 8705.4 (Human-Rating Requirements for Space Missions). This paper will summarize the approach, scope, parsing patterns applied, metamodel, and associated workflows for the As Is modeling. It will also summarize the results and insights gleaned during that phase, including the review process. These insights have informed the analysis and will be discussed. The analysis modeling phase will also be summarized including how the stakeholders were engaged, how the common elements were handled and dispositioned, and will also describe some of the plans for the future of NASA NPDs and NPRs.

Biography

Terry R. Hill (NASA) - terry.hill-1@nasa.gov
Terry R. Hill has been with NASA for over 25 years and serves as the Digital Engineering Program Manager led out of NASA Headquarters' Office of Chief Engineer and is responsible for providing a strategic and executable implementation approach for delivering digital engineering, MBSE methodology and interoperable tool chains to usher the agency into the modern world of DE design and SE.

Paper#220

Modeling Principles to Moderate the Growth of Technical Debt in Descriptive Models

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Keywords. MBSE;descriptive models;technical debt;model architecting;modeling principles

Topics. 2.4. System Architecture/Design Definition; 5.3. MBSE;

Abstract. This paper describes 18 foundational modeling principles that model architects should consider when making architectural and implementation decisions about their models and describes some of the key model technical debt tradeoffs that result when these principles are not followed. These principles address commonly observed problems regarding model federation architecture, the selection and use of model layers, the modeling of the domain, and the semantics of modeling constructs.

Paper#232

Modeling swarm mission with COTS characterization: a series of return on experience

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Keywords. Architecture Frameworks;MBSE;COTS;return on experience

Topics. 1.1. Complexity; 5.4. Modeling/Simulation/Analysis; 6. Defense;

Abstract. System design in defense systems is a competitive field, in which economical viability relies on a sequence of architectural decisions, aiming at quality, resource and time (Q,R,T) compromises. Furthermore, the investment to conduct weapon acquisitions and lifecycle maintenance until dismantlement involves major investments in industries. If systems engineering (SE) practice mostly focuses on early design activities and development, we observe that there is little information in literature in SE field that relate to general quality, resource and time compromises or quantified return-on-investment. On the other hand, we observe that low-cost unmanned ground vehicles (UGV) and drones appear as new threats on current battlefield. To face these new threats, ministries of defense have organized challenges around robotization of battlefield, to design future employment doctrines and help technologies to reach maturity in a reasonable time. This article exposes a set of NATO Architecture Framework (NAF) 3.1 views that match a recent robotic military challenge over two yearly iterations. The capabilities depicted are requirements to compete in the challenge, constituent systems are based on Components-Off-The-Shelf (COTS) answering to both edition of the challenge. For the second iteration, we re-used views that were selected at first, and realized documented return on experience (RetEx) reports for both editions. This article details how manually re-injecting feedback from field back to the system model failed to help for the second iteration of the challenge. Our works propose conclusions on capabilities iterations from a general perspective, and develop propositions that introduces the necessity to create realistic simulation environments threads to verify and validate emergent behavior of systems composed of COTS in a constrained time and resource context.

Paper#275

Multiple Pathways of Influence for Tightly and Loosely Structured Organizations: Implications for Systems Resilience

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Keywords. organizations;structure;influence;decision-making;systems resilience

Topics. 10. Environmental Systems & Sustainability; 22. Social/Sociotechnical and Economic Systems; 3.3. Decision Analysis and/or Decision Management; 4.4. Resilience; 5.4. Modeling/Simulation/Analysis; Other domain;

Abstract. Organizations play a key role in supporting various societal functions, ranging from environmental governance to manufacturing of goods. The behaviors of organization are impacted by various in-fluences, including information, technology, authority, economic leverage, historical experiences, and external factors, such as regulations. This paper introduces a generalized framework, focused on the relative structure of an organization (tight vs. loose), that can be used to understand how different influence pathways can impact decision-making within differently structured organizations. This generalized framework is then translated into a modeling and simulation platform approach to support and assess implications of these structural differences on overall behaviors of the organizations. Specifically, a systems dynamics approach is used to simulate tightly structured and loosely structured organization in the context of varying amounts of information quality present within the environment. Preliminary results indicate that a tightly structured organization is less timely at processing information within the environment, and it could be more resilient to how much poor quality information is incorporated within its final decisions under certain conditions, in comparison to the loosely structured organization. Ongoing work is underway to understand the robustness of these findings and to align current model design activities within empirical insights.

Paper#488

NASA's Use of MBSE and SysML Modeling to Architect the Future of Human Exploration

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Keywords. NASA;exploration mission planning;Moon2Mars;Artemis;complexity management;MBSE;SysML modeling

Topics. 1.1. Complexity; 2. Aerospace; 2.5. System Integration; 5.3. MBSE; #MBSE-DE;

Abstract. To enable the NASA to take on larger, more complex science and exploration missions new ways of integrating, managing, sharing and leveraging information is required with utilizing MBSE and associated models to link work groups from Headquarters to field Centers to enable mission feasibility, planning and operations in taking humanity to the Moon and on to Mars.

Biography

Terry R. Hill (NASA) - terry.hill-1@nasa.gov
Terry R. Hill has been with NASA for over 25 years and serves as the Digital Engineering Program Manager led out of NASA Headquarters' Office of Chief Engineer and is responsible for providing a strategic and executable implementation approach for delivering digital engineering, MBSE methodology and interoperable tool chains to usher the agency into the modern world of DE design and SE.

OMG Standard to Extend SysML to Reliability Engineering

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Keywords. SysML;Reliability;RAAML;Reliability Block Diagrams;MBSE

Topics. 2. Aerospace; 3. Automotive; 4.3. Reliability, Availability, and/or Maintainability; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 6. Defense;

Abstract. SysML offers the possibiltiy of integrating Reliability, Availability, and Availabiltiy (RAM) engineering with system engineering from the beginning of the design process. However, until now, are no standardized methods for performing RAM engineering within SysML models. This paper describes the RAAML (Risk Assessment and Analysis Modeling Language) standard method for Reliability Block Diagrams in SysML. AThe standard can enable interoperable, and standardized RAM engineering as part of MBSE.

One Model to Rule them All … and Through Emergence, Bind Them

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Keywords. Systems Models;Systems Thinking;Iceberg Model;MBSE;Engineering of Systems;Model of Systems Model

Topics. 1. Academia (curricula, course life cycle, etc.); 1.5. Systems Science; 1.6. Systems Thinking; 5.3. MBSE; 9. Enterprise SE (organization, policies, knowledge, etc.); #FuSE; #MBSE-DE

Abstract. In a contemporary context of models being central to understanding systems and the model-based engineering of systems, this paper explores the possibility of a meta "model of systems models", seeking to find, in "Gandalf's phraseology", "One model to rule them all, one model to find them, one model to frame them all, and through emergence bind them".

Promoting Neurodiversity Through MBSE and Other Technical Approaches

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Keywords. Neurodivergent;Autism;MBSE;Data-Driven;Lifecycle Modeling

Topics. 5.10. Diversity (cultural boundaries, diverse engineering teams, training underserved groups, etc.); 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; #TechnicalLeadership

Abstract. The Systems Engineering industry employs a large number of people from the neurodivergent community. This research is important because it explores how we can promote diversity through systems engineering. The challenge we face in the industry is finding ways to work on complex systems that are inclusive of different neurological processes. This paper begins by looking into the meaning of neurodivergence, which shows us different ways our industry can include that community. Extensive research on the neurodiverse community shows that many lean toward visual learning styles and strict rules. Using this information, the industry could use a data-driven approach to Model-Based Systems Engineering (MBSE) to help the neurodivergent community better understand systems engineering, specifically using a common ontology. This research highlights the ontology, Lifecycle Modeling Language, a structured and behavioral modeling language. Through a heavier focus on Data-Driven MBSE and a collective ontology across our industry, we can create opportunities and foster positive change from a new community with a new perspective.

Providing tailored heuristic advice to Systems Engineers

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Abstract. Difficulty Assessment Tools (DATs) have been used for many years to characterize a problem to provide tailored advice. An INCOSE-wide initiative has exposed at least 600 heuristics and counting. Previous work indicates that rationalizing and simplifying this set to make it a useful memorable set is likely to be intractable. This paper explores using a DAT to characterize a problem and provide a range of advice including heuristics advice to the users. To test this approach, 57 heuristics and 10 principles were scored and embedded into an online DAT. An experiment was conducted to determine if the discussion, ap-proach and heuristic/principles advice was relevant and/or useful. The results indicate that the discussion, approach and Heuristic advice provided were considered highly relevant by the users of the tool. The discussion was considered very useful, the approach advice somewhat useful and the heuristics considered a bit useful on average. The usefulness score was tempered by the perceived newness of the advice. The tailoring of the heuristics to the task was not noticeable by the users of the tool, though it aligned with the authors' expectations. The relevance and usefulness results indicate that Systems Engineers should use the DAT to inform their approach.

Paper#276

Real to Real: Deriving Software Development Practices from Film Production Principles

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Keywords. project management;software development;film production;cross industry learning

Topics. 11. Information Technology/Telecommunication; 3.5. Technical Leadership; 3.7. Project Planning, Project Assessment, and/or Project Control; 5.1. Agile Systems Engineering; Other domain;

Abstract. Explore parallels between film production and software development in 'Real to Real: Deriving Software Development Practices from Film Production Principles.' This paper explores project management in the film industry and identifies similar practices that could improve outcomes in software development projects that face similar challenges. Join us as we discuss a repeatable process for adapting management strategies across industries.

Paper#403

Risk Assessment Method for Systems-of-Systems Operation

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Keywords. System-of-Systems;Risk assessment;Operational strategy

Topics. 1.6. Systems Thinking; 10. Environmental Systems & Sustainability; 22. Social/Sociotechnical and Economic Systems; 4.6. System Safety; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 7. Emergency Management Systems;

Abstract. A SoS is a set of collaborating systems that act towards a common achievement. Risk assessment is important in the early stages of SoS operational development, both for mission objectives and to enable technology which is developed responsibly. The method considers risks that stems from both internal and external interactions which leads to losses for different kind of actors. The method has been applied to a case study of wildfire fighting. The internal interactions are mostly communication between the CSs while external interactions represent dependencies of other systems as well as impacts on other systems. The outcome of the methodology is a network of connected hazards to be used for risk management and for high level SoS requirements.

Paper#185

Role-Based Structuring of Systems Engineering Teams

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Keywords. Structuring;Organizing;SE Roles;Teams;Growth;Management;Leadership

Topics. 3.5. Technical Leadership; 5.5. Processes; 5.9. Teaching and Training;

Abstract. Systems Engineering technical processes are well-defined. However, the efficiency and success of a project is dependent on how these processes are tailored and integrated with the SE team structure. Leadership defines the role of and how their SE teams are structured and empowered to execute these processes. This paper explores a few organizational options for SE structures and provides two case studies from the author's personal experience on large and complex projects.

Paper#54

Secure Design: A Practical Approach for Systems Engineers

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Keywords. Security;System Security;Resilience;Design;Architecture;System Security Engineering

Topics. 2.4. System Architecture/Design Definition; 4.4. Resilience; 4.7. System Security (cyber-attack, anti-tamper, etc.); #FuSE

Abstract. Systems Engineering Vision 2035 states that security will be as foundational a perspective in systems design as system performance and safety. This paper informs such a perspective, borrowing heavily from concepts of inherently safe. Inherently secure design is a design where hazards, susceptibilities, and vulnerabilities are eliminated to the extent possible and the remaining ones are controlled, while still enabling the system to meet performance requirements.

Paper#564

Securing Your Eggs in Multiple Baskets – Assuring a Resilient and Secure Supply Chain

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Keywords. Supply Chain;UAF;Systems of Systems;MBSE;Enterprise;Assurance;Risk Management

Topics. 17. Sustainment (legacy systems, re-engineering, etc.); 20. Industry 4.0 & Society 5.0; 3.1. Acquisition and/or Supply; 4.3. Reliability, Availability, and/or Maintainability; 5.3. MBSE; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. The global supply chain is a complex system of systems made up of and relying on other complex systems of systems (SoS) to achieve its goals. When any of these complex systems fail, the impact can be global, and the results catastrophic. Threats, vulnerabilities, and risks need to be identified mitigated to ensure a solid and reliable supply chain. This paper will look at the supply chain to determine how some of these problems can be predicted, prevented, mitigated, and solved using the UAF.

Sustainability Mindshift: Incorporating the Systems Perspective

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Keywords. Sustainability;Paradigm Shift;Systems Engineering;SE Vision 2035

Topics. 1.5. Systems Science; 1.6. Systems Thinking; 10. Environmental Systems & Sustainability; 17. Sustainment (legacy systems, re-engineering, etc.); 3.5. Technical Leadership;

Abstract. The pursuit of sustainability is a noble undertaking and unarguably 'a good thing'. The concept can hardly be denied as something that is good for future societal wellbeing. However, beyond a superficial acknowledgement of the inherent 'goodness' of sustainability, there is much to be gained through the re-framing of sustainability as an engineered product from an underlying system as opposed to a 'development goal'. In pursuit of this Mindshift, following an introduction and discussion of the sustainability landscape, three challenges for sustainable systems development are explored. The first Mindshift challenge examines sustainability as a product from an underlying system. Thus, the focus is shifted from sustainability as a goal to sustainability as a purposefully designed product from an engineered system. The second Mindshift challenge explores sustainability through the lenses of Systems Theory. Systems Theory exist as a set of axioms (taken for granted 'truths') and propositions (system concepts, laws, and principles) that govern the behavior, structure, and performance of systems. The implications of Systems Theory have profound implications for how we view sustainability. The third Mindshift challenge suggests that sustainability can be enhanced through the purposeful identification, assessment, and resolution of violations of system propositions (pathologies) spanning design, execution, and development. Thus, sustainability is a 'systems engineered product' resulting from an underlying system and developed by addressing systems-based disparities (pathologies) in the system. The paper closes with a capsule of Mindshift challenges for sustainability and their implications for supporting the INCOSE SE Vision 2035.

Paper#463

Synergizing Structure and Agility: A Comprehensive Analysis of SAFe Agile Framework through the Lens of Stafford Beer's Viable System Model

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Keywords. VSM;SAFe Agile Framework®;Systems Thinking;Agile Methodologies;IDEF0 Functional Modeling;Organizational Management;Cybernetics in Business;Agile Transformation;Systemic Analysis;Agile Systems Engineering

Topics. 1.6. Systems Thinking; 3.5. Technical Leadership; 5.1. Agile Systems Engineering; 9. Enterprise SE (organization, policies, knowledge, etc.); #FuSE

Abstract. This paper presents a novel examination of the SAFe® (Scaled Agile Framework®) through the theoretical framework of Stafford Beer's Viable System Model (VSM). By applying the principles of VSM, renowned for its systemic and cybernetic approach to organizational management, we offer a unique perspective on the structural and functional aspects of SAFe® in its various configurations: Essential, Large Solution, Portfolio, and Full. The study employs functional modeling to delineate the congruencies and divergences between VSM and SAFe®, aiming to illuminate how VSM's systemic insights can enhance the implementation and efficacy of SAFe® practices. This interdisciplinary approach not only contributes to a deeper understanding of SAFe's® capabilities and limitations but also demonstrates the practical applicability of VSM in contemporary agile environments. The findings propose actionable insights for organizations seeking to optimize their agile practices through a more structured, systemic lens, thus bridging a crucial gap in agile and systems thinking literature. This paper is poised to benefit practitioners and theorists alike, offering a fresh perspective in the agile systems domain.

Paper#84

System Revisited - Again

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Keywords. system;systems engineering;concept;abstract-virtual-physical

Topics. 1. Academia (curricula, course life cycle, etc.); 1.5. Systems Science; 3.5. Technical Leadership; 5.9. Teaching and Training;

Abstract. What is a system? This paper reviews the revised foundational definitions of system and systems engineering in the new edition of the INCOSE Systems Engineering Handbook. It concludes that the concept, not rooted in a single science or exemplar domain, is a meta-concept that does not have a dominant scientific definition. It positions systems engineering as the abstract phase within an abstract-virtual-physical design process.

Paper#109

Systems Engineering Application for Better Design and Analysis of an Assembly Process

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Keywords. SysML-PPR Model Transformation;System Behavior based Trade-off Analysis;Production-Specific Simulation;Assembly Scenario;Product-Process-Resource (PPR) View

Topics. 2.2. Manufacturing Systems and Operational Aspects; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis;

Abstract. The use of systems engineering has proven effective in managing complexity and improving system design. Model based system engineering utilizing the Systems Modeling Language (SysML) espe-cially helps in multidisciplinary environments where engineering data needs to be transformed and integrated between environments. Manufacturing is another discipline same as systems engineering is on active digitalization transformation. In the paper, we propose method and solution to apply MBSE for improvement of process planning of assembly lines leveraging model based approach. SysML modeling and execution enable automation of analysis activities as trade-off, where the be-havior of various assembly scenarios of an assembly line can be captured using SysML behavioral diagrams and compared based on various evaluation criteria. However, relying solely on descriptive SysML system models without integrating the virtual representation of the assembly line is insuffi-cient to verify all aspects of system behavior, such as ergonomics and collision avoidance. The main objective of this work is to present a concept for transforming SysML assembly scenarios into the process and resources models of the computer-aided design and manufacturing (CAD/CAM) envi-ronment. This yields a holistic view that serves as a foundation for further production-related simu-lations and analyses, enhancing efficiency, ergonomic design, factory layout, and material flow, ensuring effective assembly workstation design optimized at systems engineering level.

Paper#124

Systems Engineering roles to handle emergent properties and behaviors in complex technical systems

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Topics. 2.3. Needs and Requirements Definition; 3. Automotive; 3.5. Technical Leadership; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Emerging phenomena such as autonomous driving and connectivity are rapidly changing the automotive industry. These phenomena create new challenges for systems engineers, who must be able to adapt quickly to new market needs and requirements. Specific systems engineering roles help a German OEM meet these challenges. This contribution discusses how this OEM-specific roles can be transferred to other companies and projects.

Paper#110

Systems Lessons from the Panama Canal

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Topics. 1.6. Systems Thinking; 12. Infrastructure (construction, maintenance, etc.); 2.1. Business or Mission Analysis; 3.3. Decision Analysis and/or Decision Management; 3.5. Technical Leadership; 3.7. Project Planning, Project Assessment, and/or Project Control;

Abstract. This paper reviews the construction of the Panama Canal (predominantly 1870-1914) and finds applicable lessons regarding Systems Practice applicable today. But studying old, challenging projects, seeing what went well and badly, in order to inform our current Systems Engineering practice

Paper#489

Systems-Theoretic Concept Design: An Intent Model for Early Concept Generation

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Keywords. Systems Theory;System Design;Early Concept Generation;STAMP

Topics. 1.1. Complexity; 1.6. Systems Thinking; 2. Aerospace; 6. Defense;

Abstract. Early design concept generation for major defense systems often focus no advanced technologies & future capabilities when a more top-down approach might be more applicable. Systems-Theoretic Concept Design is a new framework to generate early concepts for new systems that better captures intent using a novel application of systems theory.

Paper#519

Tailoring of NASA-STD-3001 to the Lunar Gateway Program Requirements

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Keywords. systems engineering and integration;human systems integration;moon to mars;artemis;gateway;lunar exploration

Topics. 2. Aerospace; 2.5. System Integration; 4.1. Human-Systems Integration; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.);

Abstract. The Gateway Program must meet NASA's Agency-level human rating requirements, which are in-tended to accommodate human capabilities and limitations while protecting the safety of the crew, and providing to the maximum extent practical, the capability to safely recover the crew from hazardous situations. Human systems integration requirements represent a key component of human rating of Moon to Mars systems to support the execution of Artemis missions, including compliance with mandatory standards for Health and Medical, Safety and Mission Assurance, and Engineering. The human system requirements, together with the human systems integration plan, medical operations requirements, and Gateway subsystem specifications, represent the flow-down of NASA Health and Medical Standards (NASA-STD-3001, Volumes 1 and 2) into the Gateway system. This paper discusses how these documents and other human systems integration activities provide full consideration of human capabilities and limitations as part of the total system design trade space, serving as an example on how the human must be effectively integrated as part of the system in order to achieve mission success.

The Convergence of COSYSMO Parametric Cost Estimation with Model-Based Systems Engineering

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Keywords. COSYSMO;Parametric Cost Estimation;MBSE;Systems Engineering;Project Planning;Reuse

Topics. 2. Aerospace; 3.6. Measurement and Metrics; 3.7. Project Planning, Project Assessment, and/or Project Control; 4.2. Life-Cycle Costing and/or Economic Evaluation; 5.3. MBSE; 6. Defense;

Abstract. The promise of Model-Based Systems Engineering (MBSE) and its advertised benefits hinge on the ability of our profession to integrate engineering disciplines and project management across the system life cycle. In particular, connecting system architecture to the economics of developing such a system is a critically important topic but has not drawn significant attention by the system engi-neering community. Such integration requires two things: (1) the standardization of mul-ti-disciplinary terms and functions, and (2) the establishment of rules that govern relationships be-tween cross-functional models and modeling environments. The contribution of this paper sits squarely in those two areas by (1) establishing common terminology that describes systems engi-neering and cost estimating and (2) proposing specific cost factors and counting rules that can be used to estimate systems engineering effort using the COSYSMO cost model in an MBSE environ-ment.This paper enables the convergence of COSYSMO and MBSE by updating the COSYSMO counting rules to specifically address size driver selection and assignment in a SysML model; demonstrating how advanced queries and cross cutting views provided by modern, MBSE tools increase the completeness, quality and consistency of the parametric cost estimation results, and to reduce the cycle time from architecture to cost estimation. It defines the critical modeling patterns and guidelines for identifying system model content and level of detail for cost estima-tion and provides an approach to connect attributes and properties in a system model to the vari-ables in the COSYSMO cost estimating relationship.

Paper#484

The Digital Engineering Factory: Considerations, Current Status, and Lessons Learned

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Keywords. model-based systems engineering;digital engineering;digital thread;education;semantic web technologies

Topics. 1. Academia (curricula, course life cycle, etc.); 3.4. Information Management Process; 5.3. MBSE; 5.9. Teaching and Training; 9. Enterprise SE (organization, policies, knowledge, etc.); #MBSE-DE;

Abstract. In this paper, the authors review the development of the Digital Engineering Factory, a digital engineering environment to support students. We discuss the objectives, describe the current status of the project, and highlight current limitations and lessons learned with regards to its deployment. These may be useful to inform similar developments in industrial settings.

Paper#558

The Effects of the Assessed Perceptions of MBSE on Adoption

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Keywords. model-based systems engineering;diffusion of innovations;adoption rate;MBSE adoption

Topics. 1.1. Complexity; 3.5. Technical Leadership; 5.3. MBSE; 5.9. Teaching and Training; #MBSE-DE;

Abstract. This session examines the challenge of MBSE adoption through the lens of the diffusion of innovation theory. Data collected through a survey is used to assess how MBSE is perceived by potential adopters and the effect of those perceptions on the adoption rate of MBSE.

Paper#57

The Electric Revolution: Fully Electric Transportation System On An Urban College Campus

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Keywords. electric;transportation;college;campus;implementation;systemigram

Topics. 1.6. Systems Thinking; 10. Environmental Systems & Sustainability; 21. Urban Transportation Systems; 4.6. System Safety; 5. City Planning (smart cities, urban planning, etc.);

Abstract. This paper offers a comprehensive exploration of the implementation of fully electric transportation systems within urban college campuses. Urbanization and environmental concerns have intensified the need for sustainable transportation solutions, and college campuses serve as ideal testbeds for innovative mobility initiatives.

The Human-Technology Spectrum: A Framework for Evaluating Sociotechnical System Function Allocation, Risk, and Performance

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Keywords. Sociotechnical Systems;Function Allocation;Risk Assessment;Human-Technology integration;Function Risk Analysis;System Architecture

Topics. 2.4. System Architecture/Design Definition; 2.5. System Integration; 22. Social/Sociotechnical and Economic Systems; #FuSE

Abstract. This paper investigates the interplay of human and technological elements performing functions within socio-technical systems. With rapid technological advancements, understanding the various possible human-technology configurations, and their unique implications, is crucial. This research proposes a conceptual schema to demarcate particular kinds of human-technology relationships, as it pertains to function allocation, and aims to guide system design and risk management. The Human-Technology Spectrum (HTS) framework considers a continuum of systemic risks, lifecycle management strategies, and evaluation processes, offering a valuable resource for engineers and designers. For each stage along the HTS, we provide examples and discuss function across types of sociotechnical systems. We conclude with a discussion on the importance of understanding the tradeoffs between humans versus technologies enacting system functions.

The Importance of Being Björn – Experiences from Five Age Cohorts of Female Systems Engineers

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Keywords. Systems engineers;Technical leadership;Working life;Diversity;Sociotechnical systems;EWLSE

Topics. 2. Aerospace; 22. Social/Sociotechnical and Economic Systems; 3.5. Technical Leadership; 5.10. Diversity (cultural boundaries, diverse engineering teams, training underserved groups, etc.); 6. Defense;

Abstract. This paper gives an overview of the situation for Swedish female engineers at an engineer-ing-dense company (Saab Group) and societal factors of impact for their situation. We have interviewed five generations of female engineers and let them share their personal experiences. Some key findings are that the older generation has paved the way for the younger, but that has in many cases been costly for the individuals. The changes in society have contributed to better conditions for female engineers, e.g., the parental leave compensation and possibility for childcare at a low cost. A remaining problem is the lower proportion of female technical leaders compared to female systems engineers. They are often head-hunted for roles as project manager or line manager, and therefore the technical leader roles still are heavily male dominated.

Paper#174

The Nature of Technical Debt in the Development of Descriptive Models in MBSE

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Keywords. MBSE;descriptive models;technical debt

Topics. 5.3. MBSE; #MBSE-DE;

Abstract. This paper describes how the technical debt concept widely used in the software domain—-rework deferred to the future for expediency-—needs to be modified to the domain of descriptive models. To illustrate the model technical debt concept, several examples of modeling principles pertaining to model purpose and implementation are described along with their implications on model technical debt.

Paper#163

The Updated SERC AI and Autonomy Roadmap 2023

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Keywords. Artificial Intelligence;Machine Learning;Autonomy;AI4SE;SE4AI;FuSE

Topics. 1. Academia (curricula, course life cycle, etc.); 20. Industry 4.0 & Society 5.0; 5.11. Artificial Intelligence, Machine Learning; 5.12. Automation; #AI

Abstract. The first SERC Artificial Intelligence and Autonomy Research Roadmap was developed in 2020 and published in the first quarter 2021 special INSIGHT issue on Systems Engineering and AI. In 2020 through 2023 the SERC hosted four SE4AI/AI4SE workshops that have further informed research and application at the intersection of AI and SE. This paper presents the updated version of the roadmap resulting from engagement across those four workshops.

The Use of Virtual Reality to Facilitate Interactive Classrooms for Aviation Maintenance Technicians: A Comparative Study

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Keywords. Virtual Reality;Training;Human-Systems Integration

Topics. 1. Academia (curricula, course life cycle, etc.); 2. Aerospace; 4.1. Human-Systems Integration; 5.10. Diversity (cultural boundaries, diverse engineering teams, training underserved groups, etc.);

Abstract. Aviation Maintenance Technicians (AMTs) play an important role in guaranteeing the safety, reliability, and readiness of aviation operations worldwide. Per Federal Aviation Administration (FAA) regulations, certified AMTs must document specific mechanic-related experience to maintain their certification. Currently, aviation maintenance training methods are centered around classroom instruction, printed manuals, videos, and on-the-job training. Due to the constantly evolving digitallandscape, there is an opportunity to modernize the way AMTs are trained, remain current, and are used for on-the-job training. This research explores the implementation of Virtual Reality (VR) platforms as a method for enhancing the aviation training experience in the areas of aircraft maintenance andsustainability. One outcome of this research is the creation of a virtual training classroom module for aircraft maintenance, utilizing a web- based, open-source, immersive platform called Mozilla Hubs. While there is a general belief that VR enhances learning in general, very few controlled experiments have been conducted to show that this is the case. The goal of this research is to add, and allow otherresearchers to add, to the general knowledge for the use of VR for training and specifically for aircraft maintenance training.

Paper#529

Theoretical Underpinnings to Establish Fidelity Conditions for Defining Verification Models

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Keywords. theory of SE;verification;verification models;systems theory

Topics. 1. Academia (curricula, course life cycle, etc.); 1.5. Systems Science; 2.6. Verification/Validation; 5.3. MBSE; #FuSE;

Abstract. Systems Engineering (SE), as a discipline, has not yet established the conditions for defining verification models beyond qualitative statements made at the onset of an engineering endeavor. Our research has evaluated the conditions using quantitative means, grounded in the richness of systems theory. Note, this is not a method paper. However, a systems theoretic approach with some novelty was selected to address the underlying research question. The question being: Based on what conditions should we define verification models? The current state of the discipline suggests that the conditions for verification models are defined based on qualitative statements of high-, medium-, and low-fidelity. This is an example of a SE heuristic. The existence of heuristics as a current basis for the discipline of SE is well known. However, many heuristics have not been quantitatively validated, which means there may be errors in judgement that are leading to systems being engineered that are ultimately not fit-for-purpose. Verification models are currently defined under heuristic assumptions that have not been substantiated. In this article, we provide insights from our research to discover the sufficient, science-based conditions for defining verification models.

Paper#487

Towards a Systems Engineering Ontology Stack

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Keywords. semantic web technologies;ontology;digital engineering;verification;education

Topics. 1. Academia (curricula, course life cycle, etc.); 3.4. Information Management Process; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 9. Enterprise SE (organization, policies, knowledge, etc.); #MBSE-DE;

Abstract. In this paper, we report on the development of the University of Arizona Ontology Stack (UAOS), an ontology stack to support digital engineering initiatives at the University of Arizona. We present examples of how the UAOS leverages semantic web technologies to contribute to digital engineering research, discuss the challenges of integrating ontologies from multiple sources into a cohesive stack, and highlight topics of interest for future research.

Paper#148

Traceability – A vision for now and tomorrow

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Keywords. Traceability;Systems Engineering;Configuration Management;INCOSE Vision 2035

Topics. 20. Industry 4.0 & Society 5.0; 3.2. Configuration Management; 3.7. Project Planning, Project Assessment, and/or Project Control; #FuSE

Abstract. Traceability has been addressed in the past from the perspective of relationships between the digital artifacts within the data and the information model of the system of interest (SoI) being developed. This paper enhances this view from both a systems engineering (SE) and a configuration management (CM) perspective.

Using VR to Validate and Visualize MBSE-Designed Interfaces

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Keywords. MBSE;VR;Interface;Validation

Topics. 2.5. System Integration; 2.6. Verification/Validation; 5.3. MBSE; 6. Defense; #MBSE-DE;

Abstract. The BIFROST prototype investigates the ability to link an executable system model to a VR system, enabling both systems to interact in near real time and providing an early validation test of our modeled behavior, interfaces, and User Experience. This gives engineers greater confidence in their designs prior to implementation and test while limiting the time and cost of rework experienced in those phases. This paper discusses the prototype, lessons learned, and future research areas.

Validation Framework of a Digital Twin: A System Identification Approach

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Keywords. System Validation;AI-enabled systems;Model;Digital Twins;System Identification

Topics. 2.6. Verification/Validation; 20. Industry 4.0 & Society 5.0; 5.11. Artificial Intelligence, Machine Learning; 5.4. Modeling/Simulation/Analysis; 8. Energy (renewable, nuclear, etc.); #FuSE; #AI;

Abstract. The constant improvement and developments in Artificial Intelligence/Machine learning models coupled with increased computing power have led to the incorporation of AI/ML for simulating learning and problem-solving in simple and complex engineering systems. However, the advent of AI/ML-enabled systems possesses latent uncertainty and unpredictable characteristics compared to traditional systems. This reality challenges engineers and industry stakeholders who care about ensuring the right AI-enabled systems are built (system validation). Digital Twins is an excellent example of such AI-enabled systems whose system validation has not been well-researched. This study delves into existing research and frameworks for validating Digital Twins and proposes a novel model-centric validation framework based on system identification techniques. Since Digital Twins are data-centric, system identification offers an intuitive approach to uncovering the system dynamics of physical assets' data, which Digital Twins aim to replicate, monitor, and update for structural health monitoring and control, which can further help validate Digital Twins. As a case study, we apply this model-centric validation framework towards partially validating a Digital Twin for a single-heat-pipe test article in a Microreactor Agile Non-nuclear Experimental Testbed demonstrated at a national laboratory last year. The system identification method helped identify the best mathematical process model that best represents the dynamics of the heat pipe and provides a pathway towards improving future digital twin ML prediction capabilities with a promise of finally validating future ML forecast datasets for this heat pipe on the identified process model to complete the system validation process. The outcomes of this study will help improve trust and system-level assertion for Digital Twins in practice towards sustaining the operational health of physical assets for various industry applications.

Paper#168

When Moving Backward Means Moving Forward – Educating Systems Engineers in Designerly Ways of Thinking

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Keywords. Design thinking;Education;Concept development

Topics. 1. Academia (curricula, course life cycle, etc.); 2.4. System Architecture/Design Definition; 5.9. Teaching and Training;

Abstract. Systems Engineering as a discipline provides many tools for managing complexity and reducing risks. However, these tools come with drawbacks when ideating new product concepts in early lifecycle phases when the problem and solutions spaces are open. This paper suggests that methods from the Design field have a complementing role early in the systems lifecycle, but that those methods need to be accompanied by a different way of approaching problems, something that takes time to learn. We present experience from a hybrid university course where regular students were mixed with professional systems engineers for more rapid development of design method experience in both groups.

Presentations

Presentation#70

"See it to Believe It" - MBSE Driven Next-Generation Simulation

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Keywords. digital twin;Model Based System Engineering (MBSE);visualization technologies;authoritative source of truth;specifications;simulation;SysML;Unified Architecture Framework (UAF);simulation based validation

Topics. 18. Service Systems; 2.6. Verification/Validation; 3.3. Decision Analysis and/or Decision Management; 5.4. Modeling/Simulation/Analysis; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. We view digital twins as living companions to systems, able to simulate behavior when key parameters are modified and able to present this behavior to the user in a comprehensible manner. We demonstrate how to pair MBSE models with compelling visualization technologies to produce useful digital twins. Further, we describe an ontology for an authoritative source of truth used to connect the various tools and views used in the construction of the digital twin.

Presentation#223

A Comprehensive Risk Assessment Methodology for Extended Product Lifecycles

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Keywords. Risk Management;Model-based Systems Engineering;Digital Engineering;Defense Acquisitions;Mission Readiness

Topics. 2. Aerospace; 3. Automotive; 3.3. Decision Analysis and/or Decision Management; 3.9. Risk and Opportunity Management; 5.3. MBSE; 6. Defense;

Abstract. The content of this presentation is based upon on-going internal research and development by Georgia Tech Research Institute. The authors believe that the concept and mechanics for this methodology are mature enough for discussion however they have not been applied to real world applications as of this writing.

A flexible MBSE SysML Profile for effective Test & Evaluation Planning and Integration: Approach and Lessons from the Real World

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Keywords. Test;verification;validation;MBSE;Architecture

Topics. 2. Aerospace; 2.4. System Architecture/Design Definition; 2.6. Verification/Validation; 3. Automotive; 4. Biomed/Healthcare/Social Services; 5.5. Processes;

Abstract. We present a novel SysML model architecture that addresses the full scope of T&E from initial planning and design of experiments through execution and data reduction and measures of effectiveness. Object Oriented concepts are leveraged, using SysML constructs of containment, aggregation and inheritance, through T&E specific SysML profile and stereotypes to define a re-usable and scalable architecture for model-based planning and execution of T&E. Examples from real world programs are included.

A Model-based approach to architecting and evaluating autonomous network-centric weapon systems: A UAV and Small Satellite System-of-Systems Exemplar

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Keywords. Unmanned Aerial Vehicle;Satellites;SWARN;Network-Centric Warfare;Weapon Systems

Topics. 1.6. Systems Thinking; 2. Aerospace; 2.1. Business or Mission Analysis; 5.3. MBSE; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 6. Defense;

Abstract. The need to limit the number of warfighters on the battlefield has led to an increase in research and application of unmanned robotic vehicles (URV) for battlespace operations and missions. Increasing the effectiveness, survivability and suitability of these URV systems (e.g., Unmanned Aerial Vehicles (UAV)) for successful military operations, requires an effective communication architecture that exhibits network-centric warfare capabilities. As an architectural concept for autonomous weapon systems operating collaboratively, and without an active human-in-the-loop, Network-Centric Warfare (NCW) serves as an enabler for the combination of tactics, techniques, and procedures that are employed by a URV weapon System-of-Systems (SoS) to create a decisive warfighting advantage for desired mission objective. NCW also known as Net-Centric Operations (NCO) is an information superiority-enabled concept of operations supporting a multidomain configuration that includes manned and unmanned platforms, weapons, infantry, and special operations amongst others. In order to achieve warfighting capability as an NCW weapon system, traditional NCW architecture concepts will need to be adapted to accommodate autonomous-only sets of weapon systems operating as an intelligent network of nodes. Any adaptation of NCW architecture for autonomous weapon systems must begin with the identification of stakeholder needs and requirements. Thus, the stakeholder needs directly help to identify the concept of operations and mission objectives.It is important to note that a majority of current approaches to the design of swarm URV architectures as observed in literature are examined from the perspective of specific engineering disciplines. This includes a focus on concepts such as communication network infrastructure, command and control architectures, sensors, and vehicle platforms. However, a major drawback to this development approach is the absence of a systematic and disciplined system development approach which focuses on the mission and operational contexts of the NCW SoS. A lack of mission conceptualization, operational and system contextualization will obscure gaps and vulnerabilities in the NCW architecture, and significantly impact the suitability of the autonomous weapon SoS configuration to achieve mission objectives.For this reason, the work outlined in this presentation addresses the architectural development and evaluation of a multidomain configuration of small satellites systems and a suite of autonomous heterogeneous UAVs collaborating as a multi-layered NCW weapon SoS for deployment in complex and highly specialized battlespace scenario. A model-based systems engineering approach (MBSE) utilizing the unified architecture framework (UAF) and modeling language is used to specify and define various intra- and inter-layer architecture alternatives and concept of operations for the multi-layered NCW weapon SoS architecture. In addition, an architectural trade study analysis is performed to evaluate multiple multi-layered NCW architecture configurations based on a set of defined measures of performance (MOP) and Measures of effectiveness (MOE) metrics regarding multiple attributes (i.e., networks, C2ISR, payload capability, and operational), and their suitability for specific notionally defined battlespace special operation scenario.

A More Objective Method to Determine whether Medical Benefit Exceeds Medical Risk

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Topics. 3.6. Measurement and Metrics; 4. Biomed/Healthcare/Social Services; 4.6. System Safety; 5.4. Modeling/Simulation/Analysis

Abstract. Evidence that the Benefit of a medical procedure exceeds its Risk is fundamental to all branches of medicine. From Hippocrates' "First, do no harm" to the European Union's Medical Device Regulations, the concept that Benefit exceeds Risk is the gating criteria to a host of events. This tutorial discusses a novel method to determine whether benefit exceeds risk. The method is both dramatically more objective than dominant methods and intuitively clear, making the conclusion more compelling.

A Systems Engineering Approach To An Integrated Design Controls and Risk Management Framework in Medical Device Development

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Topics. 1.6. Systems Thinking; 2.3. Needs and Requirements Definition; 3.5. Technical Leadership; 3.8. Quality Management Process; 4. Biomed/Healthcare/Social Services; 5.5. Processes;

Abstract. The presentation highlights the pivotal role of design controls in medical device development. It advocates for a shift from reactive to proactive risk methodologies in application of design controls, emphasizing a systems thinking mindset. Key insights cover an integrated framework for design controls and risk management, enabling teams to assess requirement criticalities and make informed choices early in the product lifecycle, prioritizing patient safety.

A Systems Engineering Approach to Driving the 'Right' Organizational Culture and Life at the Right Pace

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Keywords. Systems Engineering;Systems Engineering Process;Self-leadership;Leadership Theory;Authentic Leadership;Culture of Inquiry;Culture of Reflection;Culture of Innovation

Topics. 1.6. Systems Thinking; 2. Aerospace; 22. Social/Sociotechnical and Economic Systems; 3.3. Decision Analysis and/or Decision Management; 5.10. Diversity (cultural boundaries, diverse engineering teams, training underserved groups, etc.); #TechnicalLeadership

Abstract.

As systems engineering leaders, we often feel pulled in multiple directions by our desire or a call to assist and lead in multiple areas of life: work, school, non-profit organizations, family, and our communities. How should we effectively manage it all? Excellence in our organizations and lives hinges upon an individual's ability to drive towards goals, where execution quality leans upon leadership frameworks and processes that unlock timely strategic decision-making and critical thinking capabilities. The systems engineering process and systems thinking methodologies can invoke self-management and leadership practices that open equitable innovation and success pathways across life and work. The presenters will walk through their case studies (spanning various industries and engineering nonprofits) leveraging systems engineering processes and systems thinking methodologies as a methodology driving equitable success across life and work that foster thought leadership, innovation, collaboration, and positive results at work, in our communities, with our families, and within ourselves. We all want to "win" in these domains, which requires a teaming dynamic and self-management system that fosters the right culture-driving behaviors, habits, and designs that create the right future process, responses, and systems across each domain. After attending, attendees should be able to leverage the systems engineering process and systems thinking tools to identify what is and is not working to help systems engineering leaders thrive in their careers while driving an organizational culture that fosters innovation and measurable progress. The presenters will review applied research findings across engineering & tech organizations, universities, and nonprofit associations, which has led to a reusable and early framework that will be shared with attendees. Key words:§ Systems Engineering§ Self-leadership§ Leadership Theory§ Authentic Leadership§ Culture of Inquiry§ Culture of Reflection§ Culture of Innovation Topics§ Systems Thinking, Social/Sociotechnical and Economic Systems§ Decision Analysis and/or Decision Management

Diversity (cultural boundaries, diverse engineering teams, training underserved groups, etc.)

Presentation#494

A Value-Focused Thinking Approach to Assessing Container on Barge Readiness within Maritime Transportation Systems

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Keywords. Maritime transportation systems;Container on Barge;Readiness assessment;Value-focused thinking;Scorecard

Topics. 13. Maritime (surface and sub-surface); 3.3. Decision Analysis and/or Decision Management; 3.6. Measurement and Metrics;

Abstract. This presentation informs an overall understanding of Container on Barge (COB) development requirements, presents a COB Readiness Assessment Scorecard to improve the associated COB implementation decision process, and assists transportation system engineers in understanding the benefits of COB within the global supply chain. To demonstrate the application of the Scorecard, a case analysis of the Port of Shanghai is presented along with an overall assessment of nine global COB ports in total.

Presentation#72

Acquisition Security Framework (ASF): Informing Software Bill of Materials (SBOM) Use Cases and Risk Reduction

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Keywords. software supply chain risk;software bill of materials (SBOM);cybersecurity risk management

Topics. 11. Information Technology/Telecommunication; 17. Sustainment (legacy systems, re-engineering, etc.); 3.1. Acquisition and/or Supply; 4.7. System Security (cyber-attack, anti-tamper, etc.); 5.7. Software-Intensive Systems; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Systems are increasingly reliant on software. In many cases, software components within acquired software are unknown. SEI has developed an Acquisition Security Framework (ASF) of practices needed across the supply chain to begin to improve this risk situation. The SEI SBOM Framework, derived from ASF, compiles a set of leading practices for building an SBOM and using it to support risk reduction. This presentation will describe both frameworks.

Advancing Transdisciplinarity from Concept to Practice

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Keywords. transdisciplinarity;systems science;complexity

Topics. 1.1. Complexity; 1.5. Systems Science; 10. Environmental Systems & Sustainability; 20. Industry 4.0 & Society 5.0; 22. Social/Sociotechnical and Economic Systems; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); #FuSE

Abstract. Systems Science uses the concept of transdisciplinarity as a fundamental approach to exploring the nature of systems and better our understanding of how to develop systemic solutions. This presentation will discuss how Systems Science can help Systems Engineers become more transdisciplinary in their practice by focusing on outcomes and how its processes, methods, and tools can support achieving a desired outcome.

AI-Enhanced Autonomous Formation Flying - Definition of a Mission-driven and Safety-critical Software Development Environment

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Keywords. Autonomy;Mission;Safety-Critical Systems;AI/ML-Enabled Subsystems;Airworthiness;Certification;MBSE;Safety;Simulation

Topics. 14. Autonomous Systems; 2. Aerospace; 4.6. System Safety; 5.11. Artificial Intelligence, Machine Learning; 5.3. MBSE; 6. Defense; #AI

Abstract. The challenges posed by the introduction of autonomy in mission-critical and safety-critical aeronautics applications are driving a strong shift toward the utilization of Artificial Intelligence/Machine Learning (AI/ML)-based techniques. These applications must function in complex and uncertain environments, support autonomous and pilot-assistance systems, ensure system safety, and facilitate the design of efficient system performance, such as energy-aware trajectories or area-coverage maximization. Examples of such applications include formation flying and teaming, man-unmanned teaming, collision avoidance, last-mile delivery, urban air mobility (UAM) and aerial infrastructure inspection.Standardization bodies, such as SAE and EUROCAE, have explicitly identified, in the "Artificial Intelligence in Aeronautical Systems: Statement of

Concerns," the necessity to produce a standard supporting the integration of AI/ML-enabled sub-systems into safety-critical aeronautics software, hardware, and system development.To address these development and regulatory challenges, this session introduces an Autonomy Model-Based Systems Engineering (MBSE) Framework, heavily reliant on simulation, for developing and validating mission and safety-critical applications, including AI/ML-based constituents within a safety-critical function implemented in a model-based environment. This framework enables users to build digital models, covering mission and vehicle behavior, and lays down the foundations of a digital training and validation environment for autonomous systems, that can provide early and accurate feedback to autonomous systems developers. Furthermore, this framework aims at complying with emerging AI-based safety standards such as the future SAE ARP6983.Users of the Autonomy Framework include both system developers and system operators, who can build and use digital and executable reference models covering mission and vehicle behavior. This enables the inclusion of operational experience into a digital validation environment that system developers can leverage to assess their design and implementation. Reciprocally, simulating the system in an actual mission environment allows system operators to better understand system behavior and provide earlier and more accurate feedback to system developers.In this presentation, we will go over the main aspects of the Autonomy MBSE Framework, before illustrating each step of this approach with a concrete Fixed Wing Formation Flying Case Study.Autonomy MBSE Framework:In the initial stages of the system development cycle, standard Systems Engineering and Safety tasks are being performed:- Functional Hazard Assessment (FHA)- System Architecture Definition- Preliminary System Safety Assessment (PSSA)- Operational Design Domain (OOD) and Scenario Mission Definition, to train an application that is typically made of traditionally developed and AI/ML constituentsThe AI/ML training process involves simulating these scenarios within the framework, varying their parameters according to their probability distribution. This process accommodates supervised learning for perception and reinforcement learning for decision-making. Sensitivity and robustness analyses are then carried out to further characterize the resulting neural networks.Once trained and validated, the AI/ML constituents are integrated within the overall application design model, and simulation is used again to conduct reliability analysis and estimate the probability of failure of the mission. In the case where system performance and/or safety objectives of the application over its Operational Design Domain (ODD) are not met, the recommended approach is to trigger further training or redesign activities if necessary. Finally, the embedded code is generated from the software model using a certified code generator.Overall, the framework facilitates AI/ML-based decision-making for autonomous systems in complex and uncertain environments, supporting both autonomous and pilot-assistance systems while ensuring system safety.Fixed Wing Formation Flying Case Study:A Case Study will be presented to demonstrate formation flying (two fixed wing aircraft) executing a series of 90 degree turns at a high speed, following the different steps of the Autonomy MBSE Framework.The functions to be developed include:- Traditional Flight and Engine control for ego aircraft (automatically following the lead aircraft)- AI-based perception software based on camera sensors for ego aircraft calculating position and orientation of lead aircraft- AI-based automated ego aircraft stick agent to achieve formation flying objective (aircraft proximity comprised between 250ft and 500ft)As part of this demo, the use of You Only Look Once (YOLO) v7 algorithm, OpenAI's Proximal Policy Optimization (PPO) from stable-baselines3 and SysML V2 for System Architecture Modeling will be demonstrated.

Presentation#33

All Decisions Are Reconciliations of Inconsistencies: Preparing for the Digital Thread and Machine Learning

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Keywords. Decision-Making;Consistency Management;Digital Thread;Machine Learning;Innovation Ecosystem

Topics. 2. Aerospace; 3.3. Decision Analysis and/or Decision Management; 3.4. Information Management Process; 3.7. Project Planning, Project Assessment, and/or Project Control; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. This presentation characterizes, in an unconventional way, the diverse decisions that occur across system life cycles. The benefits of this framing are that it (1) unifies understanding of the life cycle, (2) enables the organization to gain from the digital thread, and (3) prepares for machine learning.

Presentation#429

An adaptation of the ISO/IEC/IEEE 29110 system engineering process for the development of CubeSats

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Keywords. systems engineering;ECSS;standards;nanosattelites

Topics. 19. Very Small Enterprises; 2. Aerospace; 5.2. Lean Systems Engineering; 5.5. Processes;

Abstract. "Explore innovative solutions for NewSpace SMEs in nanosatellite development. Learn about a tailored engineering framework, adapting ISO standards to address unique challenges, enhance reliability, and foster technological innovation. Presented by Mamadou Lamine NDAO, a Ph.D. candidate specializing in system engineering processes for nanosatellite development at the LAAS laboratory, CNRS."

An holistic view of the implementation of the Open Architecture Approach in military systems

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Keywords. Open Systems Architecture;Military Systems;Systems Thinking;Soft Systems Methodology

Topics. 1.6. Systems Thinking; 2.4. System Architecture/Design Definition; 3.1. Acquisition and/or Supply; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Open System Architectures offer benefits in terms of cost and time in the delivery and support of military systems, but the accomplishment in its implementation has varied over time, governments, and is viewed differently across the supply chain. This presentation will address the different perceptions on the open architecture approach, and the challenges for customers and suppliers that must be addressed to enable the intended benefits in life-cycle management of military systems.

An MBSE group project challenge as a learning experience for Masters degree students

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Keywords. MBSE;Education;Engineering Management;Configuration Management;Case Study

Topics. 1. Academia (curricula, course life cycle, etc.); 2.4. System Architecture/Design Definition; 3.2. Configuration Management; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 5.9. Teaching and Training; #MBSE-DE;

Abstract. This presentation reports on setting up a group project challenge for Masters students at Loughborough University, 15 groups over three years. The challenge set was a genuine leading-edge problem facing industry – how to keep multiple models of a system under development in step through joint configuration control of design changes in each model. The quality and variety of results, which will be demonstrated, have been very good, and have proved an excellent discriminator of student capability.

Presentation#156

Analytic Viewpoint for Information Normalization (AVIaN): A model-based analytic viewpoint to promote consistency in systems engineering practice

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Keywords. Model-Based Acquisition;Digital Engineering;Model-Based Systems;Unified Architecture Framework;Ontology;MOSA;Cyber Security;Architecture Assessment

Topics. 2.4. System Architecture/Design Definition; 3.1. Acquisition and/or Supply; 5.3. MBSE; 6. Defense;

Abstract. AVIaN or Analytic Viewpoint for Information Normalization is a model-based analytic framework that frames stakeholder concerns related to the analysis and assessment of an architecture against an engineering domain, such as MOSA or Cyber.

ANDES, the high resolution spectrograph for the ELT: the adoption of Model-Based Systems Engineering approach

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Keywords. astronomy;ELT;ANDES

Topics. 5.3. MBSE; #MBSE-DE;

Abstract. ANDES (ArmazoNes high Dispersion Echelle Spectrograph) is one of the second-phase instruments planned for the Extremely Large Telescope (ELT) of ESO. ANDES will provide high-resolution spectroscopy in the visible and near-infrared wavelengths, enabling a wide range of scientific investigations, such as characterizing exoplanet atmospheres, testing fundamental physics, and measuring the cosmic expansion. In this paper, we present the general strategy of the Model-Based Systems Engineering (MBSE) approach that we have used to design the instrument during the Phase B-One, which covers the system architecture review (SAR) successfully completed at end 2023. We describe how we have applied the Cameo Systems Modeler tool to create and manage the system model in compliance with the SysML standard to perform requirements and interfaces management, structure verification and validation, and trade-off analysis. We also emphasize that ANDES is used as a test case for the application of the MBSE methodology in the astronomical field, in order to create a standard of procedures to perform all the actions and tasks that serve to satisfy all the steps in the various design phases of an ESO project. In fact, the inital phases require specific tasks, such as the analysis of requirements, the flow-down of specifications to the subsystems, the tracing of interfaces, the analysis of budgets. Since there is no tool that specifically encompasses all these capabilities in the astronomical field, it is necessary to define a robust methodology that can be taken as an example for future astronomical instrumentation. We discuss the benefits and challenges of using MBSE for ANDES, as well as the lessons learned and best practices that can be useful for other astronomical instrument projects.

Dealing with Emergence in Systems Engineering Models--Fewer Surprising Failures and more "Happy Little Accidents"

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Keywords. Emergence;Emergent behavior;Complex systems;Cynefin;Ergodicity;Decision making in uncertainty;Critical Thinking;Red Teaming

Topics. 1.1. Complexity; 2. Aerospace; 22. Social/Sociotechnical and Economic Systems; 4.4. Resilience; 5.4. Modeling/Simulation/Analysis; 9. Enterprise SE (organization, policies, knowledge, etc.); #FuSE

Abstract. We both count on and fear Emergence in product development. Today we can confidently design an airplane capable of doing things that none of its parts can do alone with our SE methods and models. But as increasingly complex models feed each other the risk of unanticipated and unpredictable Emergence goes up. Increasingly complex models won't help. This presentation looks at how history has faced similar transitions and proposes the need to enhance Engineering Judgment in Systems Engineers.

Design for Future Mobility: Four-Wheel Independent Steering System Architecture Design and Technology Roadmapping Case Study

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Keywords. 4WIS (4 Wheel Independent Steering);Pareto Frontier;Technology Roadmap

Topics. 2.1. Business or Mission Analysis; 2.4. System Architecture/Design Definition; 21. Urban Transportation Systems; 3. Automotive; 3.3. Decision Analysis and/or Decision Management;

Abstract. Our presentation introduces a future mobility system design case study, where a new four-wheel independent steering system (4WIS) architecture is conceived and optimized using systems engineering process, and then its technology roadmap is created using the advanced technology roadmap architecture (ATRA) design process.

Designing for Resilience: Integrating Ecology into Engineered Systems

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Keywords. Biomimicry;Sustainability;Natural Systems;MBSE;Resilience

Topics. 1. Academia (curricula, course life cycle, etc.); 1.3. Natural Systems; 1.4. Systems Dynamics; 10. Environmental Systems & Sustainability; 17. Sustainment (legacy systems, re-engineering, etc.); 4.4. Resilience;

Abstract. Across industries, system resiliency is a foundational design goal. As both the economic and environmental landscape evolve, systems must adapt to emerging conditions. The emerging field of biomimicry presents engineers and ecologists with the opportunity to innovate while simultaneously operating within the constraints of a consumer-driven landscape. The intersection of engineering principles and ecological information empowers us to create systems capable of meeting human needs while synergizing designs with nature. The planet has been designing, testing, and evolving ecosystems for 3.8 billion years. The environment develops adaptive dynamics capable of changing to meet evolving conditions. These ecosystems present us with invaluable information on how to optimize our designs for unique environments, energy efficiency, and higher resilience. By comparing the mechanisms of ecosystems and the challenges faced in engineering resilient systems, we can discover novel solutions for resiliency-based innovation.Through the development of a technical engineering process harnessing the knowledge of ecology, systems thinking, and model-based systems engineering (MBSE), we demonstrate how ecological insights can be systematically integrated into design and development across industry scales and needs. With the intersection of engineering principles and ecological knowledge, we can enhance the adaptive dynamics, environmental specialization, and energy efficiency of a desired system.Through the development of predator-inspired models, we were able to synthesize the benefits of using nature as a blueprint for specialized system design. By analyzing the physiology and behavior of top-level trophic predators, we demonstrate how biological information can be integrated into the design of resilient and efficient systems. An adaptive methodology, the proposed process applies to diverse biomimetic design innovations. Through the development of a biomimetic design process, we also show the needed collaboration between the fields of engineering and ecology to optimize the resilience and success of biomimetic systems.

Digital Data Packages: Making the Digital Thread Work

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Keywords. MBSE;Digital Engineering;Digital Thread;Technical Data Package

Topics. 20. Industry 4.0 & Society 5.0; 5.3. MBSE; #MBSE-DE;

Abstract. The digital thread promises essential traceability, but done poorly, the digital thread becomes an overwhelming tangle. A digital data package (DDP) reconceptualizes yesterday's technical data package in the context of digital engineering encapsulating work into a black box transformation from requirements to specification. This presentation establishes the role of the DDP, the definition of a core DDP between systems architecture and detailed design, and its traceability to digital engineering.

Digital Engineering Capability Guidance and Maturity Assessment Framework

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Keywords. Digital Engineering Capability;DE Capability;Digital Engineering Maturity;DE Maturity;Digital Engineering Guidance;DE Guidance;Capability Assessment;Digital Engineering Capability Assessment;DE Capability Assessment;Digital Engineering Enterprise Assessment;DE Enterprise Assessment;Digital Engineering Enterprise;DE Enterprise;DE Tooling;Digital Engineering Tooling;DE Environments;Digital Engineering Environments;DE Ecosystems;Digital Engineering Ecosystems;Digital Engineering Data Systems;DE Data Systems;Digital Engineering Workforce;DE Workforce;Digital Engineering Workforce Assessment;DE Workforce Assessment;Digital Engineering Roadmap;DE Roadmap;Roadmap;Maturity;Capability;Assessment;Digital Engineering;DE

Topics. 2. Aerospace; 3.6. Measurement and Metrics; 3.7. Project Planning, Project Assessment, and/or Project Control; 4.5. Competency/Resource Management; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.); #MBSE-DE;

Abstract. The Digital Engineering CG-MAF in UAF is a model-based approach that fully captures and specifies DE capabilities and their associated maturity concepts in a way that is grounded in the DoD DE Strategy and yet can be tailored for an organization to create its own derived flavor of maturity assessment methods and metrics. These methods and metrics aid an organization's internal continuing maturation and ability to communicate their status to a higher-level organization.

Digital Engineering in Military Systems Integration

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Keywords. Digital Engineering;Military;Systems Integration;Acquisition;Digital Twin

Topics. 17. Sustainment (legacy systems, re-engineering, etc.); 2.5. System Integration; 3.1. Acquisition and/or Supply; 5.3. MBSE; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. This presentation highlights the importance of Digital Engineering within the military acquisition process. Specifically, we will be exploring how digital twin environments within systems integration impact systems design, efficiency, and customer relations. This presentation will examine the social impacts of Digital Engineering implementation in both traditional developmental processes as well as lab environments.

Doing Before Graduating: Experiential Learning with Part-time Internships with Industry Participants

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Keywords. Experiential Learning;Higher Education;Industry Participation;Training;Internships

Topics. 1. Academia (curricula, course life cycle, etc.); 5.10. Diversity (cultural boundaries, diverse engineering teams, training underserved groups, etc.); 5.9. Teaching and Training;

Abstract. In a field where many entry level jobs require one or two years of experience to qualify, students are finding it difficult to enter the technology field upon their graduation. This is especially true when they did not work while going to school, or did not participate in an internship prior to their graduation. Our Experiential Learning (EXL) program was created during the Spring 2021 semester, and focuses on two types projects – Business Process Improvement (BPI) and Cyber Security. This effort has been popular with our students and industry participants resulting in 79 students completing the program across 25 projects through 20 different industry participants – some of which sponsor multiple projects. The EXL program has also been recognized by the state of Virginia as an important program for the future of the cyber security workforce, resulting in two Commonwealth Cyber Initiative (CCI) Grants which provides the opportunity for student stipends and professional networking events with industry professionals and leaders.The industry participants are organizations (commercial, government, non-profits, etc.) that work with the academic faculty member to scope the project, challenge the students, and provide mentorship along their EXL journey. The students are undergraduates attending a Virginia higher education institution who desire hands-on experience, challenging work, and a resume-booster to stand out among their peers. All students are informed they should put their EXL project efforts as experience on the resume, which has helped many get jobs prior to their graduation – and some even received job offers directly following the completion of their project by the industry participants themselves.The BPI projects are run as a course elective through the student's degree program. BPI projects are focused on having students identify the organization's business challenges, recommend a technology solution to address that business challenge, and develop an implementation plan for the recommended solution. The Cyber Security projects operate similarly and have an additional benefit – they are funded by the CCI grants resulting in student stipends towards their project work. Moreover, these industry participants are required to pay the students an additional $12/hr. – to show their commitment to the cyber security workforce development.Beginning Fall 2023, the program has started to focus on making additional impact to the field through setting the goal for each project team to publish their project work in practitioner journals. Already, one project focused in the area of international cyber security cooperation has been accepted in the Information Systems Audit and Control Association (ISACA) Journal – which not only enhances the student participants' resumes, but also provides a valuable contribution to the field. Furthermore, the program has been mentioned as a success within the Department of Defense's (DoD) Press Release, specifically noting a BPI project focused on onboarding of clients to the DoD Cyber Crime Center's Vulnerability Disclosure Program.The program is gaining a lot of attention and momentum through its successes (publications, past performances, media mentions, and fundings), and has a lot of potential to scale and receive additional funding for all projects – BPI and Cyber Security.

Presentation#313

Easing SE implementation in daily life

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Keywords. SE in daily life.;Doing SE from scratch in an organization;SE instruction layer

Topics. 19. Very Small Enterprises; 2.3. Needs and Requirements Definition; 2.4. System Architecture/Design Definition; 2.5. System Integration; 3.3. Decision Analysis and/or Decision Management; 5.1. Agile Systems Engineering;

Abstract. This presentation is a view of an instruction layer for SE, which allows organizations to implement and ramp up quickly the relevant processes in the design phase of a system. To onboard new beginners at SE, one must lower the barrier to ease the use of SE. Or as we say in our company: "What exactly are organizations new to SE supposed to do next Monday 8am with SE and how?" This presentation gives you practical takeaways for this question.

Presentation#413

Enabling MBSE for SOPs through Generative AI

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Keywords. Generative AI;MBSE;Standard Operating Procedures

Topics. 2. Aerospace; 20. Industry 4.0 & Society 5.0; 5.11. Artificial Intelligence, Machine Learning; 5.3. MBSE; 5.9. Teaching and Training; 6. Defense;

Abstract. Embark on a revolutionary SOP revision journey, fusing Generative AI, MBSE, and e-PRL. Witness the transformation of static SOPs into dynamic, operator-centric guides. Uncover how generative AI enhances clarity while managing risks. Join us in revolutionizing SOPs, aligning procedures with human cognition, and putting operators at the forefront.

Enabling Systems Engineering at scale - the data asset management case

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Topics. 1.1. Complexity; 11. Information Technology/Telecommunication; 2. Aerospace; 3.4. Information Management Process; 5.2. Lean Systems Engineering; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Enabling SE at scaleBest companies apply SE for their key projects but at scale they face exponential costs to connect billions of data of various disciplines, enterprise & softwareWhy? Because they do not share the same meaning referenceThis was before using a Common Language based on standards to clarify, federate & query data, at marginal cost, at scaleThis vision will be detailed then a live demo will show that a common reference is a key practical enabler of SE at scale

Presentation#543

Engineering Technical Management (ETM) Competencies to Support the MOSA Ecosystem

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Keywords. MOSA;Modular Open Systems Approach;open architecture;open interface;intellectual property;IP;data rights;defense;Engineering;DoD;AGILE;GRA;reference architecture

Topics. 1. Academia (curricula, course life cycle, etc.); 2.5. System Integration; 3.5. Technical Leadership; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. OUSD(R&E) and DAU will comprehensively explore the complexities and demands of supporting agile product development within the intricate framework of complex systems, particularly those with numerous software and systems interfaces. This session is tailored for systems engineers who face the challenges of rapid modernization cycles in an environment where engineering is increasingly integrated and technically complex.

Presentation#234

Enhancing Capabilities of Parametric Diagrams with Opaque Behaviors

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Keywords. MBSE;Advanced Tool Features;Scripting;Parametric Diagrams;Cost Analysis;Model Query;Model Based Systems Engineering;Cameo;Opaque Behaviors

Topics. 2. Aerospace; 5.12. Automation; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. This presentation will provide details on the gap between Simulation and Crosscutting information and how it can be bridged using Opaque Behaviors. The audience will learn why it is valuable to mix these two types of information using a simple 3 step process, alternative methods, pros/cons of these methods, and get an overview of Case Studies where the process has been implemented successfully leading to decreased manual inputs.

Enhancing Data-Driven Decision Making through MBSE

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Keywords. mbse;decision analysis working group;digital transformation;decision;decision analysis;decision management;sysml;dodaf;uaf;architecture;management;project management;risk;configuration management;patterns;reuse

Topics. 1. Academia (curricula, course life cycle, etc.); 2.1. Business or Mission Analysis; 3.3. Decision Analysis and/or Decision Management; 5.3. MBSE; 9. Enterprise SE (organization, policies, knowledge, etc.); #MBSE-DE;

Abstract. In today's fast-paced data-driven landscape, the capability to make swift, consistent, and accurate multi-factored decisions is not just advantageous – it's imperative. Join INCOSE Fellow, Dr. Greg Parnell, as he guides audience participants through the Decision Analysis Data Model (DADM), a model-based data model for conducting multi-factored decision analyses. Participants will gain an understanding of the DADM and the impact it will have on the future of decision making.

Presentation#425

Enhancing Industry 4.0 Transformation Success with a Solution Debt Playbook

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Keywords. Solution Debt;Technical Debt;Industry 4.0

Topics. 2. Aerospace; 2.2. Manufacturing Systems and Operational Aspects; 20. Industry 4.0 & Society 5.0; 3.7. Project Planning, Project Assessment, and/or Project Control; 3.9. Risk and Opportunity Management; 6. Defense;

Abstract. This presentation provides a solution debt playbook with actionable guidance to help programs or Industry 4.0 initiatives systematically avoid, manage, and retire debt for tighter integration and enhanced execution.

Presentation#540

Evaluating MOSA Compliance in Defense Programs: Methodologies and Practical Approaches

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Keywords. Modular Open Systems Approach;MOSA;Open Architecture;Open Systems;Standards;IP;Intellectual Property;Data Rights;Assessment Criteria;Compliance Evaluation;Program Lifecycle Assessment;Quantitative and Qualitative Evaluation

Topics. 1.1. Complexity; 2.5. System Integration; 3.6. Measurement and Metrics; 5.5. Processes;

Abstract. Session participants attending the "Evaluating MOSA Compliance in Defense Programs: Methodologies and Practical Approaches" technical presentation will gain a deeper understanding of MOSA compliance requirements and methodologies. Participants can also apply this knowledge practically in their respective roles.

Presentation#213

Exploration of SysML V2 Capabilities to bridge the gap from System Modeling to Network Design

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Keywords. SysML V2;Network Architecture Design;System Model;Complex Systems

Topics. 1.1. Complexity; 2. Aerospace; 2.4. System Architecture/Design Definition; 3. Automotive; 3.2. Configuration Management; 5.3. MBSE;

Abstract. The promise of SysML V2 is on the verge becoming reality. The new SysML V2 standard is being released in 2024 bringing a new world of interoperability to System Engineers.This presentation will introduce you to that new world with a example familiar to many industries.

Presentation#527

Exploring the Notion of Verification Complexity

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Keywords. Verification;Modelling;knowledge graphs;complexity;verification complexity

Topics. 1.1. Complexity; 2.6. Verification/Validation; 3.6. Measurement and Metrics;

Abstract. Measuring the system complexity throughout the development lifecycle has been considered one of the core prerequisites of the system management. However, comparatively less attention was given to the complex verification strategies. As system complexity aids system design and management, we expect the verification complexity to improve the planning and execution of verification strategies. An machine learning algorithm will be trained to venture a prospect of an working VSC measure.

Presentation#492

Food Transformation (FX): A Systems Engineering Approach to Elevate Value through Cooking Recipe Design with Alternative Proteins

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Keywords. Cooking recipe;Alternative proteins;Process Design;Systems Engineering

Topics. 10. Environmental Systems & Sustainability; 18. Service Systems; 2.4. System Architecture/Design Definition; 20. Industry 4.0 & Society 5.0; 5.4. Modeling/Simulation/Analysis;

Abstract. This research aims to develop a recipe design method to realize same characteristics of conventional dishes using alternative protein. The presentation introduces an ongoing work for hamburgers using plant-based meat. The realization of a recipe design method, to delineate requirements from diverse perspectives and redesigning the architecture, with cooking processes and ingredients serving as the means to attain newly established objectives, may create recipes more flexible and value-added.

Presentation#561

From Arizona to the World: From Education to Application in Community Engaged Engineering

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Keywords. community engaged engineering;science and engineering policy;engineering ethics

Topics. 1. Academia (curricula, course life cycle, etc.); 22. Social/Sociotechnical and Economic Systems; 3.7. Project Planning, Project Assessment, and/or Project Control; 4.1. Human-Systems Integration; 5.9. Teaching and Training; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. A novel curriculum at the University of Arizona introduces students to community engaged engineering with applied projects that generate positive real-world impacts. Replication of this curriculum can enable science and engineering students at other institutions to benefit from experiential learning opportunities. This presentation seeks to spark discourse regarding the unique opportunities of systems engineers to contribute our practice to local and global improvements.

Presentation#542

Full STEDE Ahead: Developing a Simulation Training Environment for Digital Engineering

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Keywords. digital engineering;training;education;case study

Topics. 1. Academia (curricula, course life cycle, etc.); 5.3. MBSE; 5.4. Modeling/Simulation/Analysis;

Abstract. INCOSE's Vision 2035 identifies several goals that are closely related to digital transformation. The systems engineering community must teach ourselves and our colleagues to life and work in the digital ecosystem. The community must have resources that support the application of systems engineering principles in a data- and model-driven environment. This is the impetus for the Simulation Training Environment for Digital Engineering (STEDE).

Presentation#570

Hidden Beliefs in Verification Strategies

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Keywords. Verification;verification strategy;belief;AI;belief network

Topics. 1.6. Systems Thinking; 20. Industry 4.0 & Society 5.0; 3.3. Decision Analysis and/or Decision Management;

Abstract. The objective of this research is to study the formation of engineers' beliefs during the engineering and design of systems. The hypothesis is that engineers possess hidden belief networks that are used to assess the correct operation of a system, and will make those only explicit if certain design features conflict with those structures.

Presentation#87

How can INCOSE ensure SE's Future Relevance

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Michael Pennotti (Stevens Institute of Technology) - mcpennotti@icloud.com
David Rousseau (Centre for Systems Philosophy) - david.rousseau@systemsphilosophy.com

Keywords. Pursuing INCOSE's Vision;Evolving the SE Discipline;Sustainability;Global Problems;Transdisciplinarity

Topics. 1.1. Complexity; 1.5. Systems Science; 1.6. Systems Thinking; 10. Environmental Systems & Sustainability; 20. Industry 4.0 & Society 5.0; 22. Social/Sociotechnical and Economic Systems;

Abstract. This presentation will interest those who care about the future of the planet and how SE can contribute to its sustainability, so maintain its future position as a pre-eminent systems discipline.

Presentation#17

How to Develop a Digitization Plan for Standards

Leslie McKay (SAE International) - leslie.mckay@sae.org

Keywords. digital standards;natural language processing;strategic planning

Topics. 3.7. Project Planning, Project Assessment, and/or Project Control; 5.11. Artificial Intelligence, Machine Learning; 5.5. Processes; #MBSE-DE;

Abstract. As companies embark on digital initiatives, they are finding that they use large libraries of standards that consolidate requirements and information from a variety of sources. These document-based standards are distributed via PDF, making them difficult to integrate into digital product design and system modeling tools. Attend this session to learn how to plan out digitization of your company's standards.

Presentation#51

Implementing MBSE in complex organizations: Moving from Spec-Design-Build to Integrate-THEN-Build practices

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Keywords. MBSE;MBSE Implementation;System Integration;Organization Change Management

Topics. 1. Academia (curricula, course life cycle, etc.); 1.6. Systems Thinking; 2. Aerospace; 2.5. System Integration; 5.3. MBSE; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Scaling MBSE requires organization change to take advantage of the many powerful MBSE tools. Given MBSE is not just a tool, its a journey, once organizations know where they are they need to plan a successful MBSE implementation journey. Join us to learn about how to implement MBSE in your organization using standard organization change practices and theory.

Presentation#377

INCOSE and IEEE SMC Society Alliance: 5 Years In

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Haibin Zhu (Nipissing University) - haibinz@nipissingu.ca

Keywords. INCOSE Alliance;IEEE SMC Society;joint activities;SE research and practice

Topics. 1. Academia (curricula, course life cycle, etc.); 1.2. Cybernetics; 1.5. Systems Science; 14. Autonomous Systems; 4.1. Human-Systems Integration; #FuSE

Abstract. This presentation-only submission is intended for the Alliance Track planned by the INCOSE Events and Outreach Leadership.

Presentation#65

Industrial DevOps and Digital Twins for Cyber-Physical Systems

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Keywords. digital twin;cyber-physical systems;agility;safety-critical;digital engineering

Topics. 20. Industry 4.0 & Society 5.0; 5.1. Agile Systems Engineering; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.);

Abstract. Industrial DevOps applies Agile, DevOps, and digital to the full lifecycle of cyber-physical systems. As we build the physical system, we also build its digital twin. We will discuss the importance of validated learning, feedback loops, and using data for problem solving analysis for the system we are building and the digital twin of the factory. We will demonstrate the relationship of digital twins for cyber-physical systems with DevOps for software enabling agility and speed of value delivery.

Presentation#173

Integrating Arcadia and Capella with SysML v2

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Karen Ryan (Siemens) - karen.ryan@siemens.com

Keywords. SysML v2;Arcadia;Capella;Interoperability;Model libraries;Model interchange

Topics. 2.4. System Architecture/Design Definition; 5.3. MBSE; 5.5. Processes;

Abstract. Arcadia is a well-known MBSE method supported by the open-source Capella tool, developed in response issues with other methods and modeling languages such as SysML. The recently adopted SysML v2 addresses some of the same issues with earlier versions of SysML that motivated Arcadia and Capella. This presentation describes how a new opportunity for interoperability between Arcadia/Capella and SysML v2 can be realized by tailoring SysML v2 using a semantic library model of Arcadia concepts.

Presentation#74

Integrating IV&V into a generative AI Enterprise work culture

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Keywords. Chatgpt;AI;Generative AI;IV&V;Verification and Validation;Intelligence

Topics. 3.5. Technical Leadership; 4.1. Human-Systems Integration; 9. Enterprise SE (organization, policies, knowledge, etc.); #AI

Abstract. Because of the power of LLM's to generate code & narrative text, it has never been more important to apply strong IV&V principles. to ensure that the results generated by GPT models are accurate, reliable, & meet the required standard. Enterprises must prioritize IV&V in the development & deployment of GPT models. This can involve rigorous testing and validation, transparent and ethical use of data, and involving users in the design & development process.

Presentation#90

Is the Journey to the End of the Project Rainbow a Minimal Viable Capability (MVC)?

Kerry Lunney (Thales) - kjlunney@tpg.com.au

Keywords. Minimal Viable Capability (MVC);Minimal Viable Product (MVP);Agility;Lean;Iterative;Incremental;Digital Engineering;Digital Transformation

Topics. 11. Information Technology/Telecommunication; 2.4. System Architecture/Design Definition; 20. Industry 4.0 & Society 5.0; 3.7. Project Planning, Project Assessment, and/or Project Control; 5.1. Agile Systems Engineering; 6. Defense;

Abstract. Often we strive to deliver a perfect solution. Sometimes this is warranted, sometimes not. This can lead to cost and/or schedule overruns, and the introduction, or the appearance of, poor quality systems at initial deployment. A means to address this challenge is to employ a Minimal Viable Capability (MVC). Or is it? To understand the complexities of realizing MVC a number of interacting factors will be presented in a takeaway graphic(s) that Systems Engineers can add to their toolkit.

Learning System Security: Playing in an MBSE Sandbox

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Keywords. Secure cyber resilient engineering;Mbse;Workforce development

Topics. 1. Academia (curricula, course life cycle, etc.); 4.4. Resilience; 4.7. System Security (cyber-attack, anti-tamper, etc.); 5.3. MBSE; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Curriculums for learning how to design in resilience have been found lacking; however, much like playing in a sandbox, aruxents can build, adjust, and acquire lasting knowledge through understanding complex systems inbite-sized pieces. The presentation will show how a research team developed an interactive curriculum on secure cyber resilient engineering while allowing students to play in an open, yet controlled environment.

Lessons learnt about the management of a Systems Engineering trainings framework: A Safran Group return on experience

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Keywords. Trainings;Competency;Feedback;Framework;Lessons learnt;Safran

Topics. 2. Aerospace; 4.5. Competency/Resource Management; 5.9. Teaching and Training; 6. Defense;

Abstract. Past, present and future of the MBSE training framework for the Safran group. Feedbacks of the transformation journey of the group.

MBSE Methodology, Digital Engineering Ecosystem & System Architecture Modelling using SysML v2

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Bernard Dion (Ansys) - bernard.dion@ansys.com

Keywords. MBSE;Digital Engineering;System Engineering;Digital Engineering Ecosystem;Analysis;Trade Study;Requirements Verification;System Architecture Model;SAM;Model Based System Engineering;Integration;Automation

Topics. 1.1. Complexity; 2.5. System Integration; 5.3. MBSE;

Abstract. The presentation discusses and highlights an integrated digital engineering ecosystem to enable Model Based System Engineering (MBSE), as well as proposes a comprehensive MBSE Methodology supporting the same. Both MBSE Methodology and the digital engineering ecosystem enabling implementation of the methodology is showcased through a use case of antenna selection of a Digital Beamforming System for a UAV. Though the chosen use case is of an A&D background, but with complexity among various sectors like automotive, healthcare, etc. an integrated digital engineering ecosystem is the need of the hour. As known, the primary intent of MBSE is to allow early design decisions at conceptual stage itself. This can't be achieved just by system architecture modelling but requires one to analyse the system architecture model as well. The presentation discusses and showcases an MBSE Methodology and digital engineering ecosystem addressing the same as well as showcases as tool neutral framework allowing connection of SAM to various analysis tools integrated in a single & automated analytical workflow and perform Trade Study & Requirement Verification. It is also to be noted that the System Architecture Modelling is done using SysML v2 modelling language.The presentation starts with an overview of MBSE Methodology. The MBSE Methodology has four pillars:1st is Technical Management, i.e. to Support & Oversee System Engineering Process,2nd is System Development i.e. to Virtually develop the system right from requirements to virtual validation,3rd is Digital Engineering i.e. to Implement policies, processes & practices to build digital thread,and lastly, there is System Architecture Analysis to perform all-round system analysis.The presentation explains each of these in detail.It is to be noted that there are dependencies between these pillars and involves concurrent co-dependent activities.In particular, the use case highlights the 2nd-3rd & 4th pillars of system development (left side of V), digital engineering practices (creation of ASoTs) & Architecture Analysis for System Performance. The Digital Beamforming Use Case involves selection of phased array antennae design configuration of UAV communicating with a ground station, ship & a satellite. The design selection must ensure adequate link marking for communication between UAV & Ground station. MBSE Workflow is devised to verify system requirements and perform trade study for design selection.The digital engineering environment involved in this MBSE workflow included SAM tool for system architecture modelling utilising SysML V2 modelling language, Mission Analysis Tool for scenario creation and setting up of Design Reference Mission, and Integration & Automation tool performing analysis, trade study and requirements verification. The MBSE the workflow starts with setting up of Design Reference Mission (DRM) first, & then System Architecture Model, followed by Analytical Workflow after which the Trade Study is performed.The presentation highlights System Architecture Modelling using SysML V2:> Creation of element definitions for the system parts to be used later in different views of requirements & structure diagrams.> Model is organized into packages and necessary libraries needed to define the system attributes are imported.> Within the organized package requirements and structure diagram is created showcasing the derivation and decomposition of system requirements. Constraints and attributes responsible for requirements satisfaction are defined within the requirements usages. Same can be marked with 'satisfy' relationship between part usage and requirement usage in the diagram.> Within the structure diagram, decomposition of system into sub-systems is depicted through part usages having necessary system attributes inherited from definitions or defined anew within the usage.Within SAM, we started with deriving system requirements based on DRM and decomposing it further in SWaP-C requirements. Parts responsible for requirement satisfaction were identified and part attributes were traced with 'Satisfy' relationship to the requirements. The system structure was completed with depiction of all the sub-systems and attributes applicable for the use case.On completion of System Architecture Model, Analysis workflow was built-up to analyse the architecture. A multi-fidelity analysis workflow was developed to calculate the Measure of Effectiveness (MOEs) like Receiver's signal

strength, SNR, Weight, Size & Cost. The workflow constitutes both the low fidelity as well as the high-fidelity analysis, where in the antenna configurations are primarily varied through the an excel catalogue of commercial antenna designs. The low fidelity, non-DRM workflow utilized canonical equations defined within script components, whereas the high-fidelity, DRM workflow utilized the Mission Analysis Tool. This workflow is now connected with System Architecture Model.SAM is connected to Analytical Workflow using an MBSE Connector. Analytical Workflow is added as analysis within MBSE Connector interface wherein the System Structure defined in SAM can be seamlessly connected to Analytical Workflow through linking of system's part attributes to analytical workflow parameters. Similarly for requirements verification, a simple validation script can be added as an analysis within MC MBSE where in the requirements imported from SAM with MC MBSE can be linked with these validation script parameters. Bounds can be conveniently defined within connector interface or added into the scripts.Now, with the connection established, a trade study can be initiated from within connector interface. A Design of Experiments (DOE) Study is launched from within connector, and various antenna configurations can be analysed by applying the constraints and objectives. Qualifying cases can be run individually to check requirement verification status and the selected designs can thereafter be saved and passed back to SAM while also updating the baseline values within the System Architecture Model hence, allowing for a complete traceability right from requirements definition to requirements verification and design selection.The case illustrates benefits of MBSE Methodology & associated Digital Engineering ecosystem: early engagement of customers as well as SMEs in development lifecycle, ensuring continuous verification of customer needs and detection of faults errors in design.

Presentation#126

MBSE Methodology: Risk Analysis and Requirements Management

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Keywords. MBSE;Model-Based Systems Engineering;Risk;Requirements;Verification Techniques;System of Systems Architecture

Topics. 17. Sustainment (legacy systems, re-engineering, etc.); 2.6. Verification/Validation; 3.9. Risk and Opportunity Management; 5.3. MBSE;

Abstract. Verifying a system of interest functionality through a formal engineering qualification or certification process is an essential step that proves that a system complies with its requirements. In this actively developing methodology for MBSE-assisted requirements verification, a fully traceable set of hierarchical system requirements integrated with the system architecture is used to qualify a system.

Presentation#362

Mission Engineering – Extending Systems of Systems Engineering to Mission

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Keywords. Systems engineering;Systems of systems;Mission;mission engineering;digital engineering

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

Abstract. This presentation discusses the origins and motivations for mission engineering (ME), the current ME methodology and how it leverages SE approaches and tools to address the unique challenges posed by ME, and the relationship of ME to systems and systems of systems engineering. Finally, the presentation explores opportunities for applying mission engineering beyond defense.

Presentation#244

Mission Possible: Deploying MBSE Model Libraries for Optimal Systems Development

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Keywords. Library;Development;Reuse;Sharing;Governance;Training;Model Based Systems Engineering (MBSE)

Topics. 2. Aerospace; 2.4. System Architecture/Design Definition; 3.7. Project Planning, Project Assessment, and/or Project Control; 5.3. MBSE; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Embark on deploying an MBSE model library for diverse industries. Explore tailored team training, define library scope, and establish governance. Witness seamless integration for optimal support in developing complex systems. This adventure promises success through careful planning and execution, focusing on scope, training, collaborative governance, and streamlined integration. Join us to enhance efficiency in the world of MBSE.

Presentation#390

Model-Based Requirements Engineering Enabling Route to

Certification for Medical Devices

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Keywords. requirements engineering;model based requirements engineering;medical devices development;route to certification

Topics. 2.3. Needs and Requirements Definition; 4. Biomed/Healthcare/Social Services; 5.5. Processes;

Abstract. Medical devices design and development companies, have a product development cycle, heavily directed by compliance and standards. The stringent quality standards, and adherence to compliance certifications makes it difficult to quickly introduce new features. This means, that the industry needs to have a robust technology roadmap, not only from the perspective of technology maturity but from qualification aspects as well. Proactive thinking as well as change and impact analysis. There are several ISO standards referenced by engineering design and development of medical devices, such as, ISO 13485 which sets out the requirements for a quality management system in the medical device industry, including those related to design and development. ISO 14971 Focuses on risk management throughout the entire lifecycle of a medical device, including the design and development stages. It provides a systematic approach to identifying, assessing, and managing risks associated with medical devices. ISO 15189 outlines the criteria for ensuring that medical laboratories consistently produce accurate and reliable results, thereby contributing to patient safety and quality healthcare. Compliance with these and many other standards contributes to the overall safety, effectiveness, and quality of medical devices. The route to certification for medical devices involves compliance with regulatory standards, such as those set forth by organizations like the U.S. Food and Drug Administration (FDA) or the European Medicines Agency (EMA).Overall, Systems Engineering is a critical discipline in the route to certification for medical devices. By providing a structured and comprehensive approach to development, emphasizing requirements management, risk mitigation, interdisciplinary collaboration, and compliance with regulatory standards, Systems Engineering contributes significantly to the successful certification of medical devices in a highly regulated and safety-focused industry. In this presentation the presenters focus on effective requirements engineering, ensuring that all functional and non-functional requirements are identified, documented, and managed. Clear and well-managed requirements are essential for achieving and demonstrating compliance with certification standards.Requirements engineering is a systematic process of eliciting, documenting, validating, and managing requirements throughout the development of a system. This process plays a crucial role in ensuring that a product or system meets its intended purpose and satisfies the needs of its stakeholders. Traditionally it may rely on text-based requirements definition, often leading to lengthy and less intuitive documents. Also it relies on individuals for traceability of information and hence is less efficient in handling changes.Model-Based Requirements Engineering (MBRE) is an approach that leverages graphical models to define, visualize, and analyze system requirements. MBRE thereby provides a more intuitive and structured way of capturing, managing, and communicating requirements. MBRE enhances communication, facilitates collaboration, and supports automation for tasks like documentation generation and validation. It is often more flexible in managing changes and offers advantages in complex systems where visualizing interdependencies is crucial.The session will highlight the application of MBRE approach applied to projects for medical devices companies. The project involved implementation and execution of MBRE process. SysML based models and requirements management formal tools were employed for implementation. Behaviour defined in disciplinary tools was used as required. Collaboration and communication among various disciplines such as engineering, biology, medicine, and regulatory affairs has improved the most. The visual nature of models has enhanced communication, reducing the likelihood of misunderstandings and ensuring that all stakeholders are on the same page regarding requirements. The MBRE process is further enabling the following in the projects1. Clarity and Precision in Requirements Specification by developing system level artifacts which can be created for any layer of the system2. Traceability, which is a key aspect of certification processes3. Generation of test cases directly from the requirements models and early verification4. Efficiency in Documentation by representing key requirements graphically, making it easier for both developers and regulators to comprehend and evaluate5. Integration of risk analysis directly into the requirements engineering process6. Aiding in the preparation of evidence required for certification submissions.Model-Based Requirements Engineering is thereby a valuable methodology in the development of medical devices, offering benefits in terms of clarity, traceability, change management, verification, and compliance with regulatory standards. Adopting this approach significantly contributes to a smoother and more efficient route to certification for medical devices.

Model-Based Trade Studies to Inform Decision-Making

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Keywords. MBSE;Trade Study;Decision Analysis

Topics. 3.3. Decision Analysis and/or Decision Management; 5.3. MBSE; 6. Defense;

Abstract. As programs are increasingly turning to MBSE for designing system architectures, model-based trade studies can be an incredibly powerful tool for analyzing, evaluating, and comparing alternative architectures to make informed decisions. In this presentation, we will explore the design of a reusable trade study model pattern, a sample implementation of the pattern, and a novel method for sensitivity analysis to interpret the results of the trade study.

Modeling of Uncertainty in System and Enterprise Models

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Keywords. Uncertainty Modeling;System Architecture;Enterprise Architecture;Modeling Standards

Topics. 1.1. Complexity; 2. Aerospace; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.); #FuSE

Abstract. Modelers typically create system models assuming some degree of certainty in what they are describing. However, there is a need to understand how much uncertainty there is in their projections of what the system will do and how well it can do this. We will discuss a new standard from OMG called Precise Semantics for Uncertainty Modeling (PSUM) that specifies concepts of uncertainty, accuracy, precision, and related concepts, and we will describe how to PSUM concepts in modeling our systems.

MOSA Implementation Challenges and Opportunities; Perspectives from the NDIA Architecture Committee

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Keywords. MOSA;Modular Open Systems Approach;open architecture;open interface;intellectual property;IP;data rights;system architecture;architecture;DoD;interoperability

Topics. 11. Information Technology/Telecommunication; 2. Aerospace; 2.1. Business or Mission Analysis; 2.4. System Architecture/Design Definition; 3.3. Decision Analysis and/or Decision Management; 6. Defense;

Abstract. This briefing shares the findings from a new 2023 report by the NDIA SE Division's Architecture Committee on challenges and opportunities with MOSA implementations to date. It makes new recommendations following its acclaimed 2020 white paper to facilitate successful implementation of MOSA objectives by all stakeholders over the long term.

Navigating Organizational Acceptance: Leveraging the Overton Window as a Systems Thinking Tool for Radical Project Ideas Approval

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Keywords. Systems Thinking;Overton Window;Context Diagram;Larger Systems;Sociotechnical Systems

Topics. 1. Academia (curricula, course life cycle, etc.); 1.5. Systems Science; 1.6. Systems Thinking; 2.1. Business or Mission Analysis; 22. Social/Sociotechnical and Economic Systems; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. In the dynamic landscape of organizational decision-making, the notion that "the best ideas win" often collides with the reality of bureaucratic hurdles. This presentation explores the application of the Overton Window as a powerful Systems Thinking tool to address the challenge of gaining approval for radical project ideas within large corporations.The Overton Window, a political theory depicting the range of socially acceptable ideas in a given time period, serves as a lens through which employees can view their project proposals. By adopting a holistic approach, employees can consider their project idea as constituent part of a larger system encompassing organizational stakeholders and its strategic priorities, instead of just focusing on the idea itself.This presentation outlines how the Overton Window can be employed to increase the likelihood of stakeholder support for seemingly radical concepts. Employees can understand the range of ideas that are considered acceptable in the industry, organization and target stakeholders and categorize the stakeholders who see the project idea as sensible, acceptable, radical and unthinkable. Through system engineering tools such as context diagram and matrices for this larger system at hand, and analyzing the beliefs shaping these perceptions, employees can craft effective strategies for engaging stakeholders, conveying project goals/benefits, and securing essential buy-in.This proactive approach, grounded in Systems Thinking, enhances the prospects of obtaining approval from senior leadership. The absence of such holistic system analysis often leads to employee frustration, as their innovative ideas sit on the shelf just because the idea was outside of the Overton window.Learning Outcomes for Audience:1. Embrace a holistic Systems Thinking approach with the help of Overton Window and by considering project idea proposals as integral parts of a larger organizational system.2. Learn how to use system engineering tools such as context diagrams and matrices to analyze the larger system at hand.3. By the end of the presentation, the audience will be equipped with practical insights, tools, and strategies to navigate organizational acceptance successfully, for radical project ideas.

Presentation#245

On a Recursive Methodology for the Analysis of System Requirement Tolerances

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Keywords. Digital Engineering;Statistical Analysis;Verification & Validation;Test Coverage Evaluation;System Behavior

Topics. 1.6. Systems Thinking; 17. Sustainment (legacy systems, re-engineering, etc.); 2. Aerospace; 2.6. Verification/Validation; 5.5. Processes; 6. Defense;

Abstract. As a discipline, Systems Engineering, has not investigated using recursive techniques to update requirement bounds to optimize testing activities. Requirements are considered fixed elements by which the overall system adheres to. However, if test data is leveraged to challenge the validity of requirement bounds, statistics and systems theory may be utilized to increase system precision, determine test coverage, test dependencies, and characterize SoS interactions with opaque behaviors.

Presentation#315

Optimizing MBSE adoption: Identifying and prioritizing forces

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Keywords. Model-Based Systems Engineering;MBSE adoption;Force Field Analysis;Organisational change;Adoption strategy

Topics. 5.3. MBSE;

Abstract. Discover a practical approach to MBSE adoption. This session presents a methodology for practitioners to understand the complexity of MBSE adoption. The main purpose is to identify and quantify key forces impacting MBSE adoption to support practitioners in prioritizing and strategizing for successful MBSE adoption.

Presentation#271

Optimizing Systems Engineering Workflows through Novel Applications of Large Language Models

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Keywords. Large Language Models;Machine Learning;MBSE;Model Based Systems Engineering;Systems Engineering;mbX;Automation;Artificial Intelligence;System Architecture

Topics. 2. Aerospace; 2.4. System Architecture/Design Definition; 5.11. Artificial Intelligence, Machine Learning; 5.3. MBSE; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.); #AI

Abstract. This session introduces the application of large language models in streamlining system engineering processes. Through use cases and implemented examples, gain insights into how LLMs can automate and enhance tasks such as system model generation, document contextualization, and fact extraction from unstructured data. Additionally, strategies for ensuring the safety, reliability, and accuracy of LLM responses will be introduced, enabling confident adoption of LLMs in system engineering workflows.

Presentation#471

Perspective and Influence and Leverage, Oh My! Leadership for Systems Engineers

David Long (Blue Holon) - david@blueholon.com

Keywords. Technical Leadership;Facilitation;Collaboration;Influence;Perspectives

Topics. 3.5. Technical Leadership; #TechnicalLeadership

Abstract. As systems engineers, what can we do to create a better tomorrow? The answer is far more than we might think. Leveraging our principles and positions, we have the opportunity to make a unique and positive impact. But we must look beyond our technical contributions and embrace our leadership responsibilities. Doing so requires that we apply perspective, influence, and leverage to unlock our strengths in combination with those around us and lead for a better future.

PLE Digital Thread: Now and the Future

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Keywords. PLE;Product Line Engineering;PLM;Product Lifecycle Management;Digital Thread;Interoperability;Component-Based Design;Modularity;MOSA;Reuse

Topics. 1.6. Systems Thinking; 2. Aerospace; 5.6. Product Line Engineering; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. A product line approach can be seamlessly applied across proposals, development, production, and sustainment. This is already resulting in faster times to market and reduced costs, but there is even greater potential still to unlock through Digital Threads. All this promise is contingent on one central question: Can our tools pass data across all disciplines from engineering to business to production to supply chain?

Practice to adapt MBSE as agility enabler to the agile software development for mobility platforms

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Keywords. MBSE;Agile Software Development;Agile Systems Engineering;Boeing MBE Diamond Process;SysML;Ontology;Software Defined Vehicle;Mobility Platform

Topics. 14. Autonomous Systems; 3. Automotive; 5.1. Agile Systems Engineering; 5.3. MBSE; 5.7. Software-Intensive Systems; #MBSE-DE;

Abstract. Background:Woven by Toyota, it develops a mobility platform encompassing in-vehicle software, software development tools, and cloud systems to aim to enable the development of integrated, software-driven experiences for Original Equipment Manufacturers (OEMs). The company was established in 2021 and dedicated to research and development (R&D) projects for the software-centric platform, also most developers come from the software industry and do not have working experience with systems engineers. Now, the company is transforming its development phase from the R&D to a production phase that requires more harmonized work to ensure quality, costs, delivery, and risks. Also, it is required to meet customers' needs appropriately. That means the time has come for systems engineering for this young company, but there are SE challenges as described below.SE Challenges in our context:The company is young and its culture has focused on modern software engineering customs. They have adopted agile software development and Scrum framework that conducts one-month iterations and three-month releases since they conducted R&D projects. There are 2 challenges in our context. The first one is to integrate systems

engineering into agile software development. The second one is organizing terminologies that are used frequently by developers but tend to be used differently by different people.Regarding the 1st challenge, there are generally gaps between agile software development and traditional systems engineering. In addition, there is a valley of death between R&D and systems engineering in terms of engineering cultural differences or misconception that SE is a heavy process, as reported in the INCOSE INSIGHT volume 26, Issue 3 [1]. Therefore, to transform the organization from the R&D to the production phase, our 1st SE challenge is integrating systems engineering and agile software development to harmonize different software engineering teams' activities while overcoming the gaps and valley of death between SE and agile software development culture that were grown in the R&D phase.About the 2nd challenge, our company has several software development teams. They often use the words "product," "system," "software," "feature," and "function. " However, these words are used with ambiguous terminology and relationships. Unfortunately, when they consider the integration of their different teams' products, these ambiguous concepts cause problems and confuse software engineers. To get rid of confusing things, our 2nd SE challenge is letting all developers have the same understanding of the concepts of "product," "system," "software," "feature," and "function. " Why is the problem important, and what is it worth?The automotive industry is entering an era of change toward new mobility, such as software-defined vehicles (SDV). As the term SDV describes, mobility is changing from hardware to software-centric. As represented by autonomous driving (AD) and advanced driver-assistance systems (ADAS), software-centric technology advances rapidly in the automotive industry, and the demand for early adoption of R&D technologies and agile software development has been raised. On the other hand, the difficulty in ensuring quality and harmonizing R&D technologies and existing systems is increasing more and more. To overcome the difficulty, systems engineering is more in demand, but there seem to be similar challenges with us, such as:There are gaps between systems engineering and agile software developmentThere are barriers for developers who work in R&D or agile software projects to introduce systems engineering because SE seems to be a heavy process and additional work for them.Traditional V-model tends to be refused by agile software developers in terms of development style differences and the possibility of sacrificing agility.The words "product," "system," "software," "feature," and "function " are widely used in both systems engineering and software engineering, but there is no ontology to describe them and their relationship to each other.Outline methods:To overcome the 1st SE challenge, we are tailoring the "Boeing MBE Diamond" process methodology consisting of the traditional V processes for the physical system and the digital engineering processes presented by the Boeing company at the INCOSE International Workshop 2020 [2]. In our tailored diamond process, the bottom half of the diamond focuses on software development processes, and the top half focuses on the virtual systems realized by SysML system models. This tailored diamond does not add extra work, i.e., systems engineering activities, to the current software development processes on the bottom-half side. Systems engineering activities are simultaneously conducted on the top-half side. This practice tries to keep the original agility and harmonization between agile software development as a whole system. The top-half side provides system models with SysML as a single source of truth, and it enables all stakeholders to get a common understanding of the whole system.To overcome the 2nd SE challenge, we developed the ontology with SysML metamodels to provide the definition and represent the relationship between "system," "software," "product," "feature," and "function." This ontology has already enabled all developers to obtain the same understanding of these concepts and enhance the productivity for cross-functional activities. Also, this ontology has been used to develop system architecture models for our company's different products, and it succeeded in integrating different products as a single system at the design level.Expected Results:The author expected to succeed in integrating systems engineering and agile software development without sacrificing agility and establish the following achievements:Derive the tailored diamond processes for vehicle platform developmentPublished the ontology with SysML metamodels to organize the relationship between buzzwords that are used in the agile software development culture: "system," "software," "product," "feature," and "function."These would be helpful for SE practitioners in the automotive industry who are trying to adopt systems engineering to their agile software development.References:[1] https://incose.onlinelibrary.wiley.com/toc/21564868/2023/26/3[2] https://www.omgwiki.org/MBSE/doku.php?id=mbse:incose_mbse_iw_2020

Product Assurance in the Model-Based System Engineering Ecosystem: Learning from Various Vertical Lift Platforms

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Keywords. System Safety;Reliability;Product Support;Product Assurance

Topics. 2. Aerospace; 4.3. Reliability, Availability, and/or Maintainability; 4.6. System Safety; 5.3. MBSE; 6. Defense;

Abstract. This is the first in a multi-part series exploring what can be learned from applying Model-Based System Engineering to Product Assurance disciplines on aerospace/defense hardware & software platforms throughout the product/service lifecycle. System Safety analyses on civil & military rotorcraft platforms up to the conclusion of the Detailed Design stage will be discussed here, with other disciplines, lifecycle stages, & platforms beyond rotorcraft to be considered in future work.

Projects Doomed to fail before they start - Early Lifecycle Activities are missing

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Keywords.
Lifecycle;Infrastructure;Transportation;Needs;Requirements;Risk;Planning;Organization;Society;Stakeholder

Topics. 12. Infrastructure (construction, maintenance, etc.); 2.3. Needs and Requirements Definition; 21. Urban Transportation Systems; 3.1. Acquisition and/or Supply; 3.7. Project Planning, Project Assessment, and/or Project Control; 5. City Planning (smart cities, urban planning, etc.);

Abstract. Infrastructure Projects are rarely completed on time or within budget. This has become a "norm" that is begrudgingly tolerated by a jaded public. The societal waste is very high, on aggregate, in many of the highly developed nations on earth. The Infrastructure domain represents a multi-trillion-dollar global opportunity to improve deployment of systems engineering. This presentation will provide evidence to support the failure assertions, analyze root causes and present pragmatic solutions

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Right-sizing risk management approaches using lessons learned from Transportation and Infrastructure Industries

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Keywords. Organizational competency assessment;Requirements-driven risk management;Contractor-Supplier risk requirements

Topics. 12. Infrastructure (construction, maintenance, etc.); 2. Aerospace; 2.3. Needs and Requirements Definition; 3.9. Risk and Opportunity Management; 4. Biomed/Healthcare/Social Services; 4.5. Competency/Resource Management;

Abstract. How an understanding of organizational risk competencies ties to defining appropriate risk management requirements for all participants in the buyer-supplier relationship is explored using case studies from industry. This presentation complements related programs including a panel of risk management experts from multiple industries and a hands-on tutorial where participants walk through the entire risk management lifecycle starting with a quick assessment of risk competencies.

Safer Complex Systems

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Duncan Kemp (Ministry of Defence) - duncan@17media.co.uk

Keywords. Safety;Complexity;Complex Systems;Socio-technical Systems

Topics. 1.1. Complexity; 22. Social/Sociotechnical and Economic Systems; 4.6. System Safety;

Abstract. To enable safer complex systems, we need effective governance with mechanisms for planned adaptation to ensure appropriate agility and resilience. This presentation will provide an overview of recent work by INCOSE and the Engineering X: Safer Complex Systems Initiative.

Seeing the bigger picture with the Unified Architecture

Framework (UAF) - Offshore Wind to Hydrogen Enterprise

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Keywords. MBSE;UAF;System of Systems;SoS;Offshore Wind;Green Hydrogen;Wind Power;Sustainable;Simulation

Topics. 10. Environmental Systems & Sustainability; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 8. Energy (renewable, nuclear, etc.); 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Offshore wind to hydrogen generation and distribution represents a ground-breaking enterprise, intricately weaving together multiple independent systems to mitigate global challenges related to climate change and energy security. This complex yet vital endeavour is not merely a response to the urgent need for clean, renewable energy but also a multifaceted exploration fraught with technical, economic, and social barriers. As such, a holistic and systemic approach to design and analysis becomes not only preferable but imperative.This presentation delves into the utilization of the Unified Architecture Framework (UAF) to model an enterprise strategically incorporating offshore wind and hydrogen systems. UAF, a standardized representation of enterprise architecture through a Model-Based Systems Engineering (MBSE) approach, stands as a robust tool for evaluating various design choices and scenarios within the offshore wind to hydrogen enterprise. The UAF model embraces diverse views, capturing strategic vision, operational processes, resources, services, projects, and security controls.The system of systems within this enterprise consists of offshore wind farms, hydrogen production through to hydrogen storage along with integration to the power grid. Leveraging offshore wind, a renewable energy source, this enterprise aspires to produce green hydrogen, contributing significantly to the decarbonization of various sectors. This system of systems is not without its set of challenges, ranging from determining optimal configurations for systems to grappling with the variable and intermittent nature of offshore wind, in tandem with the demand and supply of hydrogen. The challenges extend to the enterprise too; needing to ensure the economic feasibility within an unknown market, along with conducting comprehensive environmental and social impact assessments and engaging with a wide variety of stakeholders to garner public acceptance and support.Addressing these multifaceted challenges necessitates not only technical prowess but also multidisciplinary research and innovation, demanding collaboration across industries, academia, government, and society. While the enterprise holds promise as a key solution in achieving net-zero emissions, it must traverse barriers and risks that may impede its development and deployment.By skilfully utilizing UAF, the presentation seeks to propel the knowledge and practice in the realm of the energy industry, illustrating how this framework empowers systems engineers to comprehend the complexity of their challenges on a grand scale. The presentation endeavours to equip the audience with an understanding of the Offshore Wind to Hydrogen enterprise, underscoring the significance of Model Based Systems Engineering (MBSE) in addressing its challenges and steering sustainable energy solutions. The UAF model is used in conjunction with Trade Analysis Simulation (TAS) and Monte Carlo simulation to help evaluate design alternatives, ensure coherence and consistency, and paving the way for future applications in concrete energy enterprise case studies.To enhance the learning experience, the presentation will include a live demonstration of the tools and techniques discussed, providing attendees with a first-hand insight into the practical application of UAF, MBSE, TAS, and Monte Carlo simulation.The presentation will be given by Joseph Hughes and Matti Koskipää, both esteemed experts at Dassault Systèmes. Joseph, an INCOSE Certified Systems Engineering Professional, leverages over a decade of experience as an MBSE Senior Specialist in the UK, specializing in SysML and UAF. With a background in Computing and Electronics, Joseph's global impact spans high-speed rail and renewable energy projects, embodying a commitment to excellence in shaping the future of systems engineering. Meanwhile, Matti, with over 15 years at Dassault Systèmes, manages the Model-Based Systems Engineering expert team, showcasing versatility across various industries and processes. His influential role in spreading MBSE knowledge includes serving as a visiting lecturer at Oulu University. Together, Joseph and Matti bring a wealth of knowledge and practical insights to the forefront of the presentation, offering a comprehensive view of advancements in Model-Based Systems Engineering.

Presentation#533

Shifting Left: A Test-Integrated System Modeling Approach to Reduce System Development Cycle Time

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Keywords. Model-Based Systems Engineering;Model-Based Test and Evaluation;Shift Left;MB-Testing;System Development Cycle Time

Topics. 1.6. Systems Thinking; 2.4. System Architecture/Design Definition; 2.6. Verification/Validation; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis;

Abstract. Problem Discovery during operational test and evaluation (T&E) has a significant impact on the acquisition cycle time of systems. A loss in competitiveness in the marketplace due to delays in fielding systems or products can prove detrimental to the survivability of organizations, and is a critical risk that must be actively monitored and mitigated. To achieve a reduction in the acquisition cycle time, i.e., a Shift Left, for a given system, traditional methods of testing need to be modified to accommodate more systemic and disciplined approaches that consider T&E more as a continuum, beginning at the conceptual phase of system design and development. Consequently, a systems engineering approach that introduces test capability modeling as an integral part of the model-based systems modeling methodology would result in a fully test-integrated MBSE approach to descriptive system modeling that emphasizes alongside the system-of-interest's (SOI) architecture, a test capability architecture, i.e., the necessary test resource artifacts required for verification and validation.This proposed approach differs from most Model-based T&E approaches reviewed in literature due to the specification of testing capabilities as an inherent part of a model-based test context and configuration. Most traditional model-based approaches usually capture a tester model element within the test context as the model element initiating a given test case. However, our approach specifies within a test capability model, the test facility and test resources required to perform testing of the system and/or specific capabilities as part of the test context. This approach accomplishes several T&E goals: firstly, it alerts the system architects and decision makers to the suitability of a specific test facility's ability to test to the system requirements and/or operational capabilities due to the availability of either adequate or inadequate test resources.Secondly, the approach utilizes a model-based test environment which could significantly reduce the overall T&E costs for the actual system by enabling the exploration of multiple test case specifications using testing techniques such as simulation via model execution, and analysis in order to identify the right tests and methods that could be deployed in testing the actual system. Performing verification and validation of a system using system models is a cost-effective way to show theoretical compliance of the system architecture prior development. Accordingly, in this work we demonstrate how a model-based test integrated configuration can improve a system's acquisition cycle time with a specific use case. A notional Missile System constitutes the SOI/SUT for our exemplar and is modeled using SysML. The notional test facility, i.e., the test capability model is defined as a model-based representation of required test resources — including representations of the system's operational environment — required to enable testing of a given set of system capabilities.

Presentation#547

Spares Strategy for Programs in Development Phases: Quantifying Hardware Needs Prior to Production

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Keywords. Verification and Validation;Integration and Test;Development;Systems Engineering;Spares;Project Management

Topics. 2. Aerospace; 2.6. Verification/Validation; 3. Automotive; 3.7. Project Planning, Project Assessment, and/or Project Control; 4.2. Life-Cycle Costing and/or Economic Evaluation; 6. Defense;

Abstract. Sparing strategies are widely employed for systems in production or operation where the system has completed development/certification and has a statistically significant set of failure data. However, there is no quantitative approach for a sparing strategy supporting a program in development phases. This research proposes a modified set of equations for calculating 'Cost VS Risk of Failure' and a process to create a quantitative sparing strategy for a system in the development phase.

Presentation#379

Spreading the word: How the Brazilian INCOSE Chapter is Contributing to the Growth of the Local Systems Engineering Community

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Keywords. systems thinking;community;social media

Topics. 1. Academia (curricula, course life cycle, etc.); 1.6. Systems Thinking; 19. Very Small Enterprises; 22. Social/Sociotechnical and Economic Systems; 3.5. Technical Leadership; 5.9. Teaching and Training;

Abstract. This presentation highlights the challenges and unique circumstances faced by the INCOSE chapter in Brazil in promoting systems engineering concepts. It emphasizes the limited recognition of systems engineering's value in organizations in South America, particularly in Brazil. To address the challenges, the chapter has undertaken marketing initiatives, producing technical content on social media platforms, including a podcast featuring professionals sharing real-world experiences.

Start with the End in Mind: Envisioning the Strategic Role of MOSA in Defense Modernization

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Keywords. Modular Open Systems Approach;MOSA;Defense Modernization;Systems Engineering;Architecture;Interoperability;Incremental Development;Open Architecture;Open Systems;System Integration;Resilience;Adaptability

Topics. 1.1. Complexity; 17. Sustainment (legacy systems, re-engineering, etc.); 2.5. System Integration; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. By attending the "Start with the End in Mind: Envisioning the Strategic Role of MOSA in Defense Modernization" session, participants will learn how to strategically apply MOSA principles to build adaptable, resilient, and effective defense systems. Participants will gain an understanding of the importance of MOSA in staying ahead of adversaries.

Survey of LLM Applications for Systems Engineering

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Keywords. Large Language Model;Artificial Intelligence;Systems Engineering

Topics. 11. Information Technology/Telecommunication; 5.11. Artificial Intelligence, Machine Learning; #AI

Abstract. Much of systems engineering work is carried out through the use of text, in the form of requirements, specifications, and other documents. Generative AI, especially Large language models are a natural fit to support many aspects of systems engineering. In this presentation, we survey how large language models (LLMs) are being used in systems engineering applications. Live demonstrations of many of the techniques will be included.

Sustainably Designing Products / Designing Sustainable Products

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Keywords. Sustainability;Sustainability Technologies;Requirements Management;Compliance;Systems Engineering;Sustainable Design

Topics. 1.6. Systems Thinking; 10. Environmental Systems & Sustainability; 12. Infrastructure (construction, maintenance, etc.); 2.3. Needs and Requirements Definition; 2.4. System Architecture/Design Definition; 3. Automotive;

Abstract. Sustainability is an outcome of two interrelated product engineering dimensions.Sustainably Designing Products - becoming more efficient in the actual development/building/creation of products.Designing Sustainable Products - Building a product that meets our efficiency goals to consume less energy, provide new efficiency methods, reusable products, etc

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Symbiotic relationship between neurodiversity and systems thinking

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Keywords. • Diversity;• Systems thinking;• Inclusion

Topics. 1.6. Systems Thinking; 3.5. Technical Leadership; 4.5. Competency/Resource Management;

Abstract. Addressing diversity and inclusion is important to innovation in engineering. Diversity is not limited to differences that are only visible, it is also about creating teams with diverse thinking. Neurodivergent describes people with variation in their cognitive functions and can include conditions such as attention-deficit/hyperactivity disorder (ADHD). ADHD, despite its challenges, can offer unique perspectives and strengths that are conducive to systems thinking.

System Engineering Challenges at Los Alamos National Laboratory: Modernizing the System's Thinking Approach

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Keywords. System Engineering;DOE;NNSA;Defense;Energy

Topics. 1.6. Systems Thinking; 2.3. Needs and Requirements Definition; 2.5. System Integration; 2.6. Verification/Validation; 6. Defense; 8. Energy (renewable, nuclear, etc.);

Abstract. Los Alamos National Laboratory (LANL) plays a crucial role in national security, managing the development and stewardship of the nation's deterrent system. Following the Phase X engineering process, LANL oversees responsibilities throughout the stockpile system lifecycle and new system technologies. Emerging challenges for the next generation of systems engineers will be addressed, emphasizing the importance of knowledge transfer, continuous learning, and fostering a positive work environment.

System Product Line Cost and Investment Modeling Applied to UUVs

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Keywords. product lines;economics;COPLIMO;COSYSMO;cost modeling;ROI;UUV;systems engineering

Topics. 1. Academia (curricula, course life cycle, etc.); 2. Aerospace; 4.2. Life-Cycle Costing and/or Economic Evaluation; 5.4. Modeling/Simulation/Analysis; 5.6. Product Line Engineering; 6. Defense;

Abstract. Integrated cost and product modeling applied to the acquisition of Unmanned Underwater Vehicles (UUVs) demonstrated the economic benefits of a product line strategy. The modeling framework includes System Modeling Language (SysML) for product modeling and a constructive cost model set for product line ROI, investment and reuse costs. Cost model inputs were extracted directly from the SysML requirements and executable activity models for the UUVs.

Presentation#27

Systematically Pulverised EARS - Improvements in requirements authoring and presentation

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Keywords. Requirements;Presentation;Syntax;Authoring

Topics. 2.3. Needs and Requirements Definition; 5.5. Processes;

Abstract. Guidelines are a starting point for requirement writing, but are not sufficient to ensure sensible and well-crafted statements. We draw inspiration from New Zealand major infrastructure projects, a 1957 paper on legal documents, a viral social media maths puzzle, and the rules of the Road Runner cartoons, to propose syntax extensions, syntax highlighting, and a set of rules and suggestions around grammar and structure that can be used to write and present easily understood requirements.

Presentation#404

Systems and Software Engineering Cost Modeling of AI Assistance

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Keywords. Artificial Intelligence (AI);Generative Artificial Intelligence;Cost Modeling;COSYSMO;COCOMO;Systems Engineering;software engineering;Large Language Models (LLMs);Parametric Cost Modeling

Topics. 1. Academia (curricula, course life cycle, etc.); 2. Aerospace; 3.7. Project Planning, Project Assessment, and/or Project Control; 4.2. Life-Cycle Costing and/or Economic Evaluation; 5.11. Artificial Intelligence, Machine Learning; 6. Defense; #AI

Abstract. Artificial Intelligence (AI) based tools that assist in generating system artifacts are transforming systems and software engineering lifecycles. Drastic reductions in effort are possible using tools that use large language models. This research addresses new challenges in systems and software cost modeling with the introduction of cost factors and size measures to incorporate into existing parametric cost models. An online data form has been developed to support the model development.

Systems Engineering Capability Development using the "Green and Blue Track Approach"

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Keywords. Enterprise Capability development;Tailoring;Organizational maturity;Evolutionary development

Topics. 3.5. Technical Leadership; 4. Biomed/Healthcare/Social Services; 4.5. Competency/Resource Management; 5.9. Teaching and Training; 8. Energy (renewable, nuclear, etc.); 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. How to build a lasting SE capability? This presentation describes an approach that is: systemic, recognizing that an enterprise SE capability is built up by a balanced set of Governance, Organisation, Processes, Information and Tools; systematic, providing a strategic direction for the enterprise capability (Green Track); and pragmatic, prioritizing building the capability incrementally supporting needs of ongoing projects (Blue Track). A case is presented along with lessons learned.

Systems Engineering Innovation through 'Futures' Methods

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Keywords. systems engineering;futures methods;forecasting;systems analysis;technology assessment;emerging technology;system design

Topics. 1.1. Complexity; 1.5. Systems Science; 1.6. Systems Thinking; 11. Information Technology/Telecommunication; 14. Autonomous Systems; 6. Defense; #FuSE

Abstract. This presentation will discuss how concepts and methods from the emerging field of futures studies can be applied to systems engineering to promote more far-reaching and innovative technology solutions.

Presentation#91

The A to Z for Implementing a Digital Transformation on a Systems Project

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Keywords. Digital Transformation;Digital Engineering;Agile;System Modernization;Systems of Systems (SoS);Engineering Management;Digital culture;Digital thread;SE Toolkit

Topics. 11. Information Technology/Telecommunication; 5.12. Automation; 5.3. MBSE; 5.5. Processes; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.); #MBSE-DE;

Abstract. Digital Transformations (DT) continue to change our products, systems, services, and the way we work. We are moving to model-based approaches faster with knowledge sharing exponentially increasing. Will we be ready for this future? To tackle such challenges we will present the "A to Z guide" for a DT, including the digitalization of applicable SE practices. This guide is built from experience on multiple projects, across different organizations and countries, and is applicable to all domains.

Presentation#85

The Contextual Metadata Layer (CoML) concept - unlocking collaboration in an uncertain/ BANI world

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Keywords. CoML;MoSSEC;Complexity;Uncertainty;BANI;Nonlinear

Topics. 1.1. Complexity; 2.4. System Architecture/Design Definition; 5.4. Modeling/Simulation/Analysis;

Abstract. The Contextual Metadata Layer, in conjunction with the concepts, processes and methods proposed in the INCOSE SE Handbook provide the needed clarity on how we may realize complex products through effective collaboration in an uncertain BANI world.

The Latest on the INCOSE-PMI Alliance and integration between Program Management and Systems Engineering

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Keywords. PMI;Project management;Roles and responsibilities;Project tension

Topics. 1.4. Systems Dynamics; 3.7. Project Planning, Project Assessment, and/or Project Control; 5.5. Processes;

Abstract. A decade into INCOSE's Alliance with PMI, the Project Management Institute, this presentation will share highlights from the past decade and how we are forging the path forward together. This presentation examines the relationship between systems engineers and program managers. It identifies roles performed by each discipline, areas of tension, and ways to overcome the tension.

Presentation#511

Think Like an Ecosystem: Deploying MBSE Within Your Organization

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Keywords. MBSE;CATIA;Biomimicry;Sustainability;MBSE Deployment;Systems Design;Systems Thinking

Topics. 1. Academia (curricula, course life cycle, etc.); 1.6. Systems Thinking; 10. Environmental Systems & Sustainability; 17. Sustainment (legacy systems, re-engineering, etc.); 5.3. MBSE; 5.7. Software-Intensive Systems;

Abstract. The systems we design are inherently natural. Every ecosystem on this planet operates within the laws of physics and subsequently the laws of ecology. All systems undergo change. These disruptions to the status quo may be unexpected or introduced intentionally. Fortunately, we can leverage the sophistication of our ever-changing and adaptive natural ecosystems to better understand how we can manage change within our human and engineered systems. We propose that an organization can improve and accelerate the deployment of a new initiative by looking to nature and taking cues from ecosystem succession principles. Specifically, we translate characteristics of each stage of ecosystem succession and apply them to the stages of deployment of MBSE within an organization. We draw on analogies from ecosystem disruption to develop resilient processes, leverage patterns, utilize resources, and advance the system model and modeling ecosystem. We offer practical tools for organizational leaders, program managers and MBSE practitioners involved in both small and large-scale technological transformations. We discuss where to start when introducing your team to MBSE and how to evolve your MBSE practice over time and with growing system complexity. We offer guidance to modelers on how to build efficiency into the modeling endeavor with reusable model elements and libraries. Finally, we will use nature as a guide to better understand the concept of integration and modeling system interfaces. We will perform a live demonstration using CATIA to illustrate these constructs.The adoption of a metaphorical biomimetic model enriches the discourse surrounding MBSE adoption, recognizes the complexities of the organizational ecosystem, and provides a foundation for developing an adaptive organizational strategy. Natural systems are not stagnant, and an MBSE initiative should not be either. With a diverse span of stakeholders, approaching MBSE deployment with an adaptive process facilitates resilience and success.

Presentation#552

Three Dimensions of Precision Digital Engineering

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Keywords. Digital Engineering;Digital Thread;Model-based Systems Engineering;System Family Engineering;Feature-based Product Line Engineering;Variation Management;Temporal Management;Configuration Management

Topics. 1.6. Systems Thinking; 3.2. Configuration Management; 5.3. MBSE; 5.6. Product Line Engineering;

Abstract. While the digital representation for digital twins, digital threads, MBSE, and digital simulations is the central concern for a Digital Engineering approach, there are two additional engineering concerns that must be addressed for a successful DE solution. We refer to these three concerns as the three dimensions of Precision Digital Engineering: Multi-discipline, Multi-product, and Multi-baseline. Carefully separating each of these concerns enables a precise holistic solution for advanced DE.

Presentation#270

Towards a Reusable Model Based Systems Integration Framework

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Keywords. System of Systems;Emergence;Interoperability;Model-Based Systems Integration;Element of definition;Element of usage

Topics. 12. Infrastructure (construction, maintenance, etc.); 16. Rail; 2.4. System Architecture/Design Definition; 2.5. System Integration; 5.3. MBSE; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.);

Abstract. This session will present the transitioning of an interoperable systems integration approach towards a model-based systems integration framework ("element of definition") that can be tailored and re-used in various transportation programs ("element of usage"). The presented MBSI framework will include various viewpoints and views with examples of real-world program structure, key interfaces, interface requirements and interoperability standards "in the loop".

Towards an Ontology of Digital Engineering Terminology to Support Digital Information Exchange

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Keywords. digital engineering;digital transformation;systems engineering;ontology;standards

Topics. 22. Social/Sociotechnical and Economic Systems; 5.3. MBSE; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. In this presentation, we describe the current status of the DE ontology under development by the DEIX Taxonomy WG. We highlight the standards from which terminology has been extracted, and discuss decisions that have been made regarding the classification of this terminology. We show how the outcomes from the DE Taxonomy session at the INCOSE IW have influenced those decisions. Through example use cases, we demonstrate how this ontology can be used to support digital information exchange.

Trade Space Wonders: Expanding Horizons with Graph Embeddings to understand large trade space from generative methods.

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Keywords. trade space wonders;generative methods;graph embeddings

Topics. 2. Aerospace; 3. Automotive; 3.3. Decision Analysis and/or Decision Management; 5.11. Artificial Intelligence, Machine Learning; 6. Defense; #AI;

Abstract. In systems engineering, automated trade space generation surpasses manual methods, offering efficient and innovative solutions. But it also poses challenges in analyzing the vast trade space generated. In this work, we study three systems engineering cases in mission, system, and subsystem design across automotive and aerospace industries. We demonstrate how graph embeddings created by unsupervised machine learning can capture structural information, similar to human understanding of systems.

Presentation#388

Tradestudy for Platforming strategy and Product Line Engineering

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Keywords. PLE;Platform;Product line engineering;framework;variant;tradestudy;tradespace

Topics. 1.1. Complexity; 3. Automotive; 5.6. Product Line Engineering; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Is managing variants of huge and complex systems on your mind? You have a digital solution to manage and deploy PLE, but not sure where to begin? Or are you simply looking to understand how to come up with platforming strategy in the first place? If any of your answers is yes, this presentation will give you insights on how the authors have strategized, developed and managed complex Product Portfolios, by identifying the right set of variants.

Presentation#233

Unlocking Value in MBSE – Consistent Data Extraction & Visualisation from SysML Models with Rule-based Analysis

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Peri Mehmet (The Systems Thinking & Eng. Co Ltd) - peri.mehmet@systems-tec.co.uk

Keywords. MBSE;Data Analytics;Visualisation;Metrics;Dashboard

Topics. 13. Maritime (surface and sub-surface); 3.3. Decision Analysis and/or Decision Management; 3.6. Measurement and Metrics; 5.3. MBSE; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Unlock the full potential of Model Based Systems Engineering! Join us in exploring our solution in addressing the challenges in extracting data from SysML models and tracking project progress. The tool agnostic queries applied to the underlying models generate insightful metrics that can be visualised on open-source dashboard platforms such as Grafana. Experience a live demonstration, empowering engineers and stakeholders to make informed, data-driven decisions.

Presentation#528

Using AI tools for SE, from Requirements Generation and Management to Risk Identification, Analysis, and Management

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Keywords. Systems Engineering;Model Based Systems Engineering;AI;Generative AI;Requirements;Risk Identification;Risk Analysis;Risk Management;Large Language Model (LLM)

Topics. 1. Academia (curricula, course life cycle, etc.); 3.9. Risk and Opportunity Management; 5.11. Artificial Intelligence, Machine Learning; 5.3. MBSE; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Our research aims to demonstrate the efficacy of LLMs in interacting with Systems Modeling Language (SysML) models. This includes not just meeting predefined requirements but also uncovering derived requirements essential for mitigating risks. We propose a detailed case study that showcases the integration of LLMs in streamlining the systems engineering process.

Using Systems Engineering and Decision Analysis in Descriptive, Predictive, and Prescriptive Analytics

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Keywords. Analytics;Data Analytics;System Engineering;Decision Analysis;AI;Machine Learning

Topics. 10. Environmental Systems & Sustainability; 3.3. Decision Analysis and/or Decision Management; 5. City Planning (smart cities, urban planning, etc.); 5.1. Agile Systems Engineering; 5.7. Software-Intensive Systems; 6. Defense;

Abstract. Our research uses data analytics to provide data driven insights to Army installation management decisions in three areas: severe weather alerts, avoiding heat related injuries in training, and evaluating the financial return on investment of installation resilience options to reduce the impact of severe weather influenced by climate change. Our research team involves installation managers, Engineer Research and Development Center project managers, contractors, and university researchers.

V&V in Boeing's 2nd Century

James Craig (The Boeing Company) - James.P.Craig2@boeing.com

Keywords. verification;validation;V&V;digital engineering

Topics. 2. Aerospace; 2.6. Verification/Validation; 5.5. Processes; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. As Boeing has begun its 2nd century, it has been reevaluating its approach to verification and validation (V&V). This has ranged from resolving long-standing terminology disagreements to developing a scalable framework for implementing a "V&V System". In this presentation, Boeing will cover discrepancies in industry guidance it has encountered, the company's resultant V&V framing, the core elements of its V&V conceptual data model, and Boeing's approach to realizing a scalable V&V framework.

Key Reserve Papers

Key Reserve Paper#441

A Configuration Management Strategy for Model-based Product Line Engineering in Aircraft Systems Development

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Keywords. model-based systems engineering;model-based product line engineering;change and configuration management

Topics. 3.2. Configuration Management; 5.3. MBSE; 5.6. Product Line Engineering;

Abstract. Aircraft systems development is complex and time-consuming. Model-based Product Line Engineering (MBPLE) aims to reuse assets between projects to accelerate the development of systems at their early stage. Despite guidance from standards, MBPLE practitioners still face the challenge of deploying an appropriate configuration management strategy. This paper presents and demonstrates a configuration management strategy to support practitioners deploying MBPLE for aircraft systems development. We developed this strategy to comply with ISO/IEC 26580 and address pending standard ambiguities using best practices from product lines for systems, software, business processes, and systems of systems. The proposed strategy supports long-term product line evolution, management of different asset types, and independent product environments

Key Reserve Paper#548

A Framework to use Bifurcation Analysis for Insight into Complex Systems Resilience

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Bryan Watson (Embry-Riddle Aeronautical University) - Watsonb3@erau.edu

Keywords. Critical Transitions;Bifurcation Analysis;Resilience Engineering;Complex Systems

Topics. 1.1. Complexity; 1.3. Natural Systems; 12. Infrastructure (construction, maintenance, etc.); 14. Autonomous Systems; 22. Social/Sociotechnical and Economic Systems; 4.4. Resilience;

Abstract. The increasing complexity and integration of systems present challenges in understanding and managing these systems, as highlighted by the INCOSE Systems Engineering Vision for 2035. Bifurcation analysis, a mathematical system dynamics technique, offers a different perspective by examining how systems behave under changing conditions. This paper aims to bridge the gap between bifurcation analysis and Resilience Engineering, offering a framework for integrating both approaches.

A modular simulation-based MBSE approach applied to a cloud-based system

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Keywords. cloud-based system estimation;model-based systems engineering;time-base simulation;modular modeling approach

Topics. 1. Academia (curricula, course life cycle, etc.); 11. Information Technology/Telecommunication; 2. Aerospace; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 5.7. Software-Intensive Systems;

Abstract. Data systems consist of a network of communication channels, applications that trans-mit data across these channels, and the hardware running these applications or generating the data. Most modern data systems include cloud storage or compute which has unpredictable or stochastic properties making estimations of cloud behavior and performance difficult. Resource usage is function of behavior and performance on software/hardware. Cloud cost is a function of resource usage and hardware used. Public cloud spend was over budget by an average 18% for 2022 with organizations reporting an estimated 28% public cloud waste. The scale of this problem is a measure of the difficulty of accurate cloud-based system performance and cost predictions. The goal of this paper is to develop and demonstrate a modular and scalable Model-Based Systems Engineering (MBSE) approach for designing, updating, and managing cloud-based data systems. Our use-case based Agile MBSE approach is developed to integrate with commonly used Agile software development processes to increase collaboration between system engineers and developers. We embed simulation behaviors within the lowest level of system specification activities to produce a modular andreusable set of simulation-ready system activities. Our approach uses a combination of languages (SysML, fUML, Apache Groovy, and the Action Language Helper (ALH)) to develop these modular system activities for scalability and speed. We applied this approach to the simulation of a cloud-based data system. The results show that our approach produces a modular, time-dependent, executable system model that can estimate cloud-based system performance and storage cost as a function of time. Emergent behavior observed from the simulation results indicate that the systemmodel is capable of providing system engineers and management teams valuable insight into the behavior of the system they are designing or upgrading.

A Rapid Review of How Model-based Systems Engineering is Used in Healthcare Systems

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Keywords. Model-based systems engineering (MBSE);healthcare systems;sociotechnical systems;human-in-the-loop systems

Topics. 18. Service Systems; 4. Biomed/Healthcare/Social Services; 4.1. Human-Systems Integration; 5.3. MBSE;

Abstract. This study presents the results from rapid review of how model-based systems engineering (MBSE) is utilized in healthcare systems (HSs). We conduct a review of the last twelve years and find that MBSE adoption in HSs is accelerating, with use of various MBSE languages and tools, as well as their integration with other simulation and modeling techniques. We find that similar to engineered systems, the most common MBSE language is systems modeling language (SysML), followed by unified modeling language (UML) and others such as OPM. Additionally, we observe that MBSE methods are frequently used in conjunction with other analytical techniques, such as simulation and co-simulations, to analyze and enhance various HS operations, or to assist with making tradeoffs between HS attributes such as quality and cost. Moreover, we provide a non-exhaustive classification of current research based on two dimensions: healthcare applications and MBSE use cases. Notably, MBSE is being implemented generally with patient-centric objectives in various HS domains, including IoT-enabled smart healthcare, clinical medicine, medical device development, healthcare process enhancement, and healthcare facilities management. While the primary MBSE use case involves modeling different aspects of healthcare operations, there is a significant number of studies that pursue requirements engineering, systems analysis, integration, verification and validation, as well as risk analysis and management. Furthermore, we identify two promising research gaps. First, there is a need for the integration of MBSE with state-of-the-art data-driven analytical methodologies such as hybrid simulation and artificial intelligence techniques. Second, HSs could greatly benefit from representing the cognitive functions and processes of human decision-makers in the loop, such as healthcare providers (e.g., doctors and nurses), who are instrumental in sustaining the HS performance and functionality. We contend that MBSE and other SE methods and techniques could improve HSs design, operations, and management; while fostering resilience and long-term sustainability.

A Technical Approach to the Digital Signature of MBSE Models

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Keywords. Model-Based Systems Engineering (MBSE);Digital Signature;Authoritative Sources of Truth (ASOTs)

Topics. 11. Information Technology/Telecommunication; 3.2. Configuration Management; 3.4. Information Management Process; 5.3. MBSE; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. This paper describes an approach to apply digital signatures to MBSE models. This approach enables the digital signing of a portion of a model using a signer's digital certificate, allows for the verification of the signed model content against the signature and indicates if information is altered from what the signer intended. This paper captures the technical challenges and lessons learned applying this approach as a prototype to an existing MBSE modeling tool.

Addressing Cross-Domain Interoperability between Automotive and Smart Grid Architecture Models

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Keywords. Model-Based Systems Engineering;Domain Specific Languages;Cross-Domain Interoperability

Topics. 1.1. Complexity; 3. Automotive; 5. City Planning (smart cities, urban planning, etc.); 5.3. MBSE; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 8. Energy (renewable, nuclear, etc.);

Abstract. The rapid advancement and diversification of technical domains, particularly in automotive and smart grid sectors, are pivotal in driving the emerging energy revolution. This evolution is instrumental in governing the future of smart cities, characterized by escalating complexity and diversity within these domains. Such a landscape necessitates seamless collaboration among various domain experts, a task often complicated by the prevalent use of domain-specific languages and tools tailored to specific engineering needs. This poses a significant challenge towards cross-domain interoperability.Addressing this challenge, our research introduces a novel approach leveraging abstraction layers inspired by the Software Platform Embedded Systems (SPES) methodology. This approach aims to enhance the compatibility of domain-specific frameworks, with a focus on the Smart Grid Architecture Model (SGAM) and the Automotive Reference Architecture Model (ARAM). By applying these SPES-inspired abstraction layers, our work facilitates the reconciliation of varying levels of detail across different domains.The paper culminates in a proof of concept that demonstrates the practical implementation of this approach, showcasing a method to achieve effective cross-domain interoperability. This implementation not only underscores the feasibility of our proposed solution but also illuminates a pathway for managing the intricate interplay of systems in the rapidly evolving landscape of smart cities.

An ontology example in Configuration Management at Airbus

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Keywords. Ontology;Configuration Management;Digital

Topics. 2. Aerospace; 3.2. Configuration Management; 5.12. Automation;

Abstract. This paper presents the effort performed at Airbus in the configuration management domain to structure the data through abstract ontology models of processes, tools and workflows. The ontology objects are then implemented and exposed as a data product to be used in digital transformation initiatives. This ontology based approach has encouraged harmonization of digital initiatives across different aircraft programs.

Analysis of the Ability of the OSLC Standard to Improve Data Traceability in System Development

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Keywords. Open Services for Lifecycle Collaboration OSLC;Traceability;Digital Thred;MBSE

Topics. 1.6. Systems Thinking; 2.5. System Integration; 5.3. MBSE; 5.5. Processes; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. The development of systems offers a particular challenge for the interoperability of different tools used by collaborating developers like requirements management, design, or simulation tools. The difficult and time-consuming process to integrate and exchange data between different systems can lead to data inconsistencies and reduced efficiency in the development process. The integration standard Open Services for Lifecycle Collaboration (OSLC) targets the integration of engineering software applica-tions. Its approach supports loose tool coupling, in which each application autonomously manages its own product data, while providing RESTful web services through which other applications can interact. This paper aims to analyze the suitability of OSLC as an overarching integration mechanism for the complete set of engineering artifacts created during system development. This paper presents use cases for the application of OSLC at the company MAHLE. For these use cases, the employed OSLC based toolchain is assessed. The analysis in this paper confirms that OSLC's capabilities allow users to support traceability and can support the exchange and integrate data according to the defined re-quirements, but it is not sufficient for sophisticated data processing functionalities, such as safety analysis or simulation. The OSLC integration does correspondingly compare favorably to integration technologies already in use regarding traceability, while transformation of data in domain specific tools is needed to achieve deeper levels of integration.

Application of Model-Based Systems Engineering Within the Automotive Industry — a Current State

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Keywords. Model-Based Systems Engineering;MBSE;Automotive;Survey

Topics. 3. Automotive; 5.3. MBSE;

Abstract. Model-Based Systems Engineering (MBSE) has been utilized within the automotive industry for several years. Increasing complexity due to highly automated, connected vehicles demand more than ever methods to cope with this complexity. In most cases, currently only specific partial aspects or single methods of MBSE are used, which even varies across different companies. This paper aims to examine the current implementation of MBSE based on samples collected from various automotive suppliers (referred to as "Tier 1"). Various aspects are explored, including the scope of application throughout the product lifecycle, the use of simulation methods and the collaboration with other disciplines within product development. In the end an evaluation dis-cusses reasons for the current state and recommendations are given.

Application of SysMLv1 vs SysMLv2 in the Scope of the MagicGrid Framework

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Keywords. Model-Based Systems Engineering (MBSE);Systems Modeling Language (SysML);SysMLv1;SysMLv2;MBSE methodology;MagicGrid

Topics. 2.3. Needs and Requirements Definition; 2.4. System Architecture/Design Definition; 5.3. MBSE;

Abstract. This paper aims to assess the impact of the next generation Systems Modeling Language, SysMLv2, on the established framework for the model-based systems engineering (MBSE), MagicGrid. The research involves the parallel application of SysMLv1 and SysMLv2 to build two models of the problem domain definition by following the steps defined by the framework. Modeling concepts of both languages used to create the models are compared, differences disclosed, and advantages and disadvantages assessed.

Applied Ideation Methodology Selector Tool

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Keywords. Ideation;Concept Generation;Product Development;Innovation

Topics. 1. Academia (curricula, course life cycle, etc.); 2.4. System Architecture/Design Definition; 5.5. Processes; 5.9. Teaching and Training;

Abstract. This session presents an Excel-based tool designed to allow engineers to select the most appropriate/likely useful tools for ideation. The tool involves having the user input importances of seven selection criteria, and from that input, it recommends the top five ideation tools (out of 13 currently included in the tool) for their situation. Embedded in the tool are pocket guides to the included ideation tools.

Are Electric Vehicles Always Better for the Environment?

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Keywords. carbon emissions;electric vehicles;environmental impact;life cycle assessment

Topics. 1.6. Systems Thinking; 10. Environmental Systems & Sustainability; 3. Automotive; 4.2. Life-Cycle Costing and/or Economic Evaluation; 5.4. Modeling/Simulation/Analysis; 8. Energy (renewable, nuclear, etc.);

Abstract. Not applicable

Configuration Management of Sets of Links in a Federated Tool Environment

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Keywords. Configuration management;model-based systems engineering;traceability

Topics. 2. Aerospace; 3.2. Configuration Management; 5.1. Agile Systems Engineering; 5.3. MBSE; 5.6. Product Line Engineering;

Abstract. The relationships between the artifacts managed by different tools in a federated architecture are the glue that holds the overall design together. This paper explores the different mechanisms that exist for managing those relationships, discusses pitfalls of each one of them and provides a list of critical capabilities a complete engineering data management solution must provide.

Context-Based Systems Engineering

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Keywords. Requirements;Decomposition;Context-Based;Processes

Topics. 2. Aerospace; 2.3. Needs and Requirements Definition; 2.4. System Architecture/Design Definition; 3. Automotive; 5.5. Processes; 6. Defense;

Abstract. Context-Based Systems Engineering, a new problem/system decomposition approach. Instead of the traditional way, where stakeholder requirements are transformed into system requirements on the system-of-interest, stakeholder requirements are decomposed into requirements for modified context subsystems. This will enable executable requirments and very early integration, verification and validation.

Data Element Mapping And Analysis (DEMA) To Enable Systematic Model Creation Using SysML

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Keywords. Data Element Mapping and Analysis (DEMA);Model-Based Systems Engineering (MBSE);System Verification;System Modeling Language (SysML);Digital Engineering;Data Mapping

Topics. 2. Aerospace; 2.4. System Architecture/Design Definition; 2.6. Verification/Validation; 5.3. MBSE; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.)

Abstract. Data Element Mapping and Analysis (DEMA) represents a new and systematic methodology for the standardized capture, mapping, and analysis of data threads essential for comprehending digital systems and their architecture. This research studies the synergies between DEMA and Systems Modeling Language (SysML). The results of this research show that DEMA can serve as a complementary tool, enhancing the creation of SysML models by improving knowledge capture and verification processes.

Key Reserve Paper#469

Developing a Model-Based Systems Engineering Tool for Cybersecurity Risk Management of Micro-Electronic Devices

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Keywords. Model-Based Systems Engineering;Cybersecurity;Risk Management

Topics. 2. Aerospace; 4.7. System Security (cyber-attack, anti-tamper, etc.); 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 6. Defense

Abstract. This presentation outlines a method to quantify cyber threats associated with micro-electronics. The method utilizes MBSE as a tool to implement a cyber-threat assessment model. The model integrates a mathematical quantification of these threats to produce a visualization of the results in a 5x5 risk matrix. This tool will help users identify unique threat vectors and analyze counter-measure strategies to mitigate the effects on system performance, safety, and security.

Key Reserve Paper#78

Do Algorithms Dream of Electric Requirements? Leveraging AI-Based Approaches for Automated Allocation and Classification of Requirements in Railway Engineering

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Keywords. Artificial Intelligence;Requirements Classification;Systems Engineering;Railway Engineering;Machine Learning

Topics. 12. Infrastructure (construction, maintenance, etc.); 16. Rail; 2.3. Needs and Requirements Definition; 2.6. Verification/Validation; 21. Urban Transportation Systems; 5.11. Artificial Intelligence, Machine Learning; #AI

Abstract. Leveraging AI-Based Approaches for Automated Allocation and Classification of Requirements in Railway Engineering

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Key Reserve Paper#419

Evaluating Automotive Spice® As Process Requirements

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Keywords. Automotive;Standard;Automotive Spice;ASPICE;Systems engineering;Requirement;Process

Topics. 1.6. Systems Thinking; 2.1. Business or Mission Analysis; 2.3. Needs and Requirements Definition; 3. Automotive; 5.5. Processes;

Abstract. Software and Systems engineering projects in the Automotive industry are often mandated to develop according to the Automotive SPICE® standard. Despite a highly qualified workforce, many projects or organizations fail to implement compliant processes. This paper reinterprets the Automotive SPICE® standard, viewing its base practices as process requirements. Using a set of derived quality criteria for requirements, the subsequent evaluation of base practices for quality results in an aggregate and individual analysis of the ASPICE base practices. The analyses reveal, amongst others, deficiencies in the aspects of atomicity, detail, unambiguity, and origin. The paper proposes a public, collaborative effort to enrich the requirements with purpose, detail and structure.

Key Reserve Paper#60

Exploring the Executable SysML Capabilities to Integrate and Operate Hardware in the Loop

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Keywords. SysML;Digital Twin of Weapon System;Lego Mindstorms;Executable Model;Hardware in the Loop

Topics. 1. Academia (curricula, course life cycle, etc.); 2.6. Verification/Validation; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 6. Defense;

Abstract. Effective modeling and integration are critical SE capabilities. The goal of this paper is to explore the capabilities of SysML to model and control HIL. The SysML model of a weapon system was created. With help of standards (SCXML, fUML), SysML can be made executable and used for simulation purposes. While SysML was selected to provide a digital model of the weapon system, a LEGO Mindstorms EV3 development kit was selected to create a mockup of a physical system.

Extending SysML Model Federation to Support Systems of Systems Multilevel Security Development

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Topics. 13. Maritime (surface and sub-surface); 2. Aerospace; 2.4. System Architecture/Design Definition; 5.3. MBSE; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 6. Defense;

Abstract. This paper builds on previously published work on SysML model federation in support of SoS architecting, extending that methodology to address the unique challenges of development in the presence of MLS policies. The paper describes a federation approach spanning classified networks, method to allow an individual system model to be divided across classification levels, and a relationship based classification profile openly published for use.

Hardware-in-the-Loop with SysML and Cameo Systems Modeler

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Topics. 2. Aerospace; 20. Industry 4.0 & Society 5.0; 3. Automotive; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis;

Abstract. This paper describes an approach for Hardware-in-the-Loop simulations with SysML models in the Cameo Systems Modeler tool. It is based on a plugin called MQTT Simulation Connector that enables bidirectional communication between the tool and hardware components using the MQTT protocol. The paper presents the applicable requirements and constraints that were considered, describes the MQTT Simulation Connector in detail and shows an example of its use in the form of a Smart Home demonstrator.

Key Reserve Paper#505

Impact Analysis of using Natural Language Processing and Large Language Model on Automated Correction of Systems Engineering Requirements

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Keywords. Requirements;Systems Engineering;Large Language Models;Natural Language Processing

Topics. 2.3. Needs and Requirements Definition; 3. Automotive; 5.11. Artificial Intelligence, Machine Learning; 5.12. Automation; 9. Enterprise SE (organization, policies, knowledge, etc.); Other domain; #AI

Abstract. The increasing complexity of Electronic Control Units (ECUs) in the Automotive Industry due to the integration of more sophisticated vehicle features led to a greater need for robust Systems Engineering (SE) to define and implement efficient solutions. In this context, requirements emerge as a critical part of the communication between cross-functional teams. The more complex systems become, the more requirements are needed to define them. Misalignment, lack of information and ambiguity on requirements impact the entire development process, resulting in issues later, harder to be fixed. Some studies are being applied to evaluate techniques using Natural Language Processing (NLP) and how it can replace extensive peer reviews, identifying weaknesses in requirements earlier in the process, avoiding wasted time and large financial losses. Normally, NLP is combined with templates such as Easy Approach Requirements to Syntax (EARS), or other techniques based on rules like the INCOSE rules to define metrics and evaluate the quality of requirements in automated way. The focus of this study is to enhance the requirements evaluation algorithm by combining NLP with Large Language Models (LLMs) and adding the ability to provide corrected requirements to Systems Engineers.

Implementation of a Technical Peer Review Process: Principles, Policy, and Cultural Change

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Keywords. design process;technical review;peer review;continuous improvement;engineering process

Topics. 2. Aerospace; 3.7. Project Planning, Project Assessment, and/or Project Control; 5.2. Lean Systems Engineering; 5.5. Processes; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Sandia has developed a continuous improvement process to institutionalize technical peer review in the design lifecycle of products. The approach focuses on translating customer and leadership expectations, utilizing current established practices, simplifying planning and execution, and providing resources to engineering teams to guide them and ensure that rigorous and consistent technical peer reviews are performed.

Introducing a Three-Layer Model Taxonomy to Facilitate System-of-Systems Co-Simulation

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Keywords. model-based systems engineering;power systems;cyber-physical systems;digital twin;modeling and simulation

Topics. 12. Infrastructure (construction, maintenance, etc.); 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 8. Energy (renewable, nuclear, etc.);

Abstract. The growing demand for efficient, resilient, and sustainable electricity infrastructure has led to the emergence of smart grids as cyber-physical systems of systems. Co-simulation has proven an effective tool for their analysis and validation by coordinating independent subsystem simulations. However, the reuse and integration of diverse models in co-simulation poses challenges, requiring compatibility and integration efforts. In response, this paper proposes a model taxonomy with the purpose of facilitating co-simulation; it comprises three layers: concrete-instance models, abstract-instance models, and type models. The taxonomy contributes to the creation of independently developed models that can be seamlessly integrated into a coupled co-simulation. Furthermore, it reflects the emergence of digital twins in smart grid engineering by the explicit distinction of abstract and concrete instances. The three-layer taxonomy was derived and validated through a case study on co-simulation of elec-tric-vehicle charging infrastructure. The research further analyzes and formalizes three model-ing-and-simulation challenges framed through the lens of the taxonomy: the integration of models across all three layers, the merging of layers, and the consolidation of instance models to craft joint co-simulation scenarios. Finally, three concrete recommendations for industrial practice and research are given. Thereby, the study contributes to the efficient and effective model-based validation of cyber-physical systems of systems using co-simulation.

Key Reserve Paper#132

Introduction of Systems Engineering Practices in a Product Lifecycle Management (PLM) course for master students

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Keywords. Product Lifecycle Management;Model-Based Systems Engineering;graduate course

Topics. 1. Academia (curricula, course life cycle, etc.); 5.3. MBSE; 5.9. Teaching and Training;

Abstract. Using system modelling approach to introduce students to PLM systems, a reflection from a graduate course.

Key Reserve Paper#171

Leading in Uncertainty: A Framework to Improve Performance

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Keywords. Uncertainty;Leadership;Technical Leadership;Framework

Topics. 1. Academia (curricula, course life cycle, etc.); 3.5. Technical Leadership

Abstract. We are all leaders in our organizations in some form. As leaders, we often face elements outside our control. As systems engineers, we think of technical uncertainties, which we attempt to predict, manage, and mitigate. As leaders many of the uncertainties experienced are not technical. They involve elements, such as people, and incorporate unknown and known unknowns. We propose a framework to provide leaders with a tool to help achieve their goals with the uncertainties they face as leaders.

Leveraging Large Language Models for Direct Interaction with SysML v2

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Keywords. API;Assistant;Large Language Model;LLM;SysMLv2

Topics. 5.11. Artificial Intelligence, Machine Learning; 5.12. Automation; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; #AI

Abstract. This paper examines the potential integration of Large Language Models (LLMs) with the Systems Modeling Language version 2 (SysML v2), proposing a novel methodology for systems engineering by capitalizing on the enhanced readability and human-friendly syntax of SysML v2. Given the emergent sophistication of LLMs and the coincidental development of SysML v2—an endeavor that presents a pivot toward naturally articulated model interaction—we explore the possibilities and implications of such an intersection. Our investigation posits that LLMs can serve not only as an interpretive layer, allowing for the syntactically simplified manipulation of system models, but also as a catalyst for a knowledge-driven design approach. We highlight the efficiencies gained by deploying LLMs for SysML v2 interactions, which reduce the dependency on technical expertise traditionally needed for API navigation and model management. Through case studies and analysis, we demonstrate that the conversational engagement with system models facilitated by LLMs can lead to a democratized and accelerated design process. However, this advent is tempered by a critical awareness of potential pitfalls, such as automation bias and overre-liance on automated systems—underscoring the need for continued human oversight and the ex-amination of ethical considerations. Emphasizing the chance of SysML v2 being inherently English-based and the parallel maturation of LLMs, this paper suggests that the collaborative utilization of these concurrent advancements may offer an opportune fusion, potentially revolutionizing the way systems are modeled and managed. Future work involves the empirical validation of these approaches and a deeper investigation into interoperability with existing and future systems engineering ecosystems. The ultimate goal is to ensure that this fusion not only complements human expertise but also propels systems engineering into a new era of innovation and holistic design.

Leveraging Mbse Usage Through Model Checkers

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Keywords. Model checkers;correctness;completeness;consistency;static analysis

Topics. 2.4. System Architecture/Design Definition; 2.6. Verification/Validation; 5.3. MBSE

Abstract. System modeling is an essential part of the systems engineering process, helping with the design, analysis, and communication of complex systems. The usage of modeling languages like SysML and UML has become increasingly prevalent in this domain. To ensure the Holy Trinity of validation of these models (correctness, completeness and consistency), model checkers play an important aspect.This paper discusses the role of model checkers in the validation of system models, and their im-portance in adopting MBSE approach with a quick benefit to system engineers. Different possible implementations are presented including one based on an ontology able to take advantage of semantic analyses. Finally, in order to deal with the number of issues due to the complexity of our models, we suggest correcting them regarding the goal of the model and the project milestones. This last point implies the need of an issue acknowledgement feature making it possible to justify the temporary or definitive rejection of these issues.

Leveraging Mission Solution Configuration Through MBSE And Tradespace Exploration

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Keywords. Systems Engineering;Tradespace Exploration;Variants Management;Pareto-Optimization;Product Management

Topics. 13. Maritime (surface and sub-surface); 2.4. System Architecture/Design Definition; 3.3. Decision Analysis and/or Decision Management; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 6. Defense;

Abstract. is a worldwide leader in innovative radar and mission solution systems used by naval ships. As the demand for personalized products increased through the time, shifted from a project-oriented to a product-oriented approach, so that it can exploit variants and reuse to create diversity and, at the same time, reduce the occurrence of specific tailoring, which needs to be performed by projects. In this context, established a mission solution configuration process (SCP) to facilitate the selection of product variants to compose a system during the bidding phase. The SCP's current state, thought, limits the solution space exploration to predefined system solutions with have limited freedom for choosing variants. Furthermore, the SCP is not directly integrated to engineering process and the actual systems information. As a consequence, the proposed systems sometimes fall short from the most optimal solution the client could get. Therefore, the objective of this work is to develop and validate an improved mission solution configuration process that facilitates the efficient creation and selection of product variants/mission solutions, aligning them more effectively with the client's needs and operational requirements, particularly within the bidding phase at . The developed method combines Model-Based Systems Engineering (MBSE) and Tradespace Exploration (TSE). In the MBSE part, ARCADIA (ARChitecture Analysis and Design Integrated Approach) is used as the method and the language, and MELODY is the used tool. A descriptive model is created, which includes the relevant information to create an analytical model to be used during the TSE, where the Multi-Attribute-Utility-Theory (MAUT) and Pareto-Optimization were used in evaluating and selecting between the most optimal mission solution variants. The method was validated through a coast guard mission case study closely resembling a real scenario of 125 solution variants. The results revealed the Pareto-optimal solution variants achieved through optimization for overall performance versus total cost. We conclude that the proposed method enhances that current configuration process by harmonizing client and operational needs with 's sales and product teams, thereby ensuring accurate interpretation of operational requirements and mitigating the potential for information inconsistencies in creating and selecting the most optimal solution variants. Using the case study results to pinpoint technological gaps in the variant designs to channel their research and development efforts towards sub-systems or components that exhibit heightened competitiveness and wield substantial influence over the overall system's performance.

LLM-based Approach to Automatically Establish Traceability between Requirements and MBSE

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Abstract. Automatically establishing traceability between requirements and Model-Based Systems Engineering (MBSE) is crucial for ensuring safety standards in development. Our session introduces a tool that utilizes Large Language Models (LLMs) to establish links between requirements and MBSE semi-automatically. We present evaluation results comparing different approaches, assessing recall, precision, and F_2 score.

Key Reserve Paper#360

Logical Architecture Optimization via a Markov chain based Hierarchical Clustering Method

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Keywords. Architecture optimization;clustering algorithm;DSM;DAL

Topics. 16. Rail; 2. Aerospace; 2.4. System Architecture/Design Definition; 3. Automotive; 4.2. Life-Cycle Costing and/or Economic Evaluation; 8. Energy (renewable, nuclear, etc.);

Abstract. We propose a variant of an existing approach originally proposed for the multi-agent reformulation of a MILP with a sparse constraint matrix. The goal is to address the optimization of the logical architecture by treating the Design Structure Matrix as the constraint matrix of a MILP. The method manipulates the DSM to possibly find its hidden block-diagonal structure with single or double border which allows to obtain a modular architecture by minimizing the interfaces across modules.

MBSE Analysis and Update of the U.S. Infrastructure Data Taxonomy (IDT) Using the U.S. National Critical Functions (NCFs)

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Topics. 1.1. Complexity; 2.4. System Architecture/Design Definition; 4.7. System Security (cyber-attack, anti-tamper, etc.); 5. City Planning (smart cities, urban planning, etc.); 5.3. MBSE; Other domain;

Abstract. In this paper, we will demonstrate the application of Model-Based Systems Engineering (MBSE) tools and techniques we have used to assist the US Department of Homeland Security (DHS) /Cybersecurity Infrastructure Security Agency (CISA) in analysis of open-source IDT data to analyze and contribute to the update of their 2011 Infrastructure Data Taxonomy (IDT).

MBSE for Real World Teams

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Topics. 16. Rail; 2.3. Needs and Requirements Definition; 2.4. System Architecture/Design Definition; 3. Automotive; 3.4. Information Management Process; 5.3. MBSE;

Abstract. With the release of the OMG SysML in 2007, there was a surge of enthusiasm for model-based systems engineering (MBSE). Expectations were high. Cumbersome, fragmented documents would be completely replaced by coherent, fully integrated models. This utopian vision has largely failed to materialize. This paper will introduce some of the basic human factors issues that were overlooked. The paper will then discuss three concrete cases in which a struggling community adapted the MBSE approach.

Key Reserve Paper#359

Migrating To ARP4754A: Tailoring Of Architecture And Systems Requirements Definition Processes In The Rotorcraft Industry

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Keywords. ARP4754A;Requirements;Architecture;Tailoring;Rotorcrafts;Function Based Systems Engineering

Topics. 2. Aerospace; 2.3. Needs and Requirements Definition; 2.4. System Architecture/Design Definition; 3.5. Technical Leadership; 5.3. MBSE; 5.5. Processes;

Abstract. Rotorcrafts are very complex systems that require a huge systems engineering effort to design, implement and integrate. A successful aircraft design is a matter of good integration between engineering disciplines and suppliers just as much as it is about finding a good technical solution to the customers' expectations. This issue is well understood within the industry and competent authorities. Companies now face the challenge of transitioning from integrating complex systems to make an aircraft (as per ARP4754) to engineering and collating a complex aircraft system as per ARP4754A, a game changer in all respects. Leonardo Helicopters is tailoring its internal processes to reflect this change and challenge. While the ideal process can be defined today, the transition takes time and a significant change in culture and organization needs to take place. To support the transition, the authors have developed a hybrid rationale to the aircraft architecture and system requirements definition process. This new approach leverages existing expertise at system level to facilitate the integration between systems and the subsequent migration to bridge the gap with the aircraft engineering activities required by the ARP4754A.

Model-Based Cybertronics Systems Engineering (MBCSE)

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Keywords. MBSE;Cybertronics;MBCSE;Arcadia;Microelectronics;Embedded Software;System of Systems;Subsystem;SysML V2;SysMD;PMM

Topics. 2. Aerospace; 2.4. System Architecture/Design Definition; 3. Automotive; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 6. Defense;

Abstract. SysML v2, Model-Based Property Design, Cross-Perspective Property Projection, Arcadia/Capella

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Model-Based Switching Costs

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Keywords. Switching cost;MBSE;Model-Based Systems Engineering

Topics. 2. Aerospace; 3.7. Project Planning, Project Assessment, and/or Project Control; 4.2. Life-Cycle Costing and/or Economic Evaluation; 6. Defense;

Abstract. In product development, rarely a product is developed from scratch. In most cases, a product is developed from a prior design or several prior designs. The associated development cost is actually a switching cost (or some called reuse cost), representing the additional cost on developing the product from prior designs. Prior works in this area were developed without considering the MBSE (Model-Based Systems Engineering). Today, MBSE is being widely adopted. It is important to develop switching cost development methods that leverage models and support model-based development needs. This paper, for the first time per the best of our knowledge, discusses switching cost development method for MBSE. Our work identifies different use case scenarios/phases in an MBSE development cycle, and provides corresponding switching cost estimation methods, to support various certification needs, laying down the fundamental methodology for the model-based switching cost estimations. Using SysML language, an example use case of derivative airplane electrical power system is used to demonstrate the effectiveness of our methods.

Key Reserve Paper#534

Model-Based Systems Engineering Approach for Designing an Artificial Magnetic Field Generator System for Spacecraft Radiation Protection

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Keywords. Model Based Engineering;Artificial Magnetic Field;Spacecraft Radiation Protection;System Design

Topics. 2. Aerospace; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis;

Abstract. Systems Engineering PhD program at Colorado State University. Dissertation topic: System Engineering design for a spacecraft artificial magnetic field generator system for radiation protection.

Key Reserve Paper#565

Modeling Enterprise Software with UAF

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Keywords. Enterprise Architecture;Software;UAF;MBSE;Frameworks;SysML

Topics. 17. Sustainment (legacy systems, re-engineering, etc.); 2.2. Manufacturing Systems and Operational Aspects; 20. Industry 4.0 & Society 5.0; 5.3. MBSE; 5.7. Software-Intensive Systems; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. The functional requirements of modern systems are mostly software requirements. At the System of Systems (SoS)/Enterprise level, defining software/systems is done at a higher level of abstraction and requires different techniques. In the UAF, capabilities are defined for the enterprise, with systems and software allocated to realize the capabilities. This paper will examine the aspects of modeling software in the UAF, and how it can help guide enterprise and system and software architecture.

Key Reserve Paper#49

Models Models Everywhere! A practitioners view on the reality of modeling

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Keywords. Model Based Systems Engineering;Modeling;Simulation;Digital Engineering;Practice

Topics. 3.3. Decision Analysis and/or Decision Management; 3.5. Technical Leadership; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis;

Abstract. The focus of this paper is the significant gap between the current potential of today's models and modelling and the actual practice. Based on over 80 years of industrial experience, the authors describe problems that plague poor modelling. The paper: describes the different types of models and their uses; provides a high-level generic model development approach; and addresses some of the real-world challenges that modelers and their managers need to address.

Outcomes and Perspectives from the 4th ESA Model- Based Space Systems and Software Engineering Workshop (MBSE2023) on reducing the gap between model-based systems engineering and domain-specific approaches.

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Keywords. Model-Based Systems Engineering;Space Systems;System Architecture;Inter-domain Data Exchange;SysML v2;Artificial Intelligence;Digital Engineering;Model-Driven Engineering;World Café;Workshop;Facilitation;Creativity

Topics. 1.6. Systems Thinking; 2. Aerospace; 2.4. System Architecture/Design Definition; 5.3. MBSE;

Abstract. In the context of its initiative to promote the adoption of model-based approaches in the development of present and upcoming missions, our organization held this year a workshop on Model-Based Space Systems Engineering. The aim of this year's workshop was to investigate how the model-based systems engineering community could contribute to bridging the gap with do-main-specific model-based approaches used in subsystem design. The World Café Method was used to facilitate the group discussions, the outcomes of which are summarized and presented in this paper.

Requirement Discovery Using Embedded Knowledge Graph with ChatGPT

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Keywords. Large Language Models;OpenAI;ChatGPT;Urban Airspace Mobility;Requirements;Advance Air Mobility;Digital Assistant;Machine Learning;Artificial Intelligence;Graph Database;Link Prediction

Topics. 2. Aerospace; 2.3. Needs and Requirements Definition; 21. Urban Transportation Systems; 5.11. Artificial Intelligence, Machine Learning; 5.12. Automation; 9. Enterprise SE (organization, policies, knowledge, etc.); #AI

Abstract. This study explores two distinct approaches to leverage LLMs in the context of Urban Airspace Mobility Requirement discovery. The first approach evaluates the LLM's ability to provide responses without relying on additional outside systems. For the second approach, the LLM acts as an intermediary between the user and a graph database, translating user questions into cypher queries for the database and database responses into human-readable answers for the user.

Risk and Systems Analysis for Renewable Power Generation with Environmental and Other Stressors

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Abstract. This work evaluates and quantifies infrastructure system risk, defined as the influence of scenarios on system priorities. A scenario-based multi-criteria preferences model assesses system component priorities, and reevaluates those priorities for a set of climate and other related scenarios. The methods are demonstrated for the case of the nascent renewable energy sector of Iraq, identifying scenarios which most affect renewable power system priorities.

Risk Management in Project Planning for Life Science R&D: An Integration of the NTCP Framework

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Keywords. Risk Management;Project Planning;NTCP;Life Science

Topics. 3.7. Project Planning, Project Assessment, and/or Project Control; 3.9. Risk and Opportunity Management; 4. Biomed/Healthcare/Social Services;

Abstract. As with most other industries, the early life science R&D drug discovery sector is facing cost-pressure and increasingly higher demands to the products in terms of cost, quality, and time-to-market. Addi-tionally, the complexity of involved targets and systems, requirements for rapid, safe, and developable candidates are increasing. The drug discovery market, often regarded as rather conservative, relies more and more on advanced technologies. It is therefore a significant task for suppliers to create good solu-tions that meet customer requirements. The life science industry has a long tradition of using projects as the preferred method to manage these complex systems developments, such as the production of target proteins, screening of compounds, and follow up of hit compounds. When applying the project ap-proach, the level of uncertainty is usually high, and the risk of those uncertainties must be managed starting in the early planning phase. Thus, this paper focuses on the issue how to manage risks in the early project planning phase. We firstly review state of the art practices in risk management for complex systems project management, and identify an important framework, NTCP, and apply it to successful risk management for early life science projects. Through an in-depth case study in the life science in-dustry, we further demonstrate a systemic integration of the NTPC framework into project planning.

Security Interpretations and Elaborations on Systems Engineering Principles

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Abstract. Systems Engineering Vision 2035 includes 31 mentions of security, including security to become as foundational perspective to system design as performance and safety. The Systems Engineering Principles technical product published a "first set of systems principles" and this paper examines interpretations of these principles for security as captured in the vision with suggested modifications and possible additional principles to see security more integrated into the systems engineering process.

Key Reserve Paper#550

SoS - Global Solutions to Global Problems Using UAF

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Keywords. System of Systems(SoS);Unified Architecture Framework (UAF);Model-Based Systems Engineering (MBSE);Circular Economy;Global Environmental Sustainment;Socio-economic Sustainment

Topics. 10. Environmental Systems & Sustainability; 17. Sustainment (legacy systems, re-engineering, etc.); 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. This paper applies Unified Architecture Framework (UAF) to a case study which defines the global copper market as an enterprise comprising a diverse set of stakeholders and independently operating businesses and industries, with the goal to understand how they might evaluate, execute, or modify their behaviors in response to the diminishing global copper supply. Specifically, we sought to determine if the framework viewpoints, modeling language, and workflow guidance provided in the UAF specification could support the analysis. In a true System of Systems(SoS), the solution (or any improvement) relies on the cooperation of a multitude of independent and unrelated businesses and industries. Several viewpoints of UAF were evaluated to model the SoS, which reveal how certain entities may be motivated to implement solutions, and how those decisions may impact others within the SoS. We also provide observations from the analysis which may serve to improve the utility of UAF in other applications.

Systems Architecture Meta-Model for the MagicGrid Framework

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Keywords. MBSE;SysML;MagicGrid;meta-model;MBSE enablers

Topics. 2. Aerospace; 2.3. Needs and Requirements Definition; 2.4. System Architecture/Design Definition; 3. Automotive; 5.3. MBSE; 6. Defense;

Abstract. This paper studies SysML as the standard language to model systems, and MagicGrid as the framework to bridge the gap between Systems Engineering (SE) terminology described in the INCOSE Systems Engineering Handbook and SysML specification. It proposes a new systems engineering meta-model to describe a common SE terminology and bind it to the SysML concepts.

Systems Perspective Outcomes from Aerospace Failure Investigations

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Keywords. Complexity;Systems Thinking;Systems Perspectives;Aerospace;Collaboration;Failure Case Studies

Topics. 1.1. Complexity; 1.6. Systems Thinking; 2. Aerospace; 5.1. Agile Systems Engineering;

Abstract. Tools exist for managing complexity in large aerospace systems where unpredicted behaviors occur. Through studies of failure investigations, recommendations coalesce on using a systems perspective to increase communication and reduce risk. A consistent outcome of these investigations is the suggestion to include as many value-added perspectives as possible. Preventing failure is managed by improving collaboration within and among teams, which is an effective way to reveal systems perspectives.

Tactical Network Bandwidth Analysis: Application of the Wearables Model-Based Systems Engineering - System Architecture (MBSE-SA)

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Keywords. Model-based systems engineering (MBSE);network bandwidth analysis;wearable sensor systems

Topics. 1.6. Systems Thinking; 4. Biomed/Healthcare/Social Services; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 6. Defense;

Abstract. Warfighters often experience high rates of stress, resulting in the degradation of their health and performance. While Wearable systems can monitor warfighter data, they must integrate into existing tactical networks without compromising network function. We extended our existing Wearables Model-Based System Engineering – System Architecture (MBSE-SA) to include a bandwidth simulation to analyze the effects wearable systems have on overall network function specifically for military use cases.

The European Space Agency MBSE Methodology

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Keywords. MBSE;methodology;space

Topics. 2. Aerospace; 5.3. MBSE;

Abstract. The Organization (organization name removed for double-blind review process) has been developing an MBSE Methodology to address the increased digitalization of systems engineering and facilitate the complex system development in European space projects. The methodology is based on the European Cooperation for Space Standardization (ECSS) standards for Systems Engineering, and feedback from projects using the methodology. By using the ECSS standards as the starting point, the processes, terminology and expected outputs are familiar to the engineers, lowering the usage barrier within the Organization. This paper describes the background of and effort for establishing the MBSE methodology and a description of the methodology. The paper also reports on the current efforts at the Organization for deploying MBSE and the way forward regarding the methodology.

Key Reserve Paper#348

Towards UAF Implementation in SysML V2

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Keywords. MBSE;UAF;SysML;SysMLV2;Enterprise Systems Engineering

Topics. 5.3. MBSE; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. With the major update of SysML, all related standards need to be redesigned. The Unified Architecture Framework (UAF) is not an exception. Currently, the development of UAF based on SysML V2 is in the very early stages, and various organizations involved in its development are independently researching the way forward. This paper describes one of the research projects to test the feasibility of SysML V2 to address UAF community needs.

Key Reserve Paper#176

Translating the STPA-SEC security method into a model-based engineering approach

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Keywords. STPA-Sec;Systems engineering;Cybersecurity;Metamodel;Model-driven engineering

Topics. 22. Social/Sociotechnical and Economic Systems; 4.7. System Security (cyber-attack, anti-tamper, etc.); 5.4. Modeling/Simulation/Analysis; 6. Defense; Other domain;

Abstract. STPA-Sec is a systematic method that allows to analyze system designs and identify vulnerabilities in those designs from the onset and throughout the system lifecycle. We describe a carefully designed metamodel that accommodates the concepts and steps of the method. We translate key concepts from STPA-Sec into a metamodel, with the intention of facilitating a more structured and disciplined application of STPA-Sec. We demonstrate the advantage of using the metamodel in two case studies.

Truly Modular and Open System Design is Difficult

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Abstract. In the United States, major defense acquisition programs must implement a modular open systems approach (MOSA). Some have focused on MOSA as a checklist compliance activity. However, designing economically and operationally competitive modular platforms is difficult. This paper will review three concrete examples of such MOSA efforts. This paper will discuss common challenges, review the results of the three cases, and offer some simple recommendations for such programs.

Unlocking Synergy: Leveraging SysML and Modelica with Bi-Directional Transformation and Simulation Integration Standards

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Keywords. SysML;Modelica;Integration;Model Transformation;Modelica Command;Simulation

Topics. 2.4. System Architecture/Design Definition; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis;

Abstract. Both the SysML and Modelica standards are used in the field of Systems Engineering (SE) to model systems from different perspectives, on different abstraction levels. SysML is strong when modeling systems on the functional level; also, because it provides different views. With the capabilities of other simulation specifications, the engineers can simulate the system architecture. On the other hand, an open standard, such as Modelica is a key enabler for representing multi-physical systems described by differential, algebraic, and discrete equations. With the symbolic manipulation, the dynamics of the systems are represented in state space form and solved by the numerical integration methods fixed or variable step. However, it is clear that the connection between systems engineering and system simulation, with their respective domain knowledge of the actual equipment in their system, is missing. By seeing these complementary values, the authors demonstrate both languages' interaction to integrate SysML and Modelica to achieve complimentary values through bi-directional transformation and simulation.

Panels

Panel#397

Building Cultural Intelligence: The Role of Organizational Culture in Nurturing Leaders in Systems Engineering

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Keywords. Nurturing Leaders;Cultural Intelligence;Systems Engineering Leadership;DEI

Topics. 3.5. Technical Leadership; 5.10. Diversity (cultural boundaries, diverse engineering teams, training underserved groups, etc.); 9. Enterprise SE (organization, policies, knowledge, etc.); #TechnicalLeadership

Abstract. In the dynamic field of systems engineering, fostering an inclusive and supportive organizational culture is critical for unlocking the full potential of systems engineers' role. This panel discussion will delve into the intricate relationship between organizational culture and the success of leaders in systems engineering. The panel will explore the challenges faced in technical leadership roles, examine the impact of organizational culture on their professional journeys, and provide actionable strategies for creating a more supportive and inclusive workplace environment. The key discussion points would include understanding the current landscape, the crucial role of organizational culture, success stories of fostered inclusive cultures in systems engineering and insights into how evolving technologies and industry dynamics may shape the future of inclusivity.

Biography

Stueti Gupta (BlueKei Solutions Pvt Ltd) - stueti.gupta@gmail.com

Stueti Gupta is the co-founder and director at BlueKei Solutions, and provides consultancy and customized training services for Enterprises and Startups looking for integrated digital engineering solutioning to solve engineering problems, embrace emerging technologies and achieve operational excellence. Over her 15+ years' experience in industry and academia she has led SE research projects and co-led SE competency development, largely around MBSE and system dynamics modeling. Stueti has a Mechanical Engineering degree from BITS Pilani, India, a second masters from Cornell University, USA. and a certificate in Systems Design and Management from MIT, USA. She is actively involved in INCOSE.

Position Paper

Stueti Gupta is honored to serve as the moderator for this insightful panel on Building Cultural Intelligence within the realm of Systems Engineering Leadership. In today's interconnected and diverse global landscape, the significance of cultural intelligence cannot be overstated. As we explore the vital role of organizational culture in shaping leaders in systems engineering, my aim is to facilitate a dynamic and enriching discussion that delves into the intersection of cultural intelligence and effective Systems Engineering leadership. Even Department of Defence emphasizes Transform the culture and workforce to adopt and support digital

engineering across the lifecycle as one of its five strategic goals for digital engineering.

We will address points such as:
The symbiotic relationship between organizational culture and effective leadership in systems engineering.
What strategies can leaders employ to foster cultural intelligence among their teams?
How can organizations create a culture that embraces diversity and inclusion in systems engineering?
The role of communication and collaboration in fostering a culturally intelligent systems engineering environment.

Alice Squires (International Council on Systems Engineering) - alice.squires@incose.net

Dr. Alice Squires has served as author, editor, manager, Professor, and systems engineer with 40 years of combined experience in industry and academia. She has served as keynote speaker, delivered workshops, and participated in peer-reviewed panels and paper presentations for the past two decades. She is Founder of the INCOSE Empowering Women Leaders in Systems Engineering (EWLSE) and is an INCOSE Expert Systems Engineering Practitioner with Acquisition (ESEP-ACQ). She wrote an ebook for IEEE-USA that describes her engineering journey: Dandelion Wishes: A World Where We Collaborate as Equals (Book 21) (2018). She is co-editor and co-author of the 2019 INCOSE Insight Diversity in Systems Engineering themed edition, the 2022 INCOSE published Letters To My Younger Self: How Systems Engineering Changed My Life ebook and the 2022 Springer Emerging Trends in Systems Engineering Leadership: Practical Research from Women Leaders book written by 26 women from around the world.

Position Paper

An organization's culture often starts at the top. To understand how the organizational culture nurtures members to become organizational leaders, one first must understand how the culture prevents members from becoming leaders. That is, what is it about the organization's culture that creates obstacles and challenges for a member to achieve their full potential? And for whom? Several years ago, I was running a workshop on enablers and inhibitors for leadership in one's organization, and as the group discussions started, I heard one young woman share with her group: "They are all inhibitors." Organizations interested in establishing cultures that allow a diverse set of members to progress into leadership positions, need to take a hard look at the impact of the established culture. Is mentoring encouraged, supported, and rewarded? Do the team's norms include communication equity and psychological safety? To what extent does the culture promote hiring members that represent diverse demographics? How does the organization's promotion process ensure an unbiased performance appraisal? In what ways does leadership require open and transparent communications? And finally, how do the organization's policies enable the creation of an inclusive and diverse leadership culture?

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Anabel Fraga is a Systems Engineer & Computer Science professional. She obtained her Master's Degree in E-Commerce and Networks and her Diploma in Advanced Studies at Carlos III University in Madrid (UC3M). She researches at the Knowledge Reuse Group. She is an Associate Tenured Professor at UC3M, the Treasurer, and President of the Spanish Association of Systems Engineering (AEIS). She is EWLSE and DEI EMEA representative, EMEA Events representative, and Cohort 6 inducted member of the INCOSE Technical Leadership Institute. She coordinates the financial management activities of the Knowledge Reuse research group. Certified in ITIL, ININ, ISO20000, and ISO15288. She has several publications in knowledge management, systems engineering, requirements engineering, software engineering, and ethics; two patents in exploitation; and she led several projects, including two EU research projects. She was the recipient of the SWE Distinguished Educator Engineering Award 2023.

Position Paper

As I stated in a publication related to this topic, keeping in mind that a leader shall grow and provide the team with an environment appropriate to develop their best, guidance, influence, inspiration, and mentoring when needed. It is stated that theory and practical sides of engineering ethics are necessary for the proper education of engineers as knowledge of differential questions, diversity, or any other technical matter. Said that inspiring diversity is required for a leader and, as a consequence, for the leadership practice.

Diversity directly relates to ethics, leadership, and how diversity improves the organization's behavior. Three indicators of inclusion in organizations are equality, belonging, and openness. Diversity aids organizations in

connecting with customers and leading new opportunities in the interrelated world.

Javier Calvo-Amodio (Oregon State University) - Javier.Calvo@oregonstate.edu

Javier Calvo-Amodio is an associate professor of Industrial and Manufacturing Engineering at Oregon State University, where he directs the Change and Reliable Systems Engineering and Management Research Group (CaRSEM). His research focus is on developing a fundamental understanding of how to integrate systems science into industrial and systems engineering research and practice to enable better engineering of organizations. At INCOSE, he serves as the chair of the Systems Science Working Group, is a member of the Bridge Team, and is the Technical Program Director for IS24. He is also a Fellow of the American Society for Engineering Management and serves as Deputy Editor of Systems Research and Behavioral Science Journal.

Position Paper

Organizations are complex systems that arise from the arrangement of various components, such as people, information, technology, and more. They not only consist of these individual constituents but also encompass how these components interact with each other. As a result, organizations can be defined as purposeful human activity systems. Organizations are a special kind of system as they are aware of their purpose and pursue it intentionally. But for organizations to be successful at pursuing their purpose they must possess 1) persistent structures -how all its individual constituents are arranged, 2) persistent processes -how flows of causal powers are managed. From the interaction between structures and processes, meanings emerge, creating a set of foundational ideas, feelings, and beliefs that form the basis for an organizational culture. The interaction between structures, processes, and meanings guides behaviors that shape what the organization can do. From a systems science perspective, culture emerges from the interactions of an organization's persistent structures, processes, meanings, and behaviors, thus making it possible to design each of these elements to influence organizational culture.

Building the digital bridge between MBSE and Engineering Simulation

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Topics. #MBSE-DE;

Abstract. This session will be a discussion on trends and next steps for collaboration across Systems Engineering & Engineering Simulation. Specific information will include The Role and Challenges of Systems Modeling and Simulation (Trends in Engineering Simulation and implications for Systems Engineering), the importance and status of relevant standards supporting Systems Modelling & Simulation, and Challenges and trends for connecting System Architecture modeling and Behaviioral Simulation. Attendees should expect to learn where to start when integrating simulation s and Systems models.

Biography

Phyllis Marbach (SMSWG - INCOSE) - prmarbach@gmail.com

Phyllis Marbach retired from Boeing Defense Space and Security (BDS) with over 40 years of experience in aerospace programs such as satellites, chemical lasers, the International Space Station, and various propulsion systems. Phyllis was a Boeing Designated Expert in agile software development, software engineering and systems engineering. Phyllis is currently a member of the INCOSE Technical Operations Leadership Team as the Associate Director of the Transformational Enablers Working Groups where she works closely with several working groups on Model Based Systems Engineering.

Ian Symington (NAFEMS) - ian.symington@nafems.org

Ian Symington holds a 1st Class Masters Degree in Engineering (MEng) from the University of Durham and is a chartered engineer (CEng) registered with the Institute of Mechanical Engineering (IMechE).

Ian has spent the last thirteen years of his career working in the field of engineering analysis and simulation. During his career Ian has had the opportunity to work for companies involved in the creation and support of engineering simulation tools, as well as for companies using engineering tools on a daily basis to design and validate engineering products, including a 5 year period working in the UK Nuclear industry where competency management was a key issue.

In his current role, Ian helps to guide the direction of NAFEMS technical activities. This involves working closely with fourteen different technical working groups and the Professional Simulation Engineer Board which provides the strategic direction for the PSE Scheme.

Position Paper

Broad understanding about engineering modeling and simulation across multiple domains.

Bernardo Delicado (INCOSE) - bernardo.delicado@gmail.com

Bernardo A. Delicado has been a professional systems engineer for 32 years in the aerospace and defense sector. For the first eight years he was employed by INTA, the aerospace research institute of the Spanish government working on a great number of European research projects. Following that time, he spent twelve years with Airbus Defense and Space assuming a wide range of systems engineering roles with transnational responsibilities within military aircraft programs developed among the UK, France, Germany, Italy and Spain. In 2011, Bernardo moved to MBDA Missile Systems (Airbus Group), assuming the role of Engineering Director to Spain, conducting a large part of his responsibilities embedded in multinational Systems Engineering teams in France and the UK. In March 2020 he joined Indra Sistemas as Engineering Director as part of the Future Combat Air System (FCAS) Program, a tri-national program between France, Germany and Spain. Since January 2023 he has been an internal advisor in Systems Engineering to Indra engineering projects.

He is an Expert Systems Engineering Professional (ESEP) and has a PhD in Interdisciplinary Engineering, M.S in Physics and a B.S in Aerospace Engineering. He is the INCOSE Outreach Director and a member of the BoD of INCOSE Central. He is active on the: Systems Engineering Body of Knowledge (SEBoK), INCOSE SE Handbook 5th Edition, ISO/IEC/IEEE 15288 standards and the Certification Advisory Group (CAG).

Position Paper

There is a real need for the ability to interface between Systems Models and simulations. How can we better serve systems engineers in accomplishing this?

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Hans Peter de Koning is an independent consultant specializing in the advancement of digital engineering standards, methods and tools. He graduated with an M.Sc. in Applied Physics from Delft University of Technology in 1984, after which he worked almost 40 years as an expert thermal, software and systems engineer. He worked mainly on space systems, first in industry and then more than 20 years at the European Space Agency (ESA). Up to retirement from ESA by the end of 2019, he led the development and application of MBSE methods, tools and standards for ESA's Concurrent Design Facility and space projects in general. He's been a main author or contributor on many ISO, ECSS and OMG engineering standards. Currently, he is a core member of the SysML version 2 team at OMG. He is also a member of the NAFEMS-INCOSE Systems Modeling and Simulation WG, where he leads the Standards Focus Team.

Position Paper

There are a number of interface standards for integrating systems models and simulations. Where does a person just getting started begin?

Alexander Busch (SMSWG, Ansys) - alexander.busch@alumni.ntnu.no

Alexander Busch, Ph.D., CSEP is a Senior Application Engineer at Ansys. Alexander works on Model-Based Engineering incl. both System Simulation and Model-Based Systems Engineering (MBSE). He has 20+ years of experience in engineering of various sorts and in various fields ranging from diving to refrigeration. He actively participates in the NAFEMS INCOSE Systems Modeling and Simulation Working Group where he leads the Focus Team "Refine the understanding of Systems Modeling and Simulation". He was part of the German translation team of the Systems Engineering Handbook v5 and lectures undergraduate fluid mechanics.

Position Paper

What are the challenges and trends for connecting System Architecture modeling and Behavioral Simulation?

Empowering real world complex problem solving: Socio-technical Applications of Model-Based Systems Thinking (MBST)

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Kirk Reinholtz (Colorado State University) - Kirk.Reinholtz@colostate.edu

Keywords. Model-Based Systems Thinking (MBST);System Dynamics;Systems Thinking Principles;Patterns of Behavior;Causal Loop Diagrams;Stocks and Flows;Modeling and Simulation;Model-Based Systems Engineering (MBSE);Systems Science

Topics. 1. Academia (curricula, course life cycle, etc.); 1.4. Systems Dynamics; 1.6. Systems Thinking; 2. Aerospace; 22. Social/Sociotechnical and Economic Systems; 5.4. Modeling/Simulation/Analysis

Abstract. Would you like to improve your odds of success when approaching complex problems? -- Model-Based Systems Thinking (MBST) offers a rigorous framework, tool and language. Yet adoption of these has been minimal in mature industries. We discuss suitable methods for MBST, real-world applications of MBST and why it has not penetrated the mature industry.

Biography

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Golam M. Bokhtier. A Systems Engineer by profession, Golam M. Bokhtier has been affiliated with several renowned aerospace companies since 2004 including Collins Aerospace/Raytheon, L3-Harris, Woodward, Northrop Grumman and several Aerospace Start-ups. He has occupied numerous management and engineering leadership roles in the aerospace and defense sectors. He earned his BS in Electrical & Computer Engineering and Mathematics from Rutgers-New Brunswick in 2004, obtained his Master's in Electrical Engineering from Iowa State University in 2009, and is presently pursuing a PhD in Systems Engineering at CSU, Fort Collins, CO. His current research interests encompass eVTOL, UAVs, and wildfire detection. He has expertise in the systems engineering domain, specifically for communication and navigation systems, RF systems, and flight control systems for aerospace platforms

Position Paper

The Framework of Model-Based Systems Thinking (MBST) integrates the utilization of mental models, a cornerstone of Systems Thinking, exemplified by the iceberg model. This integration facilitates the identification of patterns of behaviors. From these discerned patterns, it is possible to construct causal loop diagrams, which serve as a foundational step towards developing comprehensive stocks and flows dynamics models. Subsequently, these stocks and flows models form the basis for System Dynamics modeling and simulation. This sequential progression from mental models to dynamic simulations embodies the essence of MBST framework. The elements in the MBST framework aid in identifying leverage points within complex systems.

Model-Based Systems Thinking (MBST) proves highly effective in the conceptual systemic design and development of aircraft or Unmanned Aerial Vehicles (UAVs), especially for specific purposes like wildfire detection and communication. This approach begins with analyzing flight control strategies, deployment, and trajectory control using tools like Vensim, before progressing to detailed airframe design. Employing Systems

Thinking within a model-based environment can lead to significant time savings during the development process. For example, by identifying flight controls and deployment strategies as leverage points in the design process of a wildfire UAV, we can make critical design decisions supported by Systems Thinking. This leads to more targeted designs, utilizing tools such as ANSYS, Cameo/MBSE, and Monte Carlo. Utilizing this framework ensures the integration of Systems Thinking in our wildfire UAV design process.

The concepts of Systems Dynamics and MBST, while closely related and frequently used interchangeably, are not identical. The term "Model-Based Systems Thinking" (MBST) was coined and extensively discussed by Dr. Kamran Shahroudi in the 2015s. System Dynamics, potentially a subset of MBST, was originally developed by Dr. Jay W. Forrester in the 1950s. MBST integrates various model types, including systems dynamics models, combining Systems Thinking principles with System Dynamics and model-based approaches. Both MBST and System Dynamics emphasize the importance of feedback loops. MBST is acutely aware of the mental model and leverage points within a complex system. In contrast, System Dynamics does not explicitly identify the mental model.

Integration of Systems Thinking and Model-Base Systems Engineering (MBSE) is still a challenge that has not been fully discovered but it is an opportunity for the MBST and make MBSE approaches to be more Systemic instead of it being a linear approach only. MBSE automatically does not guarantee Systems Thinking but MBST increases the odds if MBSE and MBST integrated together. Furthermore, MBST plays a crucial role in addressing systemic gaps that have been identified in the development of Model-Based Systems Engineering (MBSE), Systems Dynamics, and Systems Thinking. This enhanced Model-Based Systems Thinking (MBST) approach facilitates a more comprehensive and nuanced understanding and analysis of complex systems.

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Kamran Eftekhari Shahroudi. Kamran is a Systems Fellow at the Corporate Technology Office of Woodward, Inc. working on Aerospace, Energy and Power Actuation Systems in technical lead and managerial roles since 1997.

Kamran is a Professor of Systems Engineering and a founding member of the CSU-SE program teaching and researching application of Systems Thinking and System Dynamics to Socio-Technical problems since 2009.

Position Paper

Systems Thinking (science, principles, applications) has so many facets, perspectives and dimension that we cannot claim that Systems Dynamics is the end-all rigorous method for it.

However, System Dynamics is probably the most useful rigorous framework, language and tool for MBST at this time.

A short demo of using SD to understand the impact of schedule priority versus cost priority resource decision on the complex dynamic behaviour of agile projects shows insights that years of professional practice does not!

Other rigorous methods that have great potential to boost MBST are DSMs, Data Science/Machine Learning and MBSE. However realizing this potential does not automatically come with buying and using these tools separately without a parallel integrated focus on systems science, systems principles and systems thinking.

SD has not penetrated because of many practical hurdles in the path of creating a validated model. Another speaker in this panel Kirk Reinholtz will discuss how these practical hurdles shall be overcome providing a glimpse of future SD capability that is beyond current tools.

Sarwat Chappell (Department of Defense (DoD) and Colorado State University) - Sarwat.chappell@colostate.edu

Sarwat Chappell is a PhD student in Systems Engineering at Colorado State University. Thesis work "A Systems Thinking Approach to Eliminating the DOD Science and Technology Valley of Death".

Sarwat Chappell works for the Department of Navy at the Office of Naval Research where she leads the research and development of novel technologies for the Navy. Sarwat started her career at ONR in 2008 as Program Officer for Directed Energy. She directs critical investments for Science and Technology (S&T) efforts leading to research development for Directed Energy (DE) Weapon Systems for the Navy. Sarwat was the Deputy Program Manager and the Lead Program Manager for the Free Electron Laser Innovative Naval Prototype (INP) program. Prior to joining ONR, Sarwat was Chief Scientist for Naval Gunnery at Program Executive Office Integrated Warfare Systems (PEO IWS) and the PEO IWS Advanced Technology Director for all Surface Ship Weapons. Ms. Chappell was responsible for the Surface Ship Technology Master Plan. Sarwat has published and presented on a variety of topics ranging from guidance and navigation to power and thermal management and directed energy and has received numerous awards for science and technology excellence throughout her career. Sarwat has extensive experience leading international collaborative research programs with complex, technical objectives. Sarwat has a B.S. and M.S. in Electrical Engineering from Tennessee Technological University in Cookeville, TN.

Position Paper

Systems Thinking is a framework to solve complex problems in a holistic manner. Model Based Systems Thinking is a model-based framework for Systems Thinking to solve complex problems using the seven Shahroudi Systems Thinking Principles using models that can be communicated across a wide breadth of disciplines.

Model Based Systems Thinking can be used to solve problems ranging from prediction of weather patterns, species extinction, marathon race performance, traffic flow problems, escaping the technology transition valley of death to optimizing the operation of an innovation ecosystem.

Model Based Systems Thinking uses Systems Dynamics(SD) for probabilistic inferences of future behaviors based on historical patterns and data. SD modeling is a complex problem-solving framework used to solve dynamical problems that are governed by nonlinear feedback behaviors.

Systems Thinking is an enabler of Systems Engineering and Model-based systems engineering (MBSE). Some notable differences between MBSE and MBST is that Model Based Systems Thinking uses a holistic approach and is well suited to dealing with systems evolution whereas Model Based Systems Engineering is used to build models of complex systems from requirements to specific performance specifications.

Difference between Model Based Systems Thinking(MBST) and Systems Engineering(SE) is that SE follows a document centric, linear approach to solving problems whereas MBST is suited for interconnected, diverse elements which exhibit nonlinear, emergent behaviors as a complex system.

Model Based Systems Thinking is a mental model framework that governs MBSE, SD, SE, and ST. This framework can be thought of as an underlying methodology that connects different systems engineering disciplines to solve complex, dynamical problems.

Model Based Systems Thinking is agnostic to profession or discipline because it can be applied to any phenomena and disciplines such as social, biological, economic, political, and technical.

The adoption of System Dynamics or Model Based Systems Thinking is so low in mature industries because its only taught in technical disciplines or using technical jargon which non-technical students cannot relate to. To promote adoption of Model Based Systems Thinking, teachers must use examples related to the student's field of study along with non-technical terminology which will increase their understanding of the subject matter.

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Quentin Saulter is a PhD student in Systems Engineering at Colorado State University. Thesis work is "A Dynamical Approach to Understanding the DoD Innovation Ecosystem.

Quentin Saulter works for the Department of Navy at the Office of Naval Research he is directing critical investments for research, development, test, and evaluation for the Navy. Mr. Saulter specializes in fostering

innovative technologies for Navy stakeholders. Mr. Saulter is coordinating several research, development, and testing programs.

In 2006 Mr. Saulter was selected for the position of the Chief Engineer for the Air Force Research Laboratory for Directed Energy (AFRL/DE) in Albuquerque, New Mexico. Quentin also managed AFRL/DET, Directed Energy Technology division consisting of 3 departments with 30 direct reports.

Mr. Saulter served as operational crew chief at the Continuous Electron Beam Accelerator Facility (CEBAF) now called Thomas Jefferson National Accelerator Facility (TJNAF) or JLAB. Mr. Saulter also performed research cutting edge new accelerator physics topics while at Jefferson Laboratory.

Quentin E. Saulter was the first African American recipient of the Patricia Roberts Harris Fellowship Award and the first African American to graduate from Appalachian State University, Boone, NC with a master's degree in Applied Physics. At the university, Quentin focused on thin film electron beam evaporation, high vacuum technologies, cryogenics, plasmonic oscillation theory, laser physics, and electro-optics.

Position Paper

Model Based Systems Thinking is the use of models to gain understanding and behavioural prediction of complex systems in science, engineering, political, economics, and any complex phenomena that is difficult to understand or explain. Model Based Systems Thinking encourages a holistic view of complex phenomenon instead of focusing solely on individual components. Model Based Systems Thinking considers how elements within a system interact and influence each other. This holistic understanding helps to uncover hidden connections and dynamics. Model Based Systems Thinking is a conceptual framework that could be used to encompass and bring together the separate disciplines of Systems Dynamics, System Thinking, Model Based System Engineering, and System Engineering in general. The conceptual framework of Model Based Systems Thinking can be used as a holistic framework that can be applied to science, business, academic, or social disciplines. The increasing complexity of many of today's systems make using Model Based Systems thinking necessary to explain systems operations, systems evolution, and possible systems behaviours. The explosion of the availability of mass quantities of data is an enabler to using Model Based Systems Thinking by analysing patterns and causal relationships to understand and predict complex systems structures and behaviours. Model Based Systems Thinking gives a framework of how to correlate data into information to be used by dynamical models to gain probabilistic inference of future events. Model Based Systems Thinking provides a logical and structured framework for understanding complex systems feedback. Model Based Systems Thinking can help in identifying, incorporating, and modelling variables with linear and non-linear relationships too help contribute to a clearer understanding of the underlying systemic mechanisms. Most complex systems often involve feedback loops, where the output of a process feeds back into the system. This influences subsequent behaviour. Recognizing, understanding, and modelling feedback loops is essential for predicting system behaviour over time. With this knowledge, Model Based Systems Thinking can facilitate the formulation and testing of hypotheses. By adjusting model parameters and examining their impact on predictions, one can explore various scenarios and assess the validity of different assumptions. Model Based Systems Thinking may also be used to predict and prevent complex problems by understanding the root causes and systemic structures. Model Based Systems Thinking could allow for interventions that address underlying systemic issues before they become detrimental to an organization, technology, or process. Model Based Systems Thinking has the advantage of serving as a visual or conceptual representation that can be easily shared amongst a diverse group of individuals. Model Based Systems Thinking can help distil complex information into manageable and understandable forms by simplifying and abstracting key elements and variables that make it easier for diverse groups of individuals to grasp essential features of systems or concepts.

Kirk Reinholtz (Colorado State University) - Kirk.Reinholtz@colostate.edu

Kirk Reinholtz was a Principal Engineer at the California Institute of Technology/Jet Propulsion Laboratory. He left that position in early 2023 to focus full-time on aligning with 21st-century advancements by pursuing a PhD in Systems Engineering at Colorado State University. He holds an MSCS from the University of Southern California

Position Paper

Systems Thinking is an essential concept: structures lead to behaviors, and actions have consequences, which in turn have their own repercussions. Everything is interconnected. However, the very need for

Systems Thinking highlights a critical point: if it were easy and intuitive, we wouldn't be writing books about it or discussing it in panels like this one. The crux of the matter is that complexity, when truly complex, is irreducible. It's not merely a matter of perspective; some behaviors are unpredictable regardless of how we view them. Fortunately, we can glean insights through simulations, approximations, heuristics, regressions, and various other technical methods. This leads to my stance: the efficacy of Systems Thinking would be significantly bolstered if it were taught and implemented alongside key technical tools and practices. The 21st century is ushering us into a realm of tighter constraints, with previously externalized factors re-entering our System-of-Interest (SOIs). Let's learn and teach Model-Based Systems Thinking (MBST) as a core practice of Systems Engineering to better understand and optimize the outcomes of our engineering decisions.

Panel#129

Participatory Methods in SE

Jennnifer Russell (Garver) - JLRussell@GarverUSA.com
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Keywords. Stakeholder engagement;Problem resolution;Collaboration techniques

Topics. 2.1. Business or Mission Analysis; 2.3. Needs and Requirements Definition; 22. Social/Sociotechnical and Economic Systems; 3.5. Technical Leadership; 5.10. Diversity (cultural boundaries, diverse engineering teams, training underserved groups, etc.); 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Based on the success of last year's INCOSE Invited Content, this panel extends the discussion started last year. Stakeholder engagement methods, effectiveness, and lessons learned related to a project or initiative can vary widely. This panel will share and practice stakeholder engagement tools and review their effectiveness. Attendees will leave with a practical technique for engagement and a new way to think about stakeholder engagement for systems engineering.

Biography

Jennnifer Russell (Garver) - JLRussell@GarverUSA.com

Jennifer Russell, EISE, CSEP is the Program and Management Support Leader on Garver's Water team. Over the past 25 years, she honed her West Point leadership motto of being a "Leader of Character." From strategic planning to tactical logistics, Jennifer has invested in public service and infrastructure. Currently, Jennifer is the Chair of the INCOSE Smart Cities Initiative, and has been the Outreach Director for the Transportation Working Group. At the International Symposia, Jennifer has presented several papers, on a panel, and lead several Roundtables. Jennifer holds a B.S. in Engineering Psychology from the United States Military Academy and an M.S. (2003) and Engineer Degree (2007) in Industrial and Systems Engineering from the University of Southern California.

Position Paper

As moderator for the INCOSE Invited Content Panel last year, this session is a unique opportunity for knowledge and experience sharing for a common, yet un-discussed role of systems engineers. This panel will expand the efforts from IS2023, which would allow renewal of vibrant discussions that happened during the panel session. As moderator, I'd be able leverage the themes of last year and enhance with the panelists' perspectives. I know each of the panelists and will be able to ask questions that are likely to engage the

audience and motivate participation.

As moderator and experienced infrastructure domain practicing systems engineer, stakeholder engagement and participation in planning and design is a critical part of my job. These panelists have been brought together for their depth and breadth of experience. As moderator, I will engage with the panelists, support them to draw out their root messages, and surveille the audience for ideas that spur interest.

Dale Brown (Hatch) - dale.brown@hatch.com

Dale Brown is a licensed professional engineer with 40+ years of experience and multiple design patents. Dale is co-chair of the INCOSE Transportation Working Group and Configuration Management Working Group. Dale is also the relationship manager for the APTA/INCOSE cooperative agreement and is the technical lead / project manager for the proposed APTA Systems Lifecycle Engineering Standard currently under development. Dale is the current Chair of the APTA Systems Lifecycle Engineering (SLE) Subcommittee.

Position Paper

Theme: Perspective on civil infrastructure – how can systems engineers engage stakeholders who have performed their functions for decades and "know their trade" very well? Why are we not effectively convincing these stakeholders to deploy some level of SE?

Position: Within industry segments where Systems Engineering is emerging there is a high level of psychological and practical inertia that resists brute force methods to include Systems Engineering – the result being zero to poor Systems Engineering deployment and repeated large project failure which has become an accepted "norm" in our society.

Audience engagement will begin with a set of questions: Do you face this problem? What techniques do you use to engage your stakeholders?

Discussion Questions or Poll:

How did you approach change based on your audience?

Have you ever participated in formal approaches to Stakeholder engagement?

What were your lessons learned? (What worked, what didn't?)

After audience engagement panelist will discuss the technique of having team members create stakeholder impact statements to practice building empathy for stakeholder positions. The engagement technique could follow a FMEA process.

Peace, Love, and Digital Understanding: How system models will bring us all together

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Risa Gorospe (The Johns Hopkins University Applied Physics Laboratory) - Risa.Gorospe@jhuapl.edu
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Keywords. Digital Transformation;Digital Engineering;Standards;Interoperability;Model-based;Tooling ecosystem;Collaboration;Culture

Topics. 2. Aerospace; 5.10. Diversity (cultural boundaries, diverse engineering teams, training underserved groups, etc.); 5.3. MBSE; 5.5. Processes; 6. Defense; #MBSE-DE;

Abstract. Aerospace and defense organizations are on the brink of a transformative era, where the rapid evolution of technology demands a shift in their approach to developing complex systems. There's consensus that models are fundamental to digital transformation, but wide variability in the implementation of model-based strategies presents a formidable challenge in defining and attaining this vision. The central role of system models requires that they be easily accessible and transferrable across the system development lifecycle. Embracing this imperative, our expert panel seeks to unravel the complexities of the Digital Engineering (DE) ecosystem to help us reach digital unity.Join us for an in-depth exploration of:• Challenges and Transformation: Discover the hurdles faced by AeroDef organizations as they strive to make system models central to their processes and collaboration. From overcoming organizational frictions in multi-group collaboration to redefining work methodologies, we'll delve into the transformative journey ahead.• Interconnected Teams and Models: Learn how the industry is moving from isolated to interconnected teams and models, driving the rise of methodologies like standards to ensure consensus and interoperability. Understand the evolving nature of collaboration and the tools, infrastructure, and resources needed to support this shift.Meet Our Diverse Panel: Our panel comprises leaders in various roles, each addressing multiple facets of this paradigm. Gain valuable insights into the challenges and opportunities inherent in the pursuit of a unified and efficient Digital Engineering ecosystem.

Biography

Kirsten McCane (MathWorks) - kmccane@mathworks.com

Kirsten McCane is an Industry Manager at MathWorks in Washington D.C. He works with defense industry customers on strategies and solutions to accelerate the realization of their digital transformation objectives such as digital engineering, DevOps, and MOSA.

Kirsten graduated from the University of Pittsburgh with a B.S. in Computer Engineering in 2007 and M.S. in Electrical Engineering in 2009. He joined Northrop Grumman Mission Systems upon graduation where he worked for 12 years on solutions for Multi-function Sensor Systems. While at Northrop Grumman, he received his MBA from the University of Maryland in 2017.

Position Paper

Digital transformation can deliver greater efficiencies, reduce costs, and drive competitiveness. However, implementation of the advanced workflows, tools, and processes to make digital transformation a reality varies widely within the industry. The push toward digital transformation has gained momentum recently, and aerospace organizations are aligning around a common vision for the goals of digital transformation and

digital engineering. Three fundamental objectives are emerging – investment in enterprise digital engineering environments, workflow streamlining, and workforce reskilling.

First, investment in enterprise digital engineering environments requires incorporating technologies like modeling, cloud computing, and artificial intelligence. This means creating accessible platforms that better equip engineering workforces and improve overall business practices.

Second, streamlining workflows is possible by introducing tools and processes that alleviate administrative burdens, foster collaboration among engineering groups, and enhance overall workflow efficiency.

Third, reskilling the workforce is necessary for success and includes training employees on aspects like communication techniques for digital models replacing conventional presentations. Reskilling initiatives also helps to ensure more decisions are made based on data, incorporating new data insights as support for existing subject matter expertise.

Despite this common vision, we see aerospace and defense organizations facing significant adoption challenges around the integration of new digital tools and processes, business challenges, significant cultural resistance, and how to achieve the required workforce skilling.

Today, at the root of many of these challenges is how organizations are leveraging, utilizing, and integrating system models to achieve the promise of a wider model-based approach. Most organizations have invested in creating system models with the hope of them becoming the central artifact that can drive the rest of the development process. However, we see these organizations being frustrated by an inability to move the modeling data across the lifecycle, misalignments around model specification, fidelity, purpose, as well as business impediments to how to share across organizations in a consistent and useful way. To overcome this, there is promise in popular industry approaches that enable a data centric approaches like standards and ontologies as well as new contracting frameworks that help enable collaboration and protection of intellectual property. My hope is that information exchanges that highlight the lessons learned from growing pains towards this vision, combined with these new approaches will help us go from promoting the promise to standardizing the practice.

Becky Petteys (MathWorks) - bpetteys@mathworks.com

Becky Petteys is the Systems Engineering Segment Manager at MathWorks. She joined MathWorks in 2005 as an application engineer, and then began leading a team of engineers working closely with aerospace and defense companies doing systems engineering and certification workflows. She moved over to become the primary technical point of contact for System Composer, MathWorks' MBSE platform, and helped to build the team that supports systems engineering today. She received a B.S. in physics and an M.S. in mechanical engineering from Michigan Technological University.

Position Paper
As a tool vendor, we are in the lucky position to be able to talk with systems engineers in organizations that span industry, application, region, and size. This enables us to identify trends that are common across the broad spectrum of systems engineering.
One of these common trends is systems engineers demanding more from their models. The transition to MBSE has helped systems engineering to become more formal and systematic, but building models is time-consuming, and organizations are trying to find ways to extract more value from those system models, e.g. through simulation, analysis, connections to design models, and flexible visualization.
Closely related to this trend is the requirement that, as system models start to more fully represent the system itself, that repetitive activities like analysis and requirements validation be able to be automated. Design and software models must often be incorporated in CI/CD pipelines, and that requirement is creeping up into the system models as well, as a way to rapidly deal with change management.
Finally, data access and ecosystem interoperability has become a main driver for the interest in SysML v2. The promise of easy access at the element level to large model repositories and a standard that would define how to access that data has given systems engineers a vision of what a truly interoperability digital ecosystem might look like. And they like that vision a lot.
All these trends offer a vision of how systems engineers can continue to evolve their craft and move towards a more efficient, robust, and rigorous practice.

Dennis Reed (Navy) - dennis.w.reed10.civ@us.navy.mil
Mr. Dennis W. Reed currently serves as the Director of Leveraging Innovations, Frameworks, and

Technologies (LIFT)/Integrated Modeling Environment (IME). In this capacity, he provides oversight and leadership in developing critical digital infrastructure across multiple domains. His responsibilities include spearheading initiatives in Information as a Service (IaaS), Software as a Service (SaaS), data exchange/storage/curation, integrated requirements and project management, workflow automation, advanced technologies, and SecDevOps capabilities throughout the end-to-end lifecycle.

Additionally, Mr. Reed serves as the Modeling and Simulation (M&S)/Live, Virtual, Constructive (LVC) Lead for Naval Air Warfare Center Aircraft Division (NAWCAD). In this role, he directs the infrastructure development of multi-domain LVC simulation environments supporting Research, Development, Test, and Evaluation (RDT&E) activities across the acquisition lifecycle for the Department of Defense.

With over 30 years of combined military and civil service, Mr. Reed has held various engineering and leadership positions in T&E and Acquisition. Notably, as Deputy for Department of Navy (DON) M&S, he led the establishment of M&S policy and guidance, provided oversight for Naval M&S needs, requirements, and technologies, and contributed to the development of the Naval RDT&E M&S Roadmap. He chaired the Naval M&S Leadership Council, driving standardization and implementation efforts across DON Communities.

Position Paper

Cristina Valera Munoz (Airbus) - cristina.valera@airbus.com

Cristina Valera, holding an MSc in Aerospace Engineering and CSEP certification, based in Madrid, Spain, brings over a decade of expertise in aerospace engineering and systems engineering. As the FCAS Common Working Environment Chief Engineer at Airbus, Cristina plays a decisive role in providing a secure international digital ecosystem for the Future Combat Air System (FCAS) program, transforming the digital landscape and ensuring digital continuity and collaboration across international engineering teams in a secure system. In her previous role as Digital Architect, she contributed to the development of Eurodrone digital engineering solutions, navigating similar challenges. As both Technical Lead Engineer and Dynamic Simulation Engineer, Cristina managed projects focused on the development of flight controls and landing gear systems, demonstrating a deep understanding of developing safety-critical systems within the aerospace defense sector. Her experience spans across an array of systems engineering disciplines, including requirements management, technical management, systems architecture, configuration management and various technology domains. Her commitment to delivering innovative solutions exemplified her role at the foreground of the digital transformation of aerospace defense developments.

Position Paper

In the landscape of aerospace and defense, the imperative shift towards digital transformation demands a thoughtful exploration of key elements—digital continuity, model-based development, digital engineering processes, interoperability, secure ecosystems and cross-functional collaboration.

Digital continuity emerges as the key player in the pursuit of operational excellence. Facilitating a seamless flow of information throughout the product lifecycle, it ensures a holistic understanding of complex systems. My professional journey has emphasized the critical role of digital continuity in promoting efficiency, reducing redundancies, and fostering a unified vision across development phases.

The paradigm shift towards model-based development has been transformative. Embracing models as central artifacts fosters efficiency, precision, and collaborative decision-making. Models serve as a universal language, promoting a shared understanding across diverse teams. The panel's focus on model-based strategies resonates with the transformative impact witnessed in real-world applications.

The evolution of engineering processes underpins the transformation towards a digital future. My engagements have emphasized the need for clearly defined, standardized processes that traverse the entire development lifecycle. From requirements specification to validation and verification, an integrated and transparent process framework is crucial for successful model-based development.

Interoperability, an indispensable in this digital ecosystem, ensures that diverse systems and teams can seamlessly communicate and share information. The effective design and implementation of digital interfaces become instrumental in achieving interoperability, enabling a cohesive and interconnected environment. The discussion on requisite tooling, infrastructure, and resources aligns with the pivotal role that digital interfaces play in shaping the future of aerospace and defense.

Navigating within a restricted ecosystem, safeguarding sensitive information demands a comprehensive and nuanced approach. Establishing rigorous data governance and access controls is paramount. My experiences underscore the challenges and opportunities within a restricted ecosystem, emphasizing the delicate balance between fostering collaboration and maintaining the security of sensitive data in a digital ecosystem.

Multi-group collaboration introduces a layer of complexity that demands a harmonized approach to processes, interfaces, and data governance. Achieving accessibility and transferability of system models across teams and borders imposes a shared understanding of international engineering standards. My engagements underscore the multifaceted nature of collaborations, emphasizing the need for a unified approach to overcome technical, cultural, and regulatory challenges.

In summary, the path towards excellence in aerospace and defense requires a holistic integration of digital continuity, meticulous adherence to model-based development, adherence to standardized-digital engineering processes, assurance of interoperability, meticulous management of secure ecosystems combined with multi-group collaboration. As we collectively navigate this transformative era, these concepts converge to sculpt a future marked by innovation, collaborative synergy, and sustained advancements in the aerodef sector.

Risa Gorospe (The Johns Hopkins University Applied Physics Laboratory) - Risa.Gorospe@jhuapl.edu
Risa Gorospe is a chief scientist specializing in systems engineering at the Johns Hopkins University Applied Physics Laboratory (JHU/APL). She has worked various roles in systems engineering that span the systems engineering lifecycle such as requirements development, architecture & design, modeling & simulation, and integration & test. Her experience with digital transformation includes executing model-based systems engineering (MBSE) at a major defense contractor (Lockheed Martin), providing guidance to government sponsors on systems engineering transformation at a university-affiliated research center (JHU/APL) and performing technical consulting for defense customers at an engineering software vendor (Dassault Systemes CATIA No Magic). At JHU/APL, she currently provides thought leadership in digital systems engineering supporting numerous government sponsors and regularly explores theory-to-application research in the fields of system architecting, enterprise engineering and digital threads.
Risa received her Bachelors of Science in Computer Engineering from Villanova University in 2007 and a Masters in Computer Science from Johns Hopkins University in 2013. She is an INCOSE Certified Systems Engineering Professional (CSEP).

Position Paper

A major push for digital transformation in the defense industry started with the United States Department of Defense's (DoD) publication of the Digital Engineering Strategy in 2018. Two main keys to that original strategy included the formalization of the use of models to inform decision making and establishment of enduring authoritative sources of truth (ASOTs). Defense organizations have tried to apply the principles of the DoD Digital Engineering Strategy and have uncovered various challenges.

Some organizations have settled around descriptive system modeling as a major focal point for digital transformation. However, these organizations have experienced some challenges in the execution. Today's descriptive system modeling tools are not really designed for interoperability with other tools. If there is interoperability, this is often aligned to a vendor-specific approach creating concerns of vendor lock-in. Another challenge for descriptive modeling has been too much emphasis on the definition of the system. There's not enough understanding of how the system model persists as an ASOT to support the downstream engineering activities (e.g., software engineering, manufacturing, test & evaluation, etc.).
Establishing the appropriate environments to host and manage the digital data has been its own challenge. A program may have to establish its own environment which requires an upfront investment and its own challenges of managing the supporting infrastructure. Some programs have decided to rely on enterprise resources such as US Navy's Integrated Modeling Environment (IME) to reduce upkeep on managing their environment. However, using a common environment presents its own challenges of competing with other programs on common resources (e.g., software licenses, computing hardware, etc.). Since many defense programs are programs with national security interest, programs have to establish these digital engineering environments in classified facilities which include additional requirements.
Another challenge is the inter-organization complications of digital transformation. Major programs involve many organizations beyond the primary system development organization (e.g., support contractors, program offices, test facilities, etc.). This drives unique challenges on developing a complete digital engineering ecosystem. How do we synchronize data between the program office and the contractors? What happens if the prime contractor chooses to use a software tool that isn't the same software that produced the government reference architecture? Do we mandate contractors to use specific tools or do we provide a "soft recommendation" and expect the contractor to respond appropriately? These are among the many questions

defense programs are asking themselves today.

Despite these challenges, there are many reasons to be hopeful. DoD Instruction 5000.97 "Digital Engineering" published in 2023 help to further define DoD's policy and expectations. Evolving standards such as OMG SysML 2 and ISO/IEC/IEEE 42010/42020/42030 series are more thoroughly exploring a standards-based approach to model interoperability and common terminology definition. Cross-organization forums such as US Army's Architecture Collaboration Working Group (ACWG) have sprung up to provide a more practitioner-centric approach to the sharing of best practices across programs. In my view, the defense industry still sees the value of digital transformation and is responding in various ways to continue moving the industry forward.

The NAVSEA Warfare Centers represent scientists, engineers, and analysts working a diverse portfolio of capabilities across many phases of the engineering lifecycle. Some entities support legacy systems nearing their end-of-life while others are defining requirements for capabilities over a decade in the future. Individuals attempting to advance digital engineering across such an intellectually dispersed community are forced to embrace diversity rather than enforce conformity. Working with the diversity each center and community of interest forces Mr. Pack to acknowledge that digital transformation means unification, or commonality, only where it is beneficial towards the mission of delivering greater naval capability. While the goal of any digital engineering should be the continuous transformation and evolution of all technical activities, taking a pragmatic perspective towards transformation activities helps ensure greatest likelihood of total-enterprise participation and enthusiasm.

Alexandra Beaudouin (Solent, powered by Smart4 Engineering) - abeaudouin@solent.fr

Alexandra currently leads Solent as CEO, a company part of Smart4 Engineering. Smart4 Engineering is a multidisciplinary international federation of expertise, relying on brands focused on digital engineering and R&D to enable clients in their critical digital and data journey. Prior to her current position, she supported, for 3 years, the major European industrial actors as an Aerospace and Defence Industry Manager in EMEA for MathWorks Inc, the world leader of computer science and modelling and simulation solutions. She was focused on Systems Engineering and Aeronautics Certification sharing how Systems Engineering benefit to digital transformation to support the next generation challenges in events like Complex Systems Design & Management (CSD&M) or NATO Modelling&Simulation Conferences.

From 2018 to 2020, at Thales Group, she supported several defence programs teams through bid and run phases by leading a department focused on critical and real-time embedded software systems.

Graduated in Embedded Electronic Systems, she began her career at Solent as an embedded software engineer on programs like A400M or A350 and then supported Solent's growth holding the position of Embedded Systems Department Manager until 2017.

Position Paper

Aerospace and Defence industry is one of those industries gathering a high number of safety-critical systems which require a high-level of availability to ensure that safety. Having this objective in mind, system engineers need to improve their methods and technics to reduce both development cycle duration and the risk of discrepancies, especially if they are only seen at the end of the cycle.

Systems are getting more digital and more complex, and this is not a surprise, technology is evolving faster than safety or security regulations. Digital transformation has already started and many aspects are being addressed but it keeps raising new challenges and new opportunities. Moving forward, this transformation is driven by technology but also by the cost's efficiency.

These objectives can have several faces across the system development by involving:

- Modelling and simulation to early detect discrepancies with regards to requirements (textual or modelled) and leverage simulated environments. Methods are adjusted between systems engineering teams and co-engineering is taking place. Simulated environments enable saving millions by reducing the rework effort after the late on-field test campaigns.

- Software-defined functionalities to reduce, possibly remove, the hardware ratio in embedded systems like in radios but bring in, or even increase, the safety and cybersecurity considerations,

- Artificial Intelligence to predict behaviour and improve the system's lifetime to gain in sustainability like battery behaviour prediction. Based on the massive amount of data available, next generations systems will benefit from the data analyses and enable systems to evolve.

Additionally, the digital transformation is impacting the nature of the items produced: from the inside when their architecture is modified to be more software-defined and from the outside when their format across the development cycle is modified from documents to models or from hardware to software. As a consequence, the transformation also needs to impact the methodology and the definition of the development and integration processes that the project teams have to comply with. This is probably where the definition of the development cycles encounters the biggest challenge as it could imply that their contractual references are

modified compared to what they are used to demonstrate.

Having a digital continuous environment that implements the entire system development cycle from end-to-end is probably the ultimate goal, but companies and tool providers are still figuring out what they really need.

In the meantime, transformation is happening piece by piece, domain by domain, and process by process. The companies need time to, on the one hand, commit to support change, while, on the other hand, project teams can maintain that the deliverables have the right level of conformity to the contract in terms of functionalities, performance, sustainability and availability.

Panel#382

Smart Cities from architecture to application: A socialization of industry best practices

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Keywords. Smart City;Systems Thinking;Society 5.0

Topics. 1.6. Systems Thinking; 20. Industry 4.0 & Society 5.0; 22. Social/Sociotechnical and Economic Systems; 3.5. Technical Leadership; 5. City Planning (smart cities, urban planning, etc.); 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.);

Abstract. Smart cities development includes considerations and implications for technology developers, city policy makers, and sustainability practitioners. While each of these is focused on their practice, each is creating tomorrow's smart cities. Can we, as systems engineers, find the common threads among these and where the interfaces between these distinct practices? Join us for a discussion about the current state of practice for these areas and how they are inter-dependent for creating a smart city.

Biography

Jennnifer Russell (Garver) - JLRussell@GarverUSA.com

Jennifer Russell, EISE, CSEP is the Program and Management Support Leader on Garver's Water team. Over the past 25 years +, she honed her West Point leadership motto of being a "Leader of Character." Currently, Jennifer is the Chair of the INCOSE Smart Cities Initiative and has been the Outreach Director for the Transportation Working Group. At the International Symposia, Jennifer has presented several papers, on a panel, and lead several Roundtables. Jennifer holds a B.S. in Engineering Psychology from the United States Military Academy and an M.S. (2003) and Engineer Degree (2007) in Industrial and Systems Engineering from the University of Southern California.

Position Paper

The scope of effort from the INCOSE Smart Cities Initiative and the relationships between outside partners has been collaborative and informative. Yet, there are still many opportunities for continued knowledge sharing

and best practice sharing between practitioners. Cross-collaboration is imperative as areas like MBSE, sustainability, and smart city policies mature. There is a broadening of the understanding, communication on the topics, and desire for cross-collaboration that is inspiring. Each of the practitioners invited to this panel have refined their cross-collaboration techniques and will provide valuable insight for systems engineers in any domain, and especially those working on aspects of smart cities.

Christian Neureiter (Head of Josef Ressel Center for Dependable System-of-Systems Engineering Salzburg University of Applied Sciences) - Christian.neureiter@fh-salzburg.ac.at

Christian Neureiter is a Professor at Salzburg University of Applied Sciences where he is leading the Josef Ressel Center of Dependable System-of-Systems Engineering. His main research interest is put on the development of dependable Cyber-Physical Systems.

Position Paper

Corresponding to Christian's research interests he argues that Model Based Systems Engineering is a key enabler for the development of Smart City System Architectures. Based on experiences made in the application domains of Automotive, Industry 4.0 and Smart Grids, Christian's position is that Model Based Systems Engineering approaches need to be centered around the individual user's perspective and needs. The proposed concepts of "Domain Specific Systems Engineering" (DSSE) focus on providing a domain-specific perspective on the one hand while maintaining interoperability and compatibility of architectural models between different domains (e.g., electric vehicles and the power grid) on the other hand. On this basis, understanding of the nature of System-of-Systems is supported and designing of dependable solutions is enabled.

Cecilia Haskins (Norwegian University of Science and Technology (NTNU) and the University of Southeastern Norway (USN)) - ceciliahskins25@gmail.com

Cecilia Haskins, PhD is recently retired and continues in emeritus status with the Norwegian University of Science and Technology (NTNU) and the University of Southeastern Norway (USN). Her career included over 30 years as a practicing systems engineer and over 20 years educating the next generation of engineers on the importance of systems approaches. She joined INCOSE in 1993 where she held a variety of leadership and other volunteer positions, was recognized as an INCOSE Founder, and continues to be active as a mentor and author. Her educational background includes degrees in chemistry, business, and eventually a PhD for application of systems engineering to sustainable development from NTNU.

Position Paper

Smart cities rely on providing jobs and services making industry an important contributor to value creation in today's' society. But business is also the source of undesired social impacts such as environmental degradation and exploitation of workers. Traditionally, society's response to the most severe impacts, has been to establish laws and regulations. However, negative consequences persist even when firms operate within established limits. This creates a dilemma in defining the role of industry to sustainable development as outlined in the UN SDG and considering the role of systems engineering in addressing this dilemma. This presentation offers frameworks and a toolset supported by systems engineering principles and practices to assist the business transition to sustainability drawing on recent research and cases of successful transitions.

Martin Serrano (Insight SFI Research Centre for Data Analytics) - martin.serrano@insight-centre.org

Martin Serrano (PhD, MSc, BSc Eng.) is a recognized Researcher and Data Scientist with more than 20 years of experience in applied research on semantic interoperability and distributed data systems design and their implementation in industry applications like smart cities, healthcare and wellbeing, manufacturing and control systems. **Martin Serrano** is a continuous contributor to the Scientific, Research and Innovation agenda for Europe and coordinates and manages research activities with a successful range of EU (FP5-FP7/H2020/Horizon Europe) collaborative projects, Irish (HEA PRTLI, SFI) and also Enterprise Ireland (EI) innovation projects. **Martin Serrano** is an active member of IEEE (Computer and Communication Societies) and ACM with more than 100 pair reviewed publications, Dr. Serrano is the author of 4 academic books in related areas and 6 research books advancing the state of the art in applied data science and the development of computer and software technologies using Open Source Software (OSS) approaches. Martin Serrano is the recipient of the **2023 AIOTI Best Academic Research Award** by its contributions to the scientific and industry communities on data modelling methods & semantic interoperability. In **2022 he**

received the Best NGI-Explorers Impact Award by his collaborative research with the National Institute of Technology (NIST) defining Smart City Standards. in **2018** he received the **"50 Most Transformative Smart City Project in the world" Award,** and in **2015 he was listed in the 25 Key People influencing the Internet of Things** by Silicon Republic Media, Ireland.

Position Paper

The United Nations (UN) estimates that by 2030 more than 66% of the global population will be living in cities. The increasing use of technology for digitising services is making cities 'smarter'.

Smart cities and communities commonly use Key Performance Indicators (KPIs), when evaluating or measuring their Smart City ecosystems. However, many KPI approaches are limited by their technology, or sector-specific, focus and their inability to measure benefits essential to assessing community impact and return on investment. To overcome this limitation, an Holistic Key Performance Indicators (H-KPI) Framework has been developed as part of an international collaboration between the EU and USA.

Insight SFI research Centre for Data Analytics at University of Galway and the National Institute for Standards and Technology have developed the H-KPI framework and defined what makes a city or a community 'smart' as well as laying out smart city metrics so 'smartness' can be properly measured.

The framework builds on conventional KPI methods and takes unique characteristics into account such as; different districts and neighbourhoods, differences in population and economic scale, the reuse of previously deployed technologies and other factors relevant to a city or community. In this work, the term 'smart' in 'Smart Cities' is defined as the efficient use of digital technologies to provide prioritised services and benefits to meet community goals such as; economic vitality, equity, resilience, sustainability or quality of life.

The H-KPI Framework is detailed in the NIST Special Publication 1900-206 Smart Cities and Communities: A Key Performance Indicators Framework. The Framework provides the basis for developing measurement methods and tools that allow for integration, adaptability, and extensibility at three interacting levels of analysis: technologies, infrastructure services, and community benefits. The publication describes the H-KPI method which provides a structured representation of smart city/community information flows and enables computational methods for systems design, analysis, operations and assurance.

Panel#281

What works and what does not work in teaching non-Systems Engineers about systems thinking

Jill Speece (California Polytechnic State University San Luis Obispo) - jespeece@calpoly.edu
Kamran Eftekhari Shahroudi (Woodward Inc.) - keftek@woodward.com
Martin Span (Colorado State University) - Trae.Span@colostate.edu
Kirk Reinholtz (Colorado State University) - Kirk.Reinholtz@colostate.edu
Quentin Saulter (Colorado State University) - Quentin.Saulter@colostate.edu
Sarwat Chappell (Department of Defense) - Sarwat.Chappell@colostate.edu
Graeme Troxel (Cornell University) - gwt38@cornell.edu

Keywords. Systems Thinking;Socio-Technical Systems;Penetration of Systems Thinking

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

#TechnicalLeadership

Abstract. This panel discusses the challenges of teaching systems thinking across various fields of study. It questions whether all Systems Engineers are proficient at teaching systems thinking to everyone. People from different industries, such as healthcare, education, manufacturing, aerospace, and energy, will share insights into what has succeeded and what has not in teaching systems thinking.

Biography

Jill Speece (California Polytechnic State University San Luis Obispo) - jespeece@calpoly.edu

Jill Speece is an Assistant Professor of Industrial and Manufacturing Engineering at California Polytechnic State University in San Luis Obispo. She is also currently an adjunct professor in Healthcare Administration at Pacific University and a continuous improvement consultant with Ridgerunner Engineering. Prior to her academic career, Jill worked in the manufacturing industry as an Industrial Engineer at Raytheon (2004 – 2009), Abound Solar (2009 – 2012), and Terumo BCT (2013 – 2014). She received her Lean Six Sigma Expert certification through Raytheon in 2008. She then transitioned to working in the healthcare industry and served as both a Process Improvement Consultant and the Director of Business Optimization at Radiology Associates from 2015 – 2021. She has her BS in Industrial Engineering from Cal Poly, SLO, an MS in Engineering Management from USC, and a PhD in Systems Engineering from Colorado State.

Position Paper

Systems thinking is an intentional mental practice wherein you gather and analyze all stakeholder input, understand existing systems for context, and thoroughly research the history of the problem from various angles. Anyone can become a proficient systems thinker, but not everyone is willing to put in the effort. Systems Engineers should arguably be the experts in systems thinking, just as the media should arguably present an unbiased view of current events. Despite our awareness that neither always occurs, I believe Systems Engineers are still the most qualified to teach systems thinking. Systems Engineering is a discipline, while systems thinking is a mental habit that spans all disciplines. Just like any new habit, it requires a considerable initial effort before it becomes effortless. In my experience, this aspect has been the tough sell in training non-Systems Engineers to become systems thinkers. What has proven most effective in teaching healthcare workers about systems thinking is guiding them through the creation of various artifacts from the Systems Engineering discipline (such as context diagrams, use case diagrams, requirements writing, stakeholder analysis, trade-off studies, etc.) specific to a problem that interests them. For undergraduate students, what has been most successful thus far is presenting them with a lofty challenge, such as "how would you change the world," and forming cross-discipline teams (comprising, for example, a history major, a soil science major, a marketing major, and an industrial engineering major) mentored by various faculty members to propose an idea for solving a wicked problem. What has not worked in both environments is a theoretical overview of systems (i.e., death by PowerPoint) that is not combined with hands-on, relevant practice. Systems thinking games and exercises are also helpful but remain ineffective unless the individual can begin developing the systems thinking mental habit by working on a problem of special interest to themselves.

Kamran Eftekhari Shahroudi (Woodward Inc.) - keftek@woodward.com

Kamran is a Systems Fellow at the Corporate Technology Office of Woodward, Inc. working on Aerospace, Energy and Power Actuation Systems in technical lead and managerial roles since 1997. Kamran is a Professor of Systems Engineering and a founding member of the CSU-SE program teaching and researching application of Systems Thinking and System Dynamics to Socio-Technical problems since 2009.

Position Paper

Systems engineers can become disconnected and forget that the primary raison d'être for systems engineering frameworks, tools, language, and processes is to apply systems thinking and principles to enhance the team's (not solely their own) chances of success when handling complex socio-technical challenges. Many within INCOSE still equate Systems Thinking and Systems Engineering, which is counterproductive to fostering greater adoption of a systems thinking mindset in corporate culture. Presently, practical, experience- and observation-based universally applicable systems principles constitute the most leverageable and teachable aspect of the body of knowledge on systems thinking for non-systems engineering and non-technical roles. Systems science, the source of Systems Principles, is presently not

ideally positioned for broadening the teaching of systems thinking, as highlighted in the INCOSE-IS 2023 Panel discussion where this challenge of instructing non-systems engineers was raised without a clear solution. It is imperative to formulate a set of SMART requirements for generic Systems Principles that are applicable across ANY discipline, not solely for systems engineers, to promote the broader adoption of systems thinking beyond the SE discipline. The aforementioned stances or perspectives are rooted in teaching systems thinking classes to over 80 industry professionals engaged in delivering complex actuation system products to the aerospace and energy industries, alongside instructing more than 500 mature student professionals at CSU, holding diverse technical to administrative roles since 2009. These viewpoints are supported by references to the SEBOK, standard systems engineering texts, prior INCOSE IS Panels/Publications on Systems Science and Systems Thinking, and data derived from previous instructional experiences.

Martin Span (Colorado State University) - Trae.Span@colostate.edu

Martin (Trae) Span, III is currently a PhD Candidate in Systems Engineering at Colorado State University. He is also commissioned as a Major in the United States Air Force (USAF). He has served the USAF as a Developmental Test Engineer responsible for planning and executing complex weapon system tests and evaluation. Additionally, he served as Deputy Director for the US Air Force Academy systems engineering program teaching multiple courses in systems engineering and project management. He serves as a developmental engineer and holds the Department of Defense certifications in systems engineering, science and technology management, test and evaluation, and program management. His PhD work is focused on cybersecurity requirements elicitation for complex cyber-physical systems.

Position Paper

Are systems engineers consistently practicing systems thinking? Not to its fullest...I believe systems thinking education is not a consistent part of systems thinking education and training. By default, most systems engineers are applying some tenets of systems thinking as its engrained in systems engineering processes, but there is certainly room for improvement in educating systems engineers on additional considerations and perspective gained through a systems thinking approach to understanding the complexity of their system operation and its environment. How do you differentiate between systems thinking and systems engineering?

Systems thinking is a way of viewing the world in which we understand that the most challenging problems we encounter are not decomposable and solvable by traditional engineering methods. Even a well-designed system, if not designed considering the complexity of its dynamic interactions in its operating environment (including the human element), will likely have large shortcomings throughout its lifecycle. What elements or tools of systems thinking have the highest leverage in different industries or professions? A holistic perspective -- the combination of parts does not equal the whole. Understanding that elements have dynamic relationships in the dynamic environment of the world we live in. Teaching non engineers to appreciate the implications their solutions may have (both intended and intended) is particularly powerful (Cats in Borneo Example). Who should teach systems thinking? The simplest answer is a systems thinker. I believe that an engineering degree specifically is not a requirement to teach systems thinking, but the instructor should have experience with either system design or project management. So, I would expect this course to be taught by someone from an engineering or management department. What teaching approaches have worked effectively, and what have been less successful in teaching systems thinking? A case study focused approach that highlights the failures of a lack of systems thinking has proven successful at the US Air Force Academy in introducing systems principles. Guest speakers who can speak to their own involvement in a systems thinking problem or success story are also particularly effective in conveying the complexity of interactions in our complex system design and operational challenges.

Kirk Reinholtz (Colorado State University) - Kirk.Reinholtz@colostate.edu

Kirk Reinholtz was a Principal Engineer with California Institute of Technology/Jet Propulsion Laboratory. He left that position in early 2023 to focus full-time on catching up with the 21st century by pursuing a PhD in SE. He has an MSCS from USC.

Position Paper

The challenge is much more than a lack of systems thinking. If there's money or power to be had or lost, then there are lots of people doing systems thinking. The crux of the situation is that they are often using systems thinking to achieve their own ends, not necessarily fully aligned with success of the system at hand. When the system was just a spacecraft, we systems engineers could pretty much stay out of the fray. But now we are

dealing with planetary-scale systems and existential challenges. We Systems Engineers are trained and experienced in systematically solving engineering issues of any scale. Should we join the fray? If so, how do we educate ourselves on the human behaviors that tend to thwart our most well-intentioned efforts?

Quentin Saulter (Colorado State University) - Quentin.Saulter@colostate.edu

Quentin Saulter is a PhD student in Systems Engineering at Colorado State University. Thesis work is "A Dynamical Approach to Understanding the DoD Innovation Ecosystem. Quentin Saulter works for the Department of Navy at the Office of Naval Research he is directing critical investments for research, development, test, and evaluation for the Navy. Mr. Saulter specializes in fostering innovative technologies for Navy stakeholders. Mr. Saulter is coordinating several research, development, and testing programs.

Position Paper

Systems Thinking is a discipline generally taught in Systems Engineering curricula throughout the United States. It is typically myopically applied to complex technical systems. A general application of systems thinking in social, environmental, economic, and medical disciplines is not usually taught in academic institutions. One rarely hears of Systems Thinking being taught in Law School. Systems Thinking, as taught by engineering professors is usually in terms of technical jargon of Thinking in Systems that cannot be understood by non-engineering students. Systems Thinking can be broadly applied to many different phenomena to solve complex dynamical problems. As an example, gathering data to formulate information and build models is using Systems Thinking to analyze the spread of diseases. Another example is using the historical patterns of behavior to build models to deduce whether a person possibly committed a crime. Even though these examples use some of the tools of Systems Thinking their adoption does not lead to using Systems Thinking principles.

Both classical Systems Engineering and Model Based Systems Engineering have traditionally been applied to solve problems without full application of Systems Thinking. For example, Systems Engineering is typically used to design complex systems such as ships, planes, rockets, and satellites whereas Systems Thinking can be used to predict the behavior of the system and deal with emergent behavior of the system such as stock markets, forest fires and civil unrest. The element of Systems Thinking that is agnostic to profession or discipline and has the most leverage is the ability to change mental models. A practitioner of Systems Thinking who understands systemic structures, diverse entity interactions, positive and negative feedback and emergent behaviors should teach Systems Thinking. In our experience, conducting Systems Thinking Workshops for both technical and non-technical persons, we learned that anyone could learn and apply basic systems thinking principles. This will lead to an understanding of the complexity of an enterprise culture and improve productivity. Teaching Systems Thinking using non-engineering jargon and using examples related to the student's field of study will increase their understanding and promote adoption of Systems Thinking.

Sarwat Chappell (Department of Defense) - Sarwat.Chappell@colostate.edu

Sarwat Chappell is a PhD student in Systems Engineering at Colorado State University. Thesis work "A Systems Thinking Approach to Eliminating the DOD Science and Technology Valley of Death". Sarwat Chappell works for the Department of Navy at the Office of Naval Research where she leads the research and development of novel technologies for the Navy. Sarwat has extensive experience leading domestic and international collaborative research programs with complex, technical objectives. Sarwat has a B.S. and M.S. in Electrical Engineering from Tennessee Technological University in Cookeville, TN.

Position Paper

Systems Thinking is a discipline generally taught in Systems Engineering curricula throughout the United States. It is typically myopically applied to complex technical systems. A general application of systems thinking in social, environmental, economic, and medical disciplines is not usually taught in academic institutions. One rarely hears of Systems Thinking being taught in Law School. Systems Thinking, as taught by engineering professors is usually in terms of technical jargon of Thinking in Systems that cannot be understood by non-engineering students. Systems Thinking can be broadly applied to many different phenomena to solve complex dynamical problems. As an example, gathering data to formulate information and build models is using Systems Thinking to analyze the spread of diseases. Another example is using the historical patterns of behavior to build models to deduce whether a person possibly committed a crime. Even though these examples use some of the tools of Systems Thinking their adoption does not lead to using Systems Thinking principles.

Both classical Systems Engineering and Model Based Systems Engineering have traditionally been applied to solve problems without full application of Systems Thinking. For example, Systems Engineering is typically used to design complex systems such as ships, planes, rockets, and satellites whereas Systems Thinking can be used to predict the behavior of the system and deal with emergent behavior of the system such as stock markets, forest fires and civil unrest. The element of Systems Thinking that is agnostic to profession or discipline and has the most leverage is the ability to change mental models. A practitioner of Systems Thinking who understands systemic structures, diverse entity interactions, positive and negative feedback and emergent behaviors should teach Systems Thinking. In our experience, conducting Systems Thinking Workshops for both technical and non-technical persons, we learned that anyone could learn and apply basic systems thinking principles. This will lead to an understanding of the complexity of an enterprise culture and improve productivity. Teaching Systems Thinking using non-engineering jargon and using examples related to the student's field of study will increase their understanding and promote adoption of Systems Thinking.

Tutorials

Tutorial#205

Dimensional Analysis. A helpful practice for identifying constraints on a system model developed using ISE&PPOOA MBSE methodology

Jose Luis Fernandez (Independent MBSE trainer) - joselfernandez@telefonica.net
Juan Antonio Martinez (Department of Signal Theory and Communications, Escuela Politécnica. Universidad de Alcala de Henares.) - juanan.martinez@uah.es

Keywords. Dimensional analysis;MBSE;Physical constraints;Interfaces

Topics. 11. Information Technology/Telecommunication; 17. Sustainment (legacy systems, re-engineering, etc.); 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 5.5. Processes; 8. Energy (renewable, nuclear, etc.);

Abstract. MBSE methodologies application ends with the physical architecture of the system, but a physical model is clearly incomplete without the study of its associated physical laws and phenomena related to the whole system or its parts.Here we propose the use dimensional analysis to identify from the sytem model the constraints derived from Physics laws and to be represented as SysML constraints blocks that constrain either the behavior of the complete system or one of its parts.

Biography

Jose Luis Fernandez (Independent MBSE trainer) - joselfernandez@telefonica.net

Primary instructor was tenure associate professor during 18 years teaching project management and systems engineering to students and professionals. Currently is an independent trainer for MBSE and requirements engineering. He collaborates as well as MBSE mento for research projects in aerospace and medical devices.

PhD in Computer Science, and an Engineering Degree in Aeronautical Engineering. Universidad Politecnica de Madrid. Second instructor.PhD in Physics by the Universidad Complutense de Madrid and a Psychology Degree in Educational and Developmental Psychology by the Universidad Nacional de Educación a Distancia.

First instructor is the main author of the ISE&PPOOA MBSE methodology he developed the last years. This methodology is described in the book "Practical Model-Based Systems Engineering," Artech House 2019. ISE&PPOOA was presented in diverse INCOSE webinars and tutorials to universities and industry mainly in Europe and the US.

Juan Antonio Martinez (Department of Signal Theory and Communications, Escuela Politécnica. Universidad de Alcala de Henares.) - juanan.martinez@uah.es

Secondary instructor is tenure associate professor and expert in sensors, complex systems, computational physics, modeling and dimensional analysis, as can be seen in his scientific papers. His research span from plasma spectroscopy to optical and acoustical sensing of biological matter.

Second instructor is mainly interested in extending dimensional analysis and similarity techniques to complex systems as a foundational basis of modeling in systems engineering.

Tutorial#317

Embracing the Social Dimension of Systems Engineering

David Long (Blue Holon) - david@blueholon.com
Suja Joseph-Malherbe (Letter27) - suja@letter27.co.za

Keywords. Leadership;Interpersonal skills;Elicitation;Communication;Facilitation;Teams;Collaboration

Topics. 3.5. Technical Leadership; #TechnicalLeadership

Abstract. The transdisciplinary nature of SE requires insights from a diverse set of customers, users, stakeholders, and subject matter experts. Success requires both technical and social dimensions. In this practical tutorial suitable for all experience levels, we explore how to better achieve shared understanding through effective elicitation, communication, and facilitation. We address how behavior, culture, and intent contribute to group outcomes and use perceptual positions to advance interactions.

Biography

David Long (Blue Holon) - david@blueholon.com

For over 30 years, David Long has helped organizations increase their systems engineering proficiency while simultaneously working to advance the state of the art. David was the founder and president of Vitech where he led the development of innovative, industry-leading methods and software to help organizations engineer next-generation systems.

Throughout his career, David has played a key technical and leadership role in advancing and expanding the practice of systems engineering around the world. He advises government and commercial organizations as they assess, adopt, and deploy new methods and tools to enhance their engineering enterprise. David successfully led Vitech from initial start-up to mature organization through acquisition. David has served INCOSE since 1997 including a term as the Washington Metropolitan Area chapter president and international roles including Member Board Chair, Director for Communications, Director for Strategy, and President (2014 & 2015). An INCOSE Fellow and Expert Systems Engineering Professional (ESEP), David is considered the grandfather of INCOSE's Technical Leadership Institute and has served as a coach since 2019.

David is a frequent presenter at industry events worldwide delivering keynotes, presentations, and workshops spanning introductory systems engineering, the advanced application of MBSE, digital engineering, the future of engineering systems, and leadership.

Position Paper

David is an internationally recognized leader within INCOSE and the greater systems engineering community. David has developed his leadership philosophy and behaviors based upon a unique blend of commercial experience (founding and leading a systems engineering company) and volunteer experience (leading

INCOSE at the local, regional, and international level). This has positioned David to advise diverse organizations around the world as well as coach the next generation of systems engineering leaders as part of INCOSE's Technical Leadership Institute.

Suja Joseph-Malherbe (Letter27) - suja@letter27.co.za

Suja has a passion for leadership and systems engineering and as such she is quite active in INCOSE in various roles. She is a coach at INCOSE Technical Leadership Institute since December 2020. She served as the President of INCOSE South Africa from January 2017 to December 2018.

She provides training and consulting services in systems engineering and leadership development to individuals and organizations through Letter27. She is also a sessional lecturer at the Faculty of Engineering and the Built Environment at the University of the Witwatersrand, delivering post-graduate courses on systems engineering. Her prior experience includes delivering training world-wide in systems engineering through Certification Training International (course presenter); managing software releases, including the testing, deployment, and support of new software for first-of-its-kind outdoor and fitness products at Garmin Stellenbosch (senior systems engineer); and substantial experience in modelling and simulation, image processing, and development of technology systems for the defense industry.

She is an INCOSE Certified Systems Engineering Professional (CSEP) and a Solution-focused Brief Coach (ICF-ACSTHs training).

Position Paper

Suja has a passion for leadership and prolifically engages in aspects of it in various ways. Over the years, she has delivered talks and keynotes on this topic (at local, regional, and international levels), most recently at the meeting of the International Society for the Systems Sciences (June 2023). She is a coach at the INCOSE Technical Leadership Institute and has had the privilege of being actively involved in the learning journey of about 80 systems leaders. She is registered for a PhD exploring leadership. In addition to being a practicing systems engineer, she offers coaching and leadership development to professionals.

Tutorial#374

Hands-on Journey on Variant Modelling with SysML: Features Models, Methods, SysML v2, and AI Insights

Marco Forlingieri (IBM Engineering) - marco.forlingieri@gmail.com
Tim Weilkiens (Oose) - tim.weilkiens@oose.de

Keywords. Variant Modelling in SysML;Model Based Product Line Engineering (MBPLE);Variant Modelling and SysML v2;AI-assistance for Variant Modelling

Topics. 16. Rail; 2. Aerospace; 3. Automotive; 5.11. Artificial Intelligence, Machine Learning; 5.3. MBSE; 5.6. Product Line Engineering; #AI

Abstract. Embark on a practical journey into Variant Modelling in SysML, exploring its fundamentals, alternative approaches and variability in SysML v2. A showcase on the usage of an AI-assistant for Variant Modelling, highlighting the advantages and challenges that poses to the discipline will conclude this exploration. The tutorial aims at enhancing your understanding, from Variant Modelling fundamentals to cutting-edge AI integration.

Biography

Marco Forlingieri (IBM Engineering) - marco.forlingieri@gmail.com

Marco Forlingieri, currently serving as the Technical Representative of IBM Engineering in Southeast Asia, has gathered more than 10 years in MBSE and PLE. His expertise extends across aerospace, defense, automotive, and railway industries in Europe, North America, and Asia Pacific. Marco holds key roles as co-chair of the INCOSE PLE Working Group and Assistant Director for the INCOSE Asia & Oceania Sector.

As Associate Faculty at the Singapore Institute of Technology (SIT), Marco teaches MBSE. His primary focus centers on Model-Based Product Line Engineering, where he played a pivotal role in implementing a significant PLE initiative at Bombardier Transportation in the railways sector. Additionally, during his previous role at Airbus within the Digital Design Manufacturing and Services program, he led the MB-PLE initiative.

As author, Marco has contributed to various publications focused on PLE and MBSE. His works includes "The four dimensions of Variability at Airbus", "Variability on System Architecture using Airbus MBPLE for MOFLT Framework" and "Two variants Modelling Approaches for MBPLE at Airbus," that was recognized with the "Best Paper" award at the INCOSE IS 2022 in Detroit. Marco remains dedicated to advancing the field and continues to shape the future of MBSE and PLE globally.

Position Paper

Marco Forlingieri, a leading MB-PLE expert globally, brings practical know-how from industry, consulting, and tool development to the tutorial. His rich experience in MBSE and PLE, evident in publications and PLE WG involvement, offers valuable insights. With a decade dedicated to Variant Modelling in SysML, Marco's expertise is a key asset for tutorial preparation and execution. Attendees can benefit from his simplified, hands-on approach, making complex concepts more accessible. With Marco's help, the tutorial becomes a key opportunity to improve the audience's skills in MB-PLE.

Tim Weilkiens (Oose) - tim.weilkiens@oose.de

Tim Weilkiens is a member of the executive board of the German consulting company oose, an MBSE coach, and an active member of the OMG and INCOSE communities.

Tim was a co-developer of the SysML v1 specification, was a co-lead of the last SysML v1 revision task forces, and is a co-chair of the SysML v2 finalization task force.

Additionally, Tim was also involved in the development of UML, BPMN, and the OMG certification programs.

Tim has written more than 15 books about modeling including "Model-Based System Architecture" (Wiley), and "Variant Modeling with SysML" (MBSE4U). Regarding AI, Tim currently works as a co-author on the book "AI Assisted MBSE with SysML".

Position Paper

Tim Weilkiens has deep knowledge about SysML, and the modelling of variability (see biography).

As an MBSE consultant and trainer for more than 20 years, he has a lot of experience in leading workshops and tutorials..

Open Source System Modeling with Python

Raymond Madachy (Naval Postgraduate School) - rjmadach@nps.edu
Ryan Longshore (Naval Postgraduate School) - ryan.longshore@nps.edu

Keywords. System modeling;digital engineering;open source;open source libraries;open-source tools;Python

Topics. 1. Academia (curricula, course life cycle, etc.); 2. Aerospace; 5.1. Agile Systems Engineering; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 6. Defense; #MBSE-DE;

Abstract. The tutorial will cover open-source system modeling capabilities using Python, and immediately enable participants to implement them. Modeling will include SysML v.1 and v.2, continuous and discrete event simulation, reliability, network, risk, cost, project management, and others. Participants will rapidly model, analyze, and automatically document systems. They will learn how to incorporate open source modeling in system engineering processes and toolsets, and automate digital engineering.

Biography

Raymond Madachy (Naval Postgraduate School) - rjmadach@nps.edu

Raymond Madachy, Ph.D., is a Professor in the Systems Engineering Department at the Naval Postgraduate School. His research interests include system and software cost modeling; affordability and tradespace analysis; modeling and simulation of systems and software engineering processes; integrating systems engineering and software engineering disciplines; and systems engineering tool environments. His research has been funded by diverse agencies across the DoD, National Security Agency, NASA, and several companies. Previously he was a Research Assistant Professor in the Industrial and Systems Department at the University of Southern California, and has over 20 years of management and technical experience in industry.

He has developed widely used tools for systems and software cost estimation, and is leading development of the open-source Systems Engineering Library (se-lib). He received the USC Center for Systems and Software Engineering Lifetime Achievement Award for "Innovative Development of a Wide Variety of Cost, Schedule and Quality Models and Simulations" in 2016.

His books include Software Process Dynamics, What Every Engineer Should Know about Modeling and Simulation; co-author of Software Cost Estimation with COCOMO II, and Software Cost Estimation Metrics Manual for Defense Systems. He is writing Systems Engineering Principles for Software Engineers and What Every Engineer Should Know about Python.

Position Paper

Dr. Madachy is a full tenured Professor at NPS teaching modeling and simulation, system software engineering, engineering economics and cost estimation (also course coordinator for these). He has developed full courses, short courses, and tutorials on system modeling and simulation for academia, conferences, and industry (internally and as consultant). His many publications are in these areas.

He has presented conference tutorials at IS and others for system and software cost modeling, process simulation and system dynamics.

He recently created and is lead developer for the open-source Systems Engineering Library (se-lib). He is also finishing the textbook What Every Engineer Should Know About Python.

Ryan Longshore (Naval Postgraduate School) - ryan.longshore@nps.edu

Ryan Longshore is an 18 year veteran of both the defense and electric utility industries. In his current role at Naval Information Warfare Center Atlantic (NIWC LANT), Ryan leads a diverse team of engineers and scientists developing and integrating new technologies into command and operations centers. Ryan is heavily involved in the Navy's digital engineering transformation and leads multiple efforts in the model based systems engineering and model based engineering realms.

Ryan earned a BS in Electrical Engineering from Clemson University, a MS in Systems Engineering from Southern Methodist University, and is currently pursuing his PhD in Systems Engineering from the Naval Postrgraduate School. He is a South Carolina registered Professional Engineer (PE), an INCOSE Certified Systems Engineering Professional (CSEP), and has achieved the OMG SysML Model Builder Fundamental Certification.

Position Paper

Mr. Longshore is a practicing engineer mentoring a multitude of junior engineers in systems, electrical, and mechanical engineering. Additionally, he developed and led several sessions of a Fundamentals of Engineering (FE) review course for power systems and has contributed electrical, power systems, and engineering economics chapters to three FE and Professional Engineer (PE) exam preparation books.

He contributes to the Systems Engineering Library (se-lib) and is also conducting research into incorporating Artificial Intelligence (AI) into systems engineering practices.

Tutorial#47

Security as a Foundational Perspective in Systems Engineering: Engineering Trustworthy Secure Systems

Mark Winstead (The MITRE Corporation) - mwinstead@mitre.org

Topics. 12. Infrastructure (construction, maintenance, etc.); 2.3. Needs and Requirements Definition; 2.4. System Architecture/Design Definition; 4.7. System Security (cyber-attack, anti-tamper, etc.); 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Security should be as foundational a perspective as system performance and safety (INCOSE SE Vision 2035), as engineering of systems cannot assume benign environments for development, operations, maintenance, and support. Systems engineering must think and execute to properly employ principles, concepts, and methods to coordinate, orchestrate, and direct the activities to deliver assured trustworthy secure systems in and for contested environments. This tutorial overviews the needed security proficiency elements for systems engineering with alignment to many of the concepts of INCOSE's security in the future of systems engineering efforts (INCOSE Insight June 2022).Meeting stakeholder needs within constraints of cost, schedule, and performance must include meeting the security protection needs derived from those stakeholder needs. Activities address loss concerns associated with the system-of-interest throughout its lifecycle, considering potential adversities. This includes developing an inherently assured trustworthy secure design that 1) avoids loss from occurring, 2) minimizes effects of loss that does occur and 3) is intrinsically easier to analyze for vulnerabilities and hazards during upgrades.The tutorial presents a principled strategic

approach focused on designing an intrinsically assured trustworthy design. This approach aids in realizing an intrinsically trustworthy secure system to help in prioritizations, reduce workload, and mitigate concerns of "unknowns" with assurance and thus producing trustworthiness in the system. This approach contrasts with widespread tactical risk-based approaches.This tutorial targets the experienced systems engineer who is a novice in Systems Security Engineering as a specialty discipline of systems engineering.

Biography

Mark Winstead (The MITRE Corporation) - mwinstead@mitre.org

Mark is the Systems Security Engineering department chief engineer in MITRE's Systems Engineering Innovation Center. He had over twenty-five years' STEM experience before joining MITRE in 2014, including stints as a crypto-mathematician, software engineer, systems architect, and systems engineer as well as occasionally working systems security engineering. Past employers include defense contractors, an EPA contractor, a Facebook-like start-up, a semi-conductor manufacturer, and a network performance management solutions company.

At MITRE, Mark has worked/works with various sponsors, helping programs with security engineering and teaming on integrating security into systems engineering for acquisitions and program offices. Recently, he has worked on advancing the systems engineering practice for security and resilience, working on Department of Defense (DoD) engineering standardization of practice and recently was asked to aid with an international effort in support of the US DoD.

With INCOSE, Mark serves as a co-chair of the INCOSE Systems Security Working Group, and at INCOSE IS 2023, was recognized with an Outstanding Service Award for work with advancing security and resilience within systems engineering.

Position Paper

Mark is co-author of NIST SP 800-160 Volume 1 Revision 1 Engineering Trustworthy Secure Systems, a publication intended to advance systems engineering in developing trustworthy systems for contested operational environments.

By IS 2024, Mark's book, Security: A Systems Engineering Approach is expected to be nearing publication by Wylie.

In the past, he has developed and delivered technical tutorials and other training for several employers and for customers, in recent years in security, cybersecurity and SSE. For INCOSE, he has delivered or co-delivered 7 INCOSE IS tutorials on the topic, as well as tutorials for chapters and regional conferences.

Tutorial#499

Systems Engineering for a Sustainable Future: Leveraging Emerging Technologies and Systems Modernization

Randall Anway (New Tapestry, LLC) - anwayr@gmail.com

Keywords. Semantic Computing;Bio-Inspired;Eco-mimicry;Sustainable;Trade-offs;Modernization

Topics. 1.3. Natural Systems; 10. Environmental Systems & Sustainability; 11. Information

Technology/Telecommunication; 17. Sustainment (legacy systems, re-engineering, etc.); 3.9. Risk and Opportunity Management; 5.11. Artificial Intelligence, Machine Learning; #AI

Abstract. By coalescing the fields of semantic computing, bio-inspired design, and systems evolution, the tutorial addresses the development of technological applications infused with ethical considerations, highlighting resilience against both environmental challenges and human-induced vulnerabilities, and aiming to support responsible innovation that generates social and environmental benefits.

Biography

Randall Anway (New Tapestry, LLC) - anwayr@gmail.com

Randall Anway

An active member of the American Institute of Architects, and the International Council on Systems Engineering, Randall serves in a variety of capacities supporting professional development and continuing education e"orts in the fields of architecture and engineering. He holds a Master of Architecture from the University of Illinois, Urbana-Champaign and Bachelor of Fine Arts from the University of Connecticut. A registered Architect licensed in New York and Connecticut, Randall's work draws on 30 years diverse experience wrestling with academic, corporate, non- profit, and small business design and design management challenges. Since 2011 he has been specializing in design research for managing architectural adaptation and change, synthesizing theoretical and concrete perspectives on natural and human- evolved patterns and systems, and evaluating emerging technologies.

Randall has been involved with the Natural Systems Working Group since 2014 and the Social Systems Working Group since 2019. Identifying organizational partners and key contributors jointly with the NSWG is an area of current and ongoing activity.

Position Paper

utorial Development and Delivery Team (TBD)

Semantic Computing Specialist: experience in large-scale data interpretations for deploying semantic technologies in environmental monitoring and systems modernization.

Systems scientist: experience implementing modernized technology in sustainable practices.

Visionary engineer or designer: experience applying state-of-the-art technical applications toward social impact.

Expert in Bio-Inspired Engineering: noted for their work in using biological systems as templates for technological innovation.

Global Environmental Sustainability Expert: noted for contributions to the field of environmental conservation, focusing on the application of innovative tech

Use a Framework for SE in Early-Stage R&D to Build Your Bridge that Spans the Chasm Between Research and Engineering

Ann Hodges (Sandia National Labs (ret); SE in Early-Stage R&D Working Group Co-Chair; Enchantment Chapter Secretary, Past President) - annlhod@gmail.com
Michael DiMario (CEO, Astrum Systems; Lucent Bell Labs, retired; Lockheed Martin, retired; SE in Early-Stage R&D Working Group Co-Chair) - mjdimario@outlook.com
Arno Granados (Strategic Technology Consulting; SE in Early-Stage R&D Working Group core member; Enchantment Chapter Past President) - Arno.granados@gmail.com

Keywords. SE in early-stage R&D;tailored approach;valley of death;research to engineering transition

Topics. 19. Very Small Enterprises; 3.5. Technical Leadership; 3.9. Risk and Opportunity Management; 5.5. Processes; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Researchers and funding sponsors often do not understand the value of SE in early-stage projects (TRLs 1-5), where SE is viewed as costly and solely applicable to mature technologies. This results in lack of engineering rigor and understanding innovation context leading to failures in transition of research to engineering. This tutorial presents a framework that creates a foundation to bridge the gap between research and engineering. Participants will apply this framework to a chosen case study.

Biography

Ann Hodges (Sandia National Labs (ret); SE in Early-Stage R&D Working Group Co-Chair; Enchantment Chapter Secretary, Past President) - annlhod@gmail.com

Ann Hodges retired after 48 years of service at Sandia National Laboratories (SNL) and was a distinguished member of technical staff. She was the Mission Services Division's systems engineering lead for the systems engineering part of the project and product delivery system (PPDS) at SNL and was a project manager and systems engineer for a complex exploratory-phase project. She is a primary author of the risk-informed graded approach to the application of project management, systems engineering, and quality management which is one of the key aspects of the PPDS. She collaborated with the Laboratory Directed R&D program office to tailor the application of PPDS to SNL's research portfolio.

Position Paper

Co-presented a tutorial on "Integrating SE, Project Management and Quality Management" to the INCOSE Enchantment Chapter in 9/2017 and INCOSE IS2018. Was project manager and SE for a complex exploratory-phase project and collaborated with the SNL Laboratory Directed R&D program office to tailor the application of PPDS to SNL's research portfolio. Co-developed PPDS instructional materials, and taught PPDS concepts to over 200 management and staff members. She co-chairs the SE in Early-Stage R&D Working Group and was co-editor and co-author of several papers in INSIGHT volume 26 issue 3, "SE in Early-Stage R&D: Bridging the Gap."

Michael DiMario (CEO, Astrum Systems; Lucent Bell Labs, retired; Lockheed Martin, retired; SE in Early-Stage R&D Working Group Co-Chair) - mjdimario@outlook.com

Dr. Michael DiMario is the founder and CEO of Astrum Systems, a global consulting venture focused on research and early development prototyping using a comprehensive systems approach. His corporate career began at General Electric Medical, progressed to Lucent Bell Laboratories, and Lockheed Martin. With a background in systems engineering, quality management, and software engineering, DiMario's career has

spanned the leadership and management of numerous critical R&D projects and organizations. Dr. DiMario has 6 patents, numerous corporate trade secrets, a published book on systems engineering, a book chapter on systems engineering, and 49 peer reviewed papers in regard to systems engineering, innovation, quantum magnetometry, and quality management.

Position Paper

Has 6 patents, numerous corporate trade secrets, a published book on systems engineering, a book chapter on systems engineering, and 49 peer reviewed papers in regard to systems engineering, innovation, quantum magnetometry, and quality management. Was a Lockheed Martin R&D Sr. Program Manager of early-stage R&D, Lockheed and Bell Labs Director. Co-chairs SE in Early-Stage R&D Working Group and was co-editor and co-author of a paper in INSIGHT volume 26 issue 3, "SE in Early-Stage R&D: Bridging the Gap." Co-author paper in INSIGHT vol 23 issue 3 "Perceived Conflicts of Systems Engineering in Early-Stage Research and Development."

Arno Granados (Strategic Technology Consulting; SE in Early-Stage R&D Working Group core member; Enchantment Chapter Past President) - Arno.granados@gmail.com

Arno Granados is currently a Senior Principal Systems Engineer at Strategic Technologies Corporation, where he applies more than 30 years of professional experience in systems and software engineering challenges to model-based systems engineering and digital transformation. His experience with R&D includes academic research, commercial product development, and defense systems and system of systems. His experience includes ground, airborne, and space-based systems, commercial product development, medical devices, and digital ecosystem architecture. He stood up an MBSE organization at SNL, and has been active in INCOSE as past president of a local chapter, and presenter at IW and IS.

Position Paper

Mr. Granados is a core member of the SE in Early-Stage R&D Working Group and co-author of two papers in INSIGHT volume 26 issue 3, "SE in Early-Stage R&D: Bridging the Gap". "Digital Engineering Enablers for Systems Engineering in Early-Stage Research and Development" and "A Bridge Blueprint to Span the Chasm Between Research and Engineering—A Framework for Systems Engineering in Early-Stage Research and Development" on which this tutorial is based. He was Director of Engineering at Cloud Cap Technologies successfully bringing two new products from early-stage development to the commercial market.

INCOSE Contents

Lightning Round introduction

Mark Sampson
Troy Peterson

Architecture starts when you carefully split a system into two subsystems. There it begins...

Maarten Bonnema (University of Twente) - g.m.bonnema@utwente.nl

Topics. Architecture; #SEFundamentals

Abstract. When systems become too large to be developed by a small team, the system needs to be split into smaller pieces. While this splitting can be done organically, it is much wiser to consciously create a system architecture. Such an architecture should promote coherence between the parts of the system. Also, the architecture should enable consistency in the development effort while allowing for concurrent development. In this talk we will explore the reasons for creating an architecture, the essential ingredients of an architecture, ways of describing an architecture, and discuss approaches for creating one.

Biography

Maarten Bonnema (University of Twente) - g.m.bonnema@utwente.nl

G. Maarten Bonnema is professor of Systems Engineering and Multidisciplinary Design (SEMD) at the Faculty of Engineering Technology at the University of Twente. He has worked as a Systems Engineer at ASML. His research aims at supporting system design, conceptual design and mechatronic design by improving multidisciplinary communication and systems thinking. Two main application areas are high-tech systems and electric mobility. He has a broad teaching expertise spanning design in general, industrial design engineering, and systems engineering.

Embrace Yourself! Our Responsibilities and Competencies as Complex Problem Solvers

Nicole Hutchison (Systems Engineering Research Center (SERC)) - emtnicole@gmail.com

Topics. Competencies, Career Paths, and Opportunities - giving early careers the bigger picture; #SEFundamentals; #TechnicalLeadership

Abstract. Over the last decade, the field of systems engineering has matured rapidly. As part of this, a number of systems engineering competency frameworks have been created with substantial overlap between the frameworks. As we gel as a discipline, we should also focus on the power that many systems skills bring. In particular, systems engineers should be good complex problem solvers (and according to the World Economic Forum, complex problem solving is – and has been - one of the top skills needed globally). This talk will talk about the skills required for complex problem-solving and highlight how you, as a systems engineer, are uniquely positioned to help our colleagues and organizations develop these skills.

Biography

Nicole Hutchison (Systems Engineering Research Center (SERC)) - emtnicole@gmail.com

Dr. Nicole Hutchison is a senior research scientist at the Systems Engineering Research Center. Her expertise lies in the areas of workforce development, specifically competencies and career paths. She has led and supported the creation of competency frameworks for systems engineering, mission engineering, digital engineering, and AI. Prior to joining the SERC, she worked for a defense contractor, supporting the US Departments of Defense, Homeland Security, Health and Human Services, and Justice.

Engineering in the Digital Age – Revolutionize Digital Engineering with MBSE

Prof. Dr.-Ing. Lydia Kaiser (Technische Universität Berlin) - lydia.kaiser@tu-berlin.de

Topics. MBSE and Digital Engineering; #SEFundamentals; #MBSE-DE;

Abstract. We live in the digital age, where interconnected, autonomous, and multimedia systems are the new reality. To meet the demands of the digital future, we need to revolutionize the way we engineer. Digital Engineering is poised to be a game-changer and promises to transform our industries, but it cannot succeed without MBSE. In these 30 minutes, we will take a look at the history of engineering and glimpse into its digital future. This presentation will introduce you to the fundamentals of MBSE, guiding you through its landscape and providing a roadmap for entry. It will address the most pressing questions: What exactly is a model? Why does everyone seem obsessed with SysML? Do I need to be fluent in SysML? What do I need to know to be able to talk about it and how do I start my own journey into MBSE? As well-educated engineers, stepping into your career or a new organization, you'll encounter new challenges: complexity, interdisciplinary collaboration, and an increasing number of cutting-edge technologies with immense potential and (unknown) risks. Discover how to deal with these challenges through Digital Engineering and why it demands MBSE. Shape the revolution in your organization and become a pioneer in this transformative field.

Biography

Prof. Dr.-Ing. Lydia Kaiser (Technische Universität Berlin) - lydia.kaiser@tu-berlin.de

Lydia Kaiser is the Head of the Digital Engineering 4.0 department at Technische Universität Berlin and the Einstein Center Digital Future. She teaches and conducts research in the field of digital engineering, focusing on Model-Based Systems Engineering.

She earned her degree in Physics from Paderborn University and completed her Ph.D. in 2013 in the area of Model-Based Systems Engineering. As a researcher, Lydia Kaiser worked with different industrial partners on research projects and developed new approaches to enable engineers to deal with complexity and interdisciplinarity. She trains engineers in various career steps in systems engineering and awakens enthusiasm for Model-Based Systems Engineering.

Engineering the Future

Paul Nielsen (Carnegie Mellon University) - nielsen@sei.cmu.edu

Topics. #SEFundamentals

Abstract. With the growth of complexity and interconnectedness, systems engineers find themselves on the frontiers of engineering. Furthermore today's systems engineers also need to balance legal, regulatory and social requirements. Fortunately, the practices, tools, and workforce are maturing to address these challenges. For the more experienced systems engineers, it is a time to reflect on how far we have come—because we truly have—and to partner with the next generation. For our newer colleagues, it is an exciting time to enter the field, and solve problems at the micro level, macro level, and global level. This presentation will attempt to motivate both groups, set the stage for the day, and presage the deeper presentations that will follow.

Biography

Paul Nielsen (Carnegie Mellon University) - nielsen@sei.cmu.edu

Dr. Paul D. Nielsen is the Director and CEO of Carnegie Mellon University's Software Engineering Institute. The SEI advances software engineering, cybersecurity, and artificial intelligence to support the US Department of Defense and the global community. Previously Nielsen served in the U. S. Air Force for 32 years, retiring as a major general. Nielsen is a member of the U. S. National Academy of Engineering and a Fellow of the American Institute of Aeronautics and Astronautics, IEEE, and the International Council on Systems Engineering. He received his PhD in computational plasma physics from the University of California, Davis.

Interfaces and the Somebody Else's Problem Field

Paul Davies (Thesystemsengineer.uk) - paul@thesystemsengineer.uk

Topics. Interfaces; #SEFundamentals

Abstract. Nobody working on a project wants to be tasked with resolving interfaces. It generally happens too late and is seen to be a root cause of project failures. These are sweeping generalisations, yet there is a grain of truth. It becomes a vicious circle of blame waiting for the next project to do the same. In effect, interfaces are often subject to the 'Somebody Else's Problem' field, described in 'Hitchikers' Guide to the Galaxy'. Every Interface is an opportunity to lose information, time, control and money through contention between stakeholders at either end. Interface management is perceived as a critical skill in the engineering of successful systems, but finding useful material proves elusive. It is not that there is a gap in the collective Body of Knowledge (BoK) – but there is definitely a gap in the documented BoK. This presentation explores characteristics of this gap, and strings together key concepts in best practice. Differences between best practice for interfaces and best perceived practice for architecting systems are noted with recommendations for changes in approach. The talk is based partly on the INCOSE Systems Engineering Handbook and partly on the INCOSE UK 'Don't Panic!' guide to managing interfaces, written by the.

Biography

Paul Davies (Thesystemsengineer.uk) - paul@thesystemsengineer.uk

Paul Davies is semi-retired, and was previously the Discipline Manager for Systems Engineering at Network Rail Infrastructure Projects. In that role he was responsible for promoting improvements in process and in practitioner competence in all aspects of systems engineering. Prior to this, he worked for Thales UK, with nearly thirty years' experience in SE research, innovations management, SE functional leadership, and project engineering management. Over a succession of challenging projects with challenging customers, Paul learned many empirical lessons on interfaces, internal and external to systems, and they are distilled here.

Paul is a Chartered Engineer, a Certified Systems Engineering Professional, a Past President of the UK Chapter of INCOSE, and has been a popular presenter and tutorial lead at many INCOSE events.

Lightning Round Q&A discussion

Mark Sampson
Troy Peterson

Requirements—Why Bother?

Dr. Mike Ryan (Capability Associates Pty Ltd.) - michael.ryan@incose.net

Topics. Requirements; #SEFundamentals

Abstract. The role of requirements in systems development is perhaps one of the most contentious issues in modern systems engineering. Some believe that formal requirements, particularly text-based requirements, are no longer necessary as part of modern development methodologies. Yet, others point out that the lack of adequate requirements has been shown to be one of the principal causes of project failure. So, who is correct? Why would a project team bother to expend all that effort and angst in developing requirements if they aren't necessary? This presentation will summarise the opposing perspectives and highlight the importance of a robust set of concepts, needs, and requirements in the design and development of a system of interest, as well as in the critical activities of verification and validation.

Biography

Dr. Mike Ryan (Capability Associates Pty Ltd.) - michael.ryan@incose.net

Dr. Michael Ryan is the Director of Capability Associates Pty Ltd. He lectures and regularly consults in a range of subjects including communications systems, systems engineering, requirements engineering, capability management, and project management. He is a co-chair of the INCOSE Requirements Working Group. Dr. Ryan is a Fellow of Engineers Australia, an INCOSE Fellow, a Fellow of the Institute of Managers and Leaders, a Fellow of the Royal Society of New South Wales, and a senior member of the IEEE. He is the author or co-author of 14 books, 4 book chapters, and over 450 technical papers and reports.

Systems Thinking: What Systems Engineers Need to Know

Dr. Michael C Jackson OBE (University of Hull) - m.c.jackson@hull.ac.uk

Topics. Systems Thinking; #SEFundamentals; #TechnicalLeadership

Abstract. Systems Thinking is an approach used to address complex real-world problems. According to INCOSE-UK, it is 'an essential skill for Systems Engineers … and provides a key intellectual underpinning for Systems Engineering'. Unfortunately, the literature associated with Systems Thinking can seem dense and more concerned with theoretical matters than practical application. This presentation seeks to cut through the academic noise and pinpoint the crucial features of Systems Thinking for Systems Engineers. There are four essential things that Systems Engineers need to know about Systems Thinking. First, that it developed as a complementary approach to science because the scientific method struggles in the face of complexity. Second, Systems Thinking has been successful in developing a range of systems methodologies (systems engineering, system dynamics, the viable system model, soft systems methodology, critical systems heuristics) that can engage with different aspects of complexity. Third, it is necessary to understand the strengths and weaknesses of these different methodologies and to use them in combination to bring about systemic improvement. Finally, such 'Critical Systems Thinking' requires a radical reorientation of mindset on the part of Systems Engineers.

Biography

Dr. Michael C Jackson OBE (University of Hull) - m.c.jackson@hull.ac.uk

Michael C. Jackson is Emeritus Professor at the University of Hull and MD of Systems Research Ltd. He graduated from Oxford University, gained an MA from Lancaster University and a PhD from Hull, and has worked in the civil service, in academia and as a consultant. Between 1999 and 2011, Mike was Dean of Hull University Business School, leading it to triple-crown accreditation. Mike has been President of the International Federation for Systems Research and the International Society for the Systems Sciences. He was editor-in-chief of Systems Research and Behavioral Science for 26 years. In 2011 Mike was awarded an OBE for services to higher education and business. In 2017 he received the Beale Medal of the UK Operational Research Society for 'a sustained contribution over many years to the theory, practice, and philosophy of Operational Research'. In 2022 he received the Pioneer Award of the International Council on Systems Engineering for 'the development of the foundations of systems engineering as author, educator and intellectual leader in systems thinking'. Mike is known as a key figure in the development of 'critical systems thinking' - a topic on which he has published ten books and over 150 articles. His last book Critical Systems Thinking and the Management of Complexity was published by Wiley in 2019. His new book Critical Systems Thinking: A Practitioner's Guide will be published by Wiley in 2024.