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Plenary featuring Keynote#2

Futurist

Langdon Morris

Presented on: Monday, 08:00-09:25 EDT

Biography

Langdon Morris

Langdon Morris is an award-winning innovator, futurist, and world-renowned strategy consultant. He is Senior Partner at InnovationLabs, where he leads the firm's global consulting practice with a wonderful variety of clients in business, government, and the non-profit sector. His original and ground-breaking work is being applied by corporations and universities on every continent.

Recent clients include Accor, Airbus, Bayer, France Telecom/Orange, ING, Ingersoll-Rand, Kaiser Pemanente, Leidos, L'Oreal, National Board of Medical Examiners, Stanford Health Care, Total Energies, UNICEF, US Navy, US Coast Guard, and many others.

He is also a founding partner of FutureLab Consulting, a strategy and technology firm that develops advanced AI solutions for global enterprises. He is Co-Chair of the Innovation Council at RedTeam Engineering, and in 2017-2018 he served as Innovation Coordinator at SUNY's Fashion Institute of Technology in New York.

Langdon has also written many highly acclaimed books. His most recent titles are The AI Nation and The AI Future, key works that examine the future of AI and its critically important strategic implications. His breakthrough white paper, “Business Model Warfare” is a landmark reference in the innovation field, and is now a renowned book. His book Fourth Generation R&D, coauthored with William L. Miller, is considered a classic in the field of R&D management, and other recent books include Hello, Future! The World in 2025, and Net Zero City.

He is formerly Senior Practice Scholar at the Ackoff Center of the University of Pennsylvania. He has taught MBA courses in innovation and strategy at the Ecole Nationale des Ponts et Chaussées in Paris and Universidad de Belgrano in Buenos Aires, and has lectured at universities on 4 continents. He earned his Master’s Degree in Urban Studies at the London School of Economics.

You can learn all about his work, publications, and keynote speeches at www.LangdonMorris.com

Plenary featuring Keynote#3

SE in practice

Jon Reijnevald (The Exploration Company (TEC))

Presented on: Tuesday, 08:00-09:25 EDT

Biography

Jon Reijnevald (The Exploration Company (TEC))

Jon Reijneveld is the Co-Founder and Chief Engineer at The Exploration Company (TEC), where he leads the engineering team in designing, developing, and operating innovative space capsules. With a master's degree in aerospace engineering from Delft University of Technology (TU Delft), Jon has specialized in space systems engineering.

Jon's career began at Airbus in Munich, where he worked on the European Data Relay System, managing the software for the control of the space and ground segment. He later joined the Orion Service Module (SM) team at Airbus Bremen as Deputy Chief Engineer, playing a crucial role in the qualification of the first module and leading the launch preparation campaign for Artemis I at Cape Canaveral.

Driven by a passion for advancing the space ecosystem in Europe, Jon co-founded TEC. Under his leadership, the engineering team at TEC implements practical systems engineering practices to rapidly produce innovative designs. TEC successfully launched its first capsule in July 2024 and is preparing for the launch of its second capsule in the summer of 2025. Jon and his team are currently working on their third capsule, Nyx Earth, with a planned demonstration flight to the ISS in 2028.

Plenary featuring Keynote#5

Sociotechnical

Dr. William Donaldson (Christopher Newport University)

Presented on: Thursday, 14:30-15:30 EDT

Biography

Dr. William Donaldson (Christopher Newport University)

Dr. William (Willy) Donaldson is an Associate Professor of Management at Christopher Newport University. Dr. Donaldson is the Director of the CNU Luter Business Institute and Director of the Biotechnology and Management Program. Willy has over 35 years of experience as a board member and CEO has been President of 8 companies, and helped start dozens of others. He has over 30 years of experience in higher education. Willy is the Founder and President of Strategic Venture Planning, a management consulting firm that assists boards, investors, families, and senior management teams to maximize results.

Dr. Donaldson’s research interest areas include Enterprise Management Systems, Corporate Universities and their impact on performance, Family business issues, dynamics, and transitions, Entrepreneurship and Innovation, Systems Thinking, and Corporate Governance and Board Performance.

Willy is the author of Simple_Complexity: A Management Book for the Rest of Us: A Guide to Systems Thinking, and Estimated Time of Departure: How I Talked My Parents to Death: A Love Story. He is the guest editor for a two-part Symposium for the Journal of Leadership Studies on leadership and systems thinking.

Plenary featuring Keynote#4

Space

Dr. Robert Thirsk (Canadian Space Agency)

Presented on: Wednesday, 08:00-09:25 EDT

Biography

Dr. Robert Thirsk (Canadian Space Agency)

Dr. Robert Thirsk received degrees in Mechanical Engineering, Medicine and Business Administration from the University of Calgary, MIT and McGill University. Bob has flown on two spaceflights: a mission aboard the shuttle Columbia and an expedition aboard the International Space Station. Although he is now retired from active duty, he continues to promote a role for Canada in the delivery of remote health care to astronauts who will someday venture to deep space on missions of discovery. Bob advocates for a national economy based upon exploration, innovation and lifelong learning.

Papers

Paper#87

A Digital Engineering Methodology for Design, Exploration and Validation of Safety-Critical Software for Integrating AI-based Algorithms

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Presented on: Tuesday, 16:00-16:25 EDT

Keywords. Safety;MBSE;AI/ML;Quantitative safety assessment;AI/ML validation;OD;ODD

Topics. 2. Aerospace; 3. Automotive; 4.6. System Safety; 5.11 Artificial Intelligence, Machine Learning; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 6. Defense;

Abstract. A strong shift towards the usage of AI/ML techniques is observed in a variety of applications and domains ranging from systems health monitoring, and fuel optimization up to novelties like collision avoidance and Unmanned Air Mobility. Developing such systems is challenging given the required levels of safety, autonomy, and the complexity of the environmental conditions. To provide guidance, standardization bodies like SAE and ISO work on guidelines for AI/MLs integration into safety-critical systems (e.g., ED-324/ARP6983 in aeronautics, ISO/PAS-8800 in automotive). In this work, some AI/ML challenges are first surveyed including limited embedded HW resources and the AI/ML uncertainty. Then, a modular, iterative Digital Engineering Methodology based upon SysML® v2 is introduced to support AI/ML design and development. The methodology is aligned with the Department of Defense Digital Engineering Directive 5000.97 and the standard MIL-STD-881F for structuring work breakdown. To ensure datasets quality, the methodology includes validation of the Operational Design Domain (ODD) properties like completeness, representativeness, and independence. To characterize the ML model, techniques are applied to assess stability, generalization, and robustness. Last, to validate system safety a probabilistic scenario-based method is introduced to ensure the ML performance remains within safety thresholds. The approach is illustrated by a formation flying Use Case integrating a Reinforcement Learning model, and some MBSE techniques for engineering requirements, system, architecture, and ODD. Some perspectives towards the consolidation of the proposed methodology and to foster AI/ML maturity are finally given.

Paper#336

A Double-Helix Model for the V&V of Physical and Digital Twins

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Presented on: Tuesday, 16:30-16:55 EDT

Keywords. Digital twin;verification and validation (V&V);systems theory

Topics. 1.5. Systems Science; 2. Aerospace; 2.6. Verification/Validation; 5.4. Modeling/Simulation/Analysis; 6. Defense;

Abstract. The term digital twin has increasingly been misused, often reduced to merely representing a model of a system, thereby diluting its intended meaning and potential. This conflation has led to misconceptions about the role of digital twins in systems engineering, particularly in the context of verification and validation (V&V). Some argue that a digital twin can verify a system, yet this view fails to recognize the bidirectional nature of the digital twin's relationship with its physical counterpart. In this paper, we introduce the Double-Helix Model for V&V of Physical and Digital Twins, a framework that emphasizes the mutual V&V process, where each twin inherently must be used to V&V the other. By clarifying the proper role and definition of digital twins, this paper aims to advance their application in systems engineering practices.

Paper#232

A Framework for Seamless Interoperability: Linking Mission Models, System Models, and High-Fidelity Simulations for Defense Applications

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

Keywords. SysML Integration;UAV Simulation;Model-Based Systems Engineering (MBSE);Digital Thread;Simulation Validation;Systems Engineering Framework

Topics. 5.3. MBSE; 5.4. Modeling/Simulation/Analysis;

Abstract. In the rapidly evolving domain of defense systems, operational success increasingly relies on the integration of complex subsystems to meet mission objectives. The Department of Defense (DoD) has embraced digital engineering and model-based systems engineering (MBSE) to manage this complexity, focusing on modeling and simulation for comprehensive system assessments. However, challenges persist due to the lack of seamless interoperability between mission-level models, system models, and high-fidelity simu-lations, often resulting in a disjointed toolchain and manual workarounds that hinder continuous verification and validation. This paper proposes a framework to connect mission models in Cameo (MagicDraw) with system models in MathWorks System Composer and simulations in Simulink, enabling end-to-end traceability and real-time feedback on system configurations.

Paper#179

A Framework for Structuring Research Campaigns Leveraging Model Based Systems Engineering

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Presented on: Thursday, 13:30-13:55 EDT

Keywords. MBSE;Research;Development;Traceability;Framework

Topics. 1.1. Complexity; 2.3. Needs and Requirements Definition; 2.4. System Architecture/Design Definition; 5.1. Agile Systems Engineering; 5.3. MBSE; 6. Defense;

Abstract. This manuscript presents a novel application of Model-Based Systems Engineering (MBSE) to define and execute a campaign of research aimed at addressing an ambitious system design end state. Unlike traditional approaches that begin with fixed requirements, the methodology adopts an evolutionary approach to investigate the "art of the possible." Starting with a high-level description of the end state, a series of derived research questions are defined that must be sequentially answered to achieve the final goal. These questions serve as the foundation for defining research activities, each designed to address one or more questions while incrementally advancing understanding of the solution space. Leveraging MBSE ensures traceability between research questions, research activities, and evolving system architectures, as part of a robust framework for managing complexity.

Each research activity is conducted using a specific prototype system. The architecture of that system is developed to address the scope of the research questions being asked. Initial research activities focus on simpler questions and employ straightforward architectures, establishing baseline knowledge and proof-of-concept capabilities. Subsequent research activities build on these foundations, progressively increasing in complexity as they address more challenging research questions. This incremental, evolutionary approach enables the systematic refinement of design concepts and technologies, while reducing risk and uncertainty as system design progresses towards the desired end state.

The methodology departs from traditional verification and validation (V&V) practices by focusing on exploratory research rather than verifying predetermined requirements. Instead, the aim is to probe the feasibility and potential of emerging ideas and technologies. A case study demonstrates the effectiveness of this framework, highlighting how an applied MBSE approach can guide complex research campaigns with clarity and precision. The results emphasise the value of this approach in system development for ambitious use cases that may otherwise be unattainable.

Paper#315

A Metamodel for ilities

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

Keywords. System Architecture;ilities;Model-Based Systems Engineering (MBSE)

Topics. 1.5. Systems Science; 2. Aerospace; 2.4. System Architecture/Design Definition; 5.4. Modeling/Simulation/Analysis; 6. Defense;

Abstract. This paper addresses the transformation of systems architecture from intuition-driven to scientifically grounded practices, highlighting the importance of structured frameworks due to increasing complexity in technology systems. It advocates for a “scientification” of architecture, using quantifiable methods to enhance system ilities. To achieve this, we present a metamodel for use in Model-Based Systems Engineering (MBSE). It serves as a standardized framework to represent architectural elements, support interdisciplinary collaboration, and ensure alignment with stakeholder needs. Principal objectives include enabling rigorous validation, early architectural assessments, and systematic knowledge repositories for predictable design outcomes. The metamodel standardizes architectural concepts and their relationships and promotes a universal understanding and collaborative development of them. It provides a conceptual framework that enables embedding structured scientifically grounded bodies of knowledge and approaches into the systems engineering process, facilitating data-driven decisions, improving transparency, and reducing risks associated with late-stage design decisions. It enables continuous enhancement of bodies of knowledge to support dynamic, scalable, and repeatable engineering processes that keep pace with evolving system demands.

Paper#6

A proposal for making an information model for an acquisition organization

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

Keywords. Acquisition;Information model;Modelling;Digitalization

Topics. 3.3. Decision Analysis and/or Decision Management; 3.4. Information Management Process; 5.3. MBSE; 6. Defense;

Abstract. Norwegian Defence Materiel Agency (NDMA) acquires military systems for use in the Norwe-gian Armed Forces (NAF). Acquisitions are organized as projects, and at any given time, more than 200 projects of varying complexity are running. Projects last for several years, and a lot of information is created and shared between NDMA, NAF, and the suppliers during the project phases. The goal of the research was to create an information model by collecting information elements from existing processes and presenting them in a coherent model. The information model is described in three different ways using systemigram, logical model, and physical mod-el. Main benefit of the information model is to shorten the project time, we made an estimation of time saved (up to 19%) by using Constructive Systems Engineering Cost Model. The proposed model was tested during a 5-hour-long training session and validated during a workshop session. Further validation of the proposed information model on a complete project is required

Paper#304

A Survey on MBSE Adoption Challenges in the INCOSE Asia and Oceania Sector

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Presented on: Wednesday, 15:30-15:55 EDT

Keywords. MBSE Adoption Challenges;MBSE;Lesson Learnt;Experience;Hofstede;Cultural Dimensions

Topics. 5.10. Diversity (cultural boundaries, diverse engineering teams, training underserved groups, etc.); 5.3. MBSE; Other domain;

Abstract. This survey work investigates challenges practitioners and organizations face in the adoption of Model-Based Systems Engineering (MBSE) in the Asia-Oceania sector, aiming to determine whether these challenges differ in nature or significance compared to those in the Americas and EMEA regions. The work highlights the critical role of cultural dimensions and geographical factors, aspects that have been underexplored in prior studies. Drawing on survey data and existing frameworks, this work seeks to enhance understanding of regional differences and contribute to more effective, context-sensitive MBSE adoption strategies.

Paper#147

A System-of-Systems Modeling, Simulation and Data Analytics Framework for Resilient Sustainment and Support Readiness Strategies

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Presented on: Tuesday, 14:30-14:55 EDT

Keywords. System of Systems;Simulation;Defense;Logistics;Sustainment;MRO;IoT;Data Analytics;Decision Support

Topics. 3.3. Decision Analysis and/or Decision Management; 5.4. Modeling/Simulation/Analysis; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. In today's strategic defense environment, the rapid deployment and sustainment of aircraft fleet operations are critical to maintaining mission readiness. These operations require the optimization of multiple factors, including mission intensity, equipment configuration and reliability, spare parts logistics, maintenance quality, and personnel availability.
INCOSE “Vision 2035” emphasizes the growing need for system resilience in the face of increasing complexity and highlights the evolving role of systems engineering in addressing sustainment and operational challenges through a holistic life cycle perspective.
This paper introduces a framework and case study leveraging System of Systems (SoS) modeling and simulation to enhance sustainment and support readiness for aircraft fleet operations. By integrating Model-Based Systems Engineering (MBSE) with the Unified Architecture Framework (UAF), System Modeling Language (SysML), model execution, and stochastic simulations, the study demonstrates advanced "what-if" analyses to optimize logistics flows across geographically dispersed partners. Additionally, the incorporation of real-time data from logistics, maintenance and repair operations enhances virtual models, enabling efficient resource management and ensuring sustained mission readiness under diverse operational conditions.

Paper#337

A Systems Engineering Framework for Navigating Complexity

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Presented on: Tuesday, 16:30-16:55 EDT

Keywords. Complex Systems;Cynefin Framework;Pleko;Complex;complicated;chaos

Topics. 1.1. Complexity; 3.7. Project Planning, Project Assessment, and/or Project Control; 4.2. Life-Cycle Costing and/or Economic Evaluation; 9. Enterprise SE (organization, policies, knowledge, etc.); Other domain;

Abstract. Language is the foundation of understanding. The Cynefin Framework is a popular framework, primarily designed to help leaders make strategic decisions in complex systems. Its popularity can be associated with the simplification of many complexity concepts into an accessible framework. It uses as its foundation the simple, complicated, complex and chaotic terms as defined by Snowden in 1999. The INCOSE Complex Systems Working Group has been working on Complexity understanding and how it relates to Systems Engineers since 2006. This work has led to the evolution of these terms within INCOSE. This paper explores how the developmental approaches used by Snowden to create the Cynefin framework can be used with the most recently defined terms to develop a new tool that is more relevant to engineers in navigating complexity. This work led to the development of the Pleko framework. The Pleko Framework was tested by user-testing and comparison to other engineering models. Initial results indicate that the Pleko framework aligns with the Systems Engineering insights captured in the respected COSYSMO model, and is a simple useful tool that could accelerate engineers understanding in handling, navigating and reducing the cost of complexity.

Paper#373

A TMBR-based, Semiformal Method for Early Requirements Definition of Training Simulators

Władysław Sowul (Military Aviation Works no. 2) - wladyslaw@sowul.net

Presented on: Wednesday, 11:30-12:10 EDT

Keywords. Training Simulator;Requirements;Semiformal Method;Model-based Requirements

Topics. 2. Aerospace; 2.3. Needs and Requirements Definition; 4.1. Human-Systems Integration; 5.3. MBSE; 6. Defense; Other domain;

Abstract. This paper introduces a semiformal methodology for defining requirements early for training simulators, leveraging the True Model-Based Requirements (TMBR) paradigm. Training simulators, often developed concurrently with their target systems, require solution-agnostic and system-independent requirements. This dual development process is challenged by incomplete knowledge of the simulated system's behavior and design. The proposed method addresses these challenges by adopting a human-centric approach to model key input/output requirements, ensuring the simulator replicates the target system's functional and experiential characteristics.

The methodology enables iterative transformations from the simulated system's models to the training simulator's requirements, allowing continuous updates as the target system evolves. Sensory-based interface modeling and signal decomposition are used to accommodate human factors while maintaining unambiguous, verifiable requirements. Stakeholder needs and constraints are integrated, ensuring practical alignment with real-world applications.

The findings align with INCOSE SE Vision 2035, promoting adaptable and interconnected systems engineering practices. By integrating human-centric and model-based techniques, the method enhances the rigor and completeness of requirements engineering, contributing to the advancement of Model-Based Systems Engineering (MBSE).

Paper#154

A3 Overviews for Communication in Development Projects – a Study from a Small Norwegian Company

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

Keywords. A3 Architecture Overview;Project Overview;Mine warfare;Minesweeping;Unmanned Systems;System Development

Topics. 13. Maritime (surface and sub-surface); 2.4. System Architecture/Design Definition; 6. Defense;

Abstract. Abstract. The German Navy’s current Mine Countermeasures (MCM) systems are reaching the end of design life, and new systems are to be developed. WTD 71, the German Navy’s Research Institute, is to do this development and is investigating possibilities for unmanned systems. In this process, H. Henriksen AS has been chosen as the industrial partner to develop and manufacture the physical system.
In this paper, we explore how the A3 Architecture Overview (A3AO) method can be used for com-munication in developing a new unmanned minesweeping system. Through interviews and obser-vations in a small Norwegian company in the marine and naval industry, we found challenges related to system and project overviews. These were mostly caused by communication challenges and a lack of common understanding among stakeholders. We also identified a knowledge gap in the subject of minesweeping. To support the challenge of not having an overview of the system, we developed and tested A3AOs. Further, we altered the traditional A3AO to communicate the subject of minesweeping and an overview of the project. The industry resources appreciated the overviews and reported that they believed such methods would create value in projects.

Paper#303

Accelerated Automotive Battery Development to meet Market Opportunities

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Presented on: Tuesday, 14:30-14:55 EDT

Keywords. Model-based systems engineering;system model;automotive;battery;failure mode;verification;linked data management platform

Topics. 2.4. System Architecture/Design Definition; 2.6. Verification/Validation; 3. Automotive; 5.3. MBSE;

Abstract. This paper describes a system-model-based verification method to support and accelerate the development of automotive batteries. Descriptive system architecture models, named system models, are typically created in early system design phases to enhance collaboration between all involved parties, to further specify the system, and to have a basis for further development ac-tivities, such as the definition of failure modes as a starting point for verification activities. These system models are created using model-based systems engineering methods. The created system model, the failure mode definition, the derivation of test cases and the platform to link all these development artifacts and provide them to the development process are discussed in this paper.

Paper#197

Accelerating Model-Based Systems Engineering with Large Language Models

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Presented on: Thursday, 10:45-11:15 EDT

Keywords. SysML V2;Systems Engineering;Natural Language Processing;LLMs;Automatic Code Generation;CodeT5;GPT-4;ChatGPT;Artificial Intelligence

Topics. 5.11 Artificial Intelligence, Machine Learning; 5.12 Automation; 5.3. MBSE;

Abstract. Model-Based Systems Engineering (MBSE) is a cornerstone of modern systems engineering, enabling the design and management of increasingly complex systems. However, creating models with System Modeling Language (SysML) V2 remains a highly manual and time-intensive process. As system complexity increases and interdisciplinary collaboration becomes critical, streamlining workflows and accelerating the modeling process are more important than ever. This paper investigates the use of two classes of Large Language Models (LLMs)— the general-purpose reasoning model, GPT-4, and the domain-specific fine-tuned model, CodeT5, to assist in generating SysML V2 models from natural language descriptions. Our findings reveal that while LLMs can generate initial "skeleton" models, relying solely on AI for entire model generation is not advisable due to critical errors and inconsistencies in the generated outputs. Instead, LLMs serve as effective tools for accelerating the modeling process by producing foundational prototypes that can be refined and improved through human intervention. With fine-tuning techniques for CodeT5 and prompt engineering for GPT-4, we evaluate their performance across key dimensions of syntax accuracy, semantic alignment, and structural correctness. Using a diverse set of metrics and statistical analyses, we identify the trade-offs between task-specific optimization (CodeT5) and broader contextual reasoning (GPT-4). The potential of LLMs as accelerators in MBSE workflows cannot be ignored with the “early” modeling capabilities they present. This work contributes to the growing intersection of AI and MBSE, offering practical insights into the selection and application of LLMs in systems engineering and paving the way for future advancements in the field.

Paper#314

AI outperforms 60 se graduates in creating causal loop diagram of janis groupthink phenomenon

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Presented on: Wednesday, 14:30-14:55 EDT

Keywords. Artificial Intelligence;System Dynamics;Causal Loop Diagram;LLM;Groupthink

Topics. 1.4. Systems Dynamics; 1.5. Systems Science; 1.6. Systems Thinking; 2.1. Business or Mission Analysis; 2.3. Needs and Requirements Definition; 22. Social/Sociotechnical and Economic Systems; 3.3. Decision Analysis and/or Decision Management; 5. City Planning (smart cities, urban planning, etc.); 5.11 Artificial Intelligence, Machine Learning; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 8. Energy (renewable, nuclear, etc.);

Abstract. This study examines the capacity of advanced artificial intelligence (AI) systems, specifically Mix-ture-of-Experts (MoE) models like Google's Gemini Advanced, to generate and analyze Causal Loop Diagrams (CLDs) at a level comparable to human experts. We evaluate Gemini Advanced's perfor-mance by tasking it with constructing a CLD from Irving Janis's (1982) seminal work on "groupthink." The resulting CLD was compared against those produced by a cohort of 60 graduate students with 10 to 15 years of industry experience, who completed the same task as part of a graduate-level systems thinking course. Our objective was not to analyze Janis per se, but rather use it as a vehicle for testing our hypothesis that AI can outperform graduate students in the development of causal loop diagrams from complex source material.
Our findings demonstrate that Gemini Advanced significantly outperformed the student cohort, identifying a greater number of valid causal links and feedback loops. Notably, the AI identified subtle causal relationships embedded in Janis's text that were separated by several pages, highlighting its capacity for complex textual analysis and synthesis. This suggests that large language models like Gemini Advanced possess the potential to revolutionize the use of the Causal Loop Diagram by uncovering hidden relationships and generating novel hypotheses that may elude human investigators.
This research also raises important epistemological questions regarding the role of AI in scholarly research. How can AI-generated insights be rigorously validated and integrated into established sci-entific methodologies? Can AI contribute to knowledge creation in a way that is both reliable and ethically sound? We discuss these challenges and propose future research directions to explore the evolving relationship between AI and academic scholarship, particularly within the context of Mod-el-Based Systems Thinking (MBST).

Paper#41

AI Starter Kit and Caveats for the Systems Engineer

Sarah Sheard (Retired) - sarah.sheard@gmail.com

Presented on: Tuesday, 16:30-16:55 EDT

Keywords. SE & AI;Getting Started;AI caveats;AI Cautions;AI Examples;Artificial Intelligence

Topics. 14. Autonomous Systems; 2.3. Needs and Requirements Definition; 5.11 Artificial Intelligence, Machine Learning; 5.12 Automation; 5.5. Processes; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. AI, and in particular, generative AI, burst abruptly onto the systems engineering scene. The first generative AI made available to the general public just six years ago, yet McKinsey estimates that almost three quarters of all companies use it in at least one of their business units. Engineers are adjusting to this phenomenal rate of change while trying to get their normally fast-paced work done. This paper is intended to provide a brief introduction to the INCOSE member as to how this all happened, how AI can help within the systems engineering life cycle, what cautions and caveats apply, and the results of an experiment with submitting three SE-related questions to 3 popular AI models. The paper results in recommendations for practitioners, managers, and INCOSE regarding AI adoption.

Paper#313

An Architecting Book of Knowledge (BoK) to Improve Architectural Decision-Making

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

Keywords. architecture;body-of-knowledge;design;model-based systems engineering (MBSE)

Topics. 2. Aerospace; 2.4. System Architecture/Design Definition; 3.1. Acquisition and/or Supply; 3.3. Decision Analysis and/or Decision Management; 6. Defense;

Abstract. To advance architecting from its current heuristics-based mode to a principles-based mode, the community needs to establish, this paper presents a systematic approach to architectural decision-making within the framework of a Book of Knowledge (BoK) and highlights how such decisions can shape complex systems over time. It emphasizes the need for a community-driven database of architectural knowledge, where best practices, patterns, and insights from past decisions can inform future work. Using a structured approach, the document outlines the Comprehensive Architecture Strategy (CAS), which aids architects in documenting and analyzing key elements such as patterns, ilities, and rules that govern architectural decisions. By breaking down architectural processes into well-defined components, CAS provides a standardized way to assess the impact of design choices on system ilities, supporting informed decision-making and enabling consistency across architectural projects.

Paper#165

An Initial Exploration of MULTI Level Modeling for Model-Based Systems Engineering

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Presented on: Tuesday, 10:40-11:00 EDT

Keywords. Model-Based Systems Engineering;MULTI;Traceability;RFLP;SysML

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

Abstract. Model-Based Systems Engineering (MBSE) is seen as a way of addressing the complexity of traditional document-centric development in Systems Engineering (SE). MBSE offers easier formalization of knowledge, higher abstraction, and tool support, allowing automated analysis and integration of arti-facts across different domains. However, the adoption of MBSE is hindered by the need for manually creating new models in semi-formal languages like SysML, which should cover all domains. Thus, a different modeling principle, like Multi-Level Modeling (MULTI), could ease the creation of different models, as MULTI enables modelers to abstract concepts over more than just one model. In this paper, we explore MULTI as a modeling paradigm for MBSE by applying it to a running example from the Construction Equipment (CE) domain. We analyze and contrast MULTI to the existing modeling implementation. We conclude that the MULTI paradigm opens MBSE to support traceability, re-use, verifiable design documents, and may improve communication with stakeholders. Further, we discuss future applications of MULTI and how it might be transferred to industrial settings.

Paper#324

Analyzing Systems Engineering Vision 2035 Through a Cultural Lens

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

Keywords. SE Vision;FUSE;Culture;China;Japan

Topics. 1.6. Systems Thinking; 22. Social/Sociotechnical and Economic Systems; 5.10. Diversity (cultural boundaries, diverse engineering teams, training underserved groups, etc.);

Abstract. The INCOSE Systems Engineering Vision 2035 and its associated initiatives, including the Future of Systems Engineering (FUSE), outline a roadmap for the discipline's future. While these documents aim to provide a global perspective, their content reflects a predominantly Western cultural lens, potentially limiting their applicability in non-Western contexts. This article critically analyzes SE Vision 2035, identifying cultural biases and proposing strategies to make systems engineering more inclusive and adaptable to diverse cultural paradigms. By leveraging comparative studies between Eastern and Western systems engineering practices, the article advocates for a broader, more representative approach to shaping the future of the field.

Paper#59

Application of A Verification Complexity Framework

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Presented on: Monday, 15:30-16:10 EDT

Keywords. verification;modelling;complexity;verification complexity

Topics. 1.1. Complexity; 2.6. Verification/Validation;

Abstract. Complexity is a core characteristic of concern for systems engineering practice. Verification, while a pervasive process in the engineering of systems, has been given relatively less research focus in terms of its complexity than system complexity has. We have proposed the Verification Complexity Framework as a formal definition of verification complexity to initiate a dialogue on distinguishing verification complexity from system complexity. The framework is designed to cover both static and dynamic complexity through the time axis and the hierarchical complexity layers, covering from external effects to the verification structures. This framework provides a common vocabulary for verification complexity, where both its definition and measurements can be discussed. In this paper, we showcase the application of VCF to a notional project.

Paper#118

Applying Systems Engineering to Systems Engineering Graduate Course Development

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Presented on: Thursday, 09:45-10:25 EDT

Keywords. Systems Engineering Process Application;Education and Training;Product Line Architecture;Agile Development

Topics. 1. Academia (curricula, course life cycle, etc.); 2.1. Business or Mission Analysis; 2.3. Needs and Requirements Definition; 2.4. System Architecture/Design Definition; 2.6. Verification/Validation; 5.6. Product Line Engineering; 5.9. Teaching and Training;

Abstract. Applying systems engineering technical processes and approaches to course design results in quality courses that satisfy learning needs and provide effective learning experience. We demonstrate this with successful application to a systems engineering graduate class. We use the technical processes starting with needs analysis through operations and maintenance. We use product line engineering techniques to define architecture with shared asset assessments and variation points for delivery instantiation. We use agile development to implement backward design techniques with primary focus on assessments followed by content delivery. We validate that the learning needs have been satisfied with the initial delivery of the course.

Paper#53

Applying Systems Thinking and Soft Systems Methodology to Explore the Complexity of Innovation in the Defense Industry

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Presented on: Tuesday, 05:30-05:55 EDT

Keywords. Systems Thinking;Complex Systems;Soft Systems Methodology;CATWOE;Systemic Diagram;Innovation;Defense

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

Abstract. The defense industry experiences rapid technological advancements in a dynamic environment with numerous multi-layered and interconnected forces. Therefore, it can be seen as a complex system. The innovative, cyber-physical systems developed undergo strict requirements and testing, thus making the development efforts both time-consuming and, at times, a barrier to innovation. Given the military’s need for swift responses to armed conflict situations, there is a desire for a more expedient deployment of cyber-physical systems within the operative context. To achieve this, product developers must grasp a holistic view of the problem domain.

This research employs Systems Thinking and Soft Systems Methodology (SSM) to explore the complexity of innovation within the realm of product development in the defense industry. We initially evaluated the complexity through the first steps in Soft Systems Methodology, following a prose description and creating a descriptive picture used to reason about the system boundaries. Through a combination of this methodology and CATWOE, we generated a conceptual model in the form of a systemic diagram.

The result of this research is a foundation that can be utilized in further exploration of the perceived problem and future research. This provides a critical understanding necessary for fostering innovation and efficiency in the development and deployment of cyber-physical systems within the defense industry.

Paper#167

Appropriate Simulation Model Identification during Model-Based Systems Engineering

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Presented on: Thursday, 14:00-14:25 EDT

Keywords. MBSE;Simulation;Decision-Making;Models;Appropriateness

Topics. 5.3. MBSE; 5.4. Modeling/Simulation/Analysis;

Abstract. Model-Based Systems Engineering (MBSE) hinges on the use of models during development. Models enable several capabilities during development through concrete formalization of knowledge and data, while at the same time offering communication and reasoning support from application of abstraction. A primary capability enabled by models is simulation, and as a result simulation is promoted by many MBSE methodologies to support iterative decision-making during design. Nonetheless, simulation is a very complex capability, that requires significant investment in tooling and training. Likewise, enabling credible and valid simulation is a significant challenge in terms of progressive application during decision-making in development. In this article, we leverage the notion of appropriateness in the system modelling community and transfer these principles towards simulation as a tool in MBSE. We offer a pragmatic checklist for practitioners to apply and guide them in the construction and application of simulation technologies in MBSE and discuss the consequences of certain decisions for simulation model identification.

Paper#389

Artist Intellectual Property Rights Protection & GenAI: A Systems Approach

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Presented on: Wednesday, 11:30-12:10 EDT

Keywords. systems thinking;cognitive algorithms;generative AI;artificial intelligence;comics;copyright;free Use;traditional value stream;algorithmic value stream

Topics. 1.4. Systems Dynamics; 1.6. Systems Thinking; 20. Industry 4.0 & Society 5.0; 22. Social/Sociotechnical and Economic Systems; 5.11 Artificial Intelligence, Machine Learning; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. The rise of generative AI large language models (LLMs), such as ChatGPT, has sparked legal and ethical debates over copyright infringement. Artists argue that these systems exploit their intellectual property (IP), while developers maintain their methods are non-expressive, thus avoiding direct legal violations. However, the training of AI on human-generated media patterns raises fundamental questions about the ownership of artistic algorithms and patterns—the cognitive frameworks that define an artist's style and creative fingerprint. These patterns, the result of years of practice and innovation, are appropriated by AI systems without proper recognition or compensation. This paper employs a systems approach to investigate these issues, analyzing the interplay of sociotechnical factors—technological, legal, and social—underpinning the tension between generative AI and artist IP rights. By framing the problem as a system with interdependent components, this research explores the pathways through which artists can assert ownership, developers can adopt fair practices, and legal frameworks can evolve to protect artistic integrity.

Paper#227

Assessing Management Measures in Large-Scale Residential Facilities: An SNS-Driven Evaluative Approach

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Presented on: Tuesday, 14:00-14:25 EDT

Keywords. Residential Facility Management;Social Networking Services (SNS);User Behavior Analysis;Hierarchical Clustering;Impact Assessment

Topics. 1. Academia (curricula, course life cycle, etc.); 2.3. Needs and Requirements Definition; 2.4. System Architecture/Design Definition; 3.6. Measurement and Metrics; 4.3. Reliability, Availability, and/or Maintainability; 4.5. Competency/Resource Management;

Abstract. This research proposes a novel approach to assess management measures in large-scale residential facilities using resident-exclusive Social Networking Services (SNS) data. The study develops a three-domain model ("User-Subjective-Objective") adapted from Wada's "Val-ue-Function-Activity-Entity" model to analyze resident interactions and behaviors within the SNS environment. The methodology consists of three main components: modeling the resident ex-clusive SNS, clustering users based on their browsing behaviors and developing a framework for quantitatively assessing management measures. The study employs Hierarchical Clustering Analysis to group users based on their temporal browsing patterns and introduces a method to evaluate management measures through "degree of interest fulfillment." The research applies this methodology to a case study in the Tokyo Metropolitan Area, analyzing SNS data from 495 users over a one-year period, complemented by survey responses from 78 residents. The results demonstrate the effectiveness of the approach in identifying distinct user clusters and evaluating different management measures, such as "House Reform" and "Mix Bazaar" initiatives. The findings highlight the value of integrating SNS data analysis into residential facility management, offering a more dynamic and responsive approach to understanding resident needs and evaluating management strategies' effectiveness.

Paper#283

Authoritative Broker of Truth (ABoT): Synchronizing Model-Based System Engineering with Cross-Disciplinary Simulation to Create Digital Twins

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Presented on: Wednesday, 13:30-13:55 EDT

Keywords. Digital Twins;Model Based System Engineering (MBSE);Data Analysis;User Experience Designer;Virtualization;Simulation;Authoritative Source of Truth;Validation;Verification and Uncertainty Quantification (VVUQ)

Topics. 11. Information Technology/Telecommunication; 18. Service Systems; 2.6. Verification/Validation; 3.3. Decision Analysis and/or Decision Management; 5.4. Modeling/Simulation/Analysis; 6. Defense;

Abstract. Building digital twins is a cross-disciplinary endeavor, combining the efforts of modelers, system engineers, data analysts, UX designers and domain experts. For digital twins to be able to evolve with their paired, real-world system, the artifacts associated with these various disciplines must remain synchronized and coherent throughout the digital twin lifecycle. We provide a paradigm for harmonizing this multi-disciplinary effort using an Authoritative Broker of Truth (ABoT) and apply this paradigm to a real-world case study: Can I cut the cord on my cable provider and receive free over-the-air television?

Paper#137

Automated Legacy Documentation to SysML Conversion

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Presented on: Thursday, 11:20-11:50 EDT

Keywords. SysML;Model-Based Systems Engineering;Large Language Model;Documentation

Topics. 1. Academia (curricula, course life cycle, etc.); 17. Sustainment (legacy systems, re-engineering, etc.); 5.11 Artificial Intelligence, Machine Learning; 5.3. MBSE; 6. Defense;

Abstract. The digital transformation of systems engineering requires converting legacy documentation into standardized models, but manual conversion remains time-intensive and error-prone. This paper introduces an automated pipeline that transforms unstructured documentation into SysML Block Definition Diagrams using Large Language Models (LLMs) and graph theory-based optimization. The system employs proposition-based retrieval augmented generation with smart transitive reduction for relationship refinement, achieving F1 scores of 0.95 for element identification and 0.85 for relationship extraction on test documents. Furthermore, we show that given enough compute, this pipeline can be parallelized into constant time in terms of LLM calls and scales quadratically in cost. This work represents a significant step toward automating the transition from document-based to model-based systems engineering, potentially reducing the time and effort required for digital transformation of systems engineering processes.

Paper#207

Behavior-based Confidence Scoring to Support Access Management in Zero Trust Systems

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

Keywords. Zero Trust;deep learning;Bayesian hierarchical models;identity and access management

Topics. 11. Information Technology/Telecommunication; 4.7. System Security (cyber-attack, anti-tamper, etc.); 5.11 Artificial Intelligence, Machine Learning; 5.7. Software-Intensive Systems;

Abstract. Zero Trust architectures for cybersecurity have become the default aspiration for organizations in industry and for the U.S. federal government. A significant change in Zero Trust compared to legacy paradigms is the principle that systems should grant access to resources (devices, internal websites, data, software as a service, etc.) on a per-session basis after conducting authentication and authorization that is dynamic and strictly enforced. To facilitate this tide of additional scrutiny, Zero Trust strategies also emphasize the need for data science systems that use behavioral signatures to automate elements of the authentication and authorization process. Researchers have proposed a variety of statistical and machine learning approaches to analyzing behavioral data, most often from the perspective of anomaly detection. This work simulated data from the CERT Insider Risk dataset to examine two general approaches to using behavior data to support authentication and authorization decisions: deep learning and Bayesian hierarchical models. We find that deep learning approaches, especially those with memory, have higher cumulative recall for user authentication under small budgets, but all approaches converge as budgets increase. For authorization, which scores the attribute of the user rather than his/her identify, Bayesian hierarchical models have significantly better recall because they explicitly model the group attribute. While deep learning models are likely to remain the dominant approach for large-scale network monitoring tasks, such as intrusion detection, more structured statistical models could still be a valuable tool for regulating access management under Zero Trust.

Paper#390

Bifurcation Analysis for System Resilience: A Case Study on Power Infrastructure

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Presented on: Thursday, 13:00-13:25 EDT

Keywords. Bifurcation Analysis;Resilience Engineering;Systems Engineering;Power Systems;System Complexity

Topics. 1.5. Systems Science; 4.4. Resilience; 8. Energy (renewable, nuclear, etc.);

Abstract. Modern cyber—physical systems are becoming increasingly complex, as they integrate digital and physical components to achieve higher levels of efficiency and connectivity, This complexity introduces new vulnerabilities and operational threats to the systems that are hard to predict or deal with. Resilience Engineering (RE) has emerged as a field that focuses on the ability of systems to withstand, adapt to, or recover from disruption or unexpected events, as opposed to traditional risk management methods that rely on reducing variability and uncertainty. However, RE approaches are very diverse and lack consistency, hindering the chances for more adoption, which ultimately impacts the ability to manage complex systems efficiently.This paper explores the use of Bifurcation Analysis to identify resilience capabilities in critical infrastructures. We apply a Bifurcation Analysisfor resilience framework to the IEEE 9-Bus power system to analyze its resilience and operation condition under different levels of loading stress. Eigenvalue, and continuation analysis are performed to address system stability and to measure absorptive, adaptive, and recovery capabilities. The contributions are: the demonstration of the application of the framework to a power system, identifying critical points, and an expansion of the framework by recommending different metrics for different resilient capabilities.The results confirm the utility of the framework to understand and enhance resiliency in critical infrastructure. Future work can be done to address the scalability to larger systems, add operations, and increase simulation complexity.

Paper#80

Boosting COSYSMO to derive a comprehensive Acquisition benchmarking tool

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

Keywords. COSYSMO;Public Aquisition;CMMI;TRL;TCO

Topics. 2.3. Needs and Requirements Definition; 22. Social/Sociotechnical and Economic Systems; 3.1. Acquisition and/or Supply; 4.2. Life-Cycle Costing and/or Economic Evaluation; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. The integration of the Constructive Systems Engineering Cost Model (COSYSMO) version 2.0 with the Capability Maturity Model Integration (CMMI) creates a groundbreaking approach to optimizing public sector acquisition. This methodology enhances cost estimation accuracy, supplier evaluation, and risk management by incorporating comprehensive frameworks from ANSI/EIA 632, Life Cycle Costing (LCC), and Technology Readiness Levels (TRL). The proposed model addresses the complexities inherent in public acquisition by aligning technical and organizational assessments with evidence-based metrics.
To adapt COSYSMO 2.0 for public sector use, the model incorporates metrics derived from INCOSE's Guide to Writing Requirements (GtWR), enabling the segmentation of requirements into 'easy,' 'nominal,' and 'hard' categories. This classification, based on an analysis of Request for Information (RFI) and Request for Quote (RFQ) documentation, ensures accurate baselined TCO cost estimations. The inclusion of correctness, completeness, and consistency metrics per INCOSE's standards supports a robust quality assessment of requirements early in the process helping the acquisition organization to make a robust and fair decision: Who is the best supplier from a technical, economical and project perspective?

Paper#94

Bridging Realities: Bringing MBSE Models to Life with Digital Twins

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Presented on: Tuesday, 15:30-15:55 EDT

Keywords. Model-Based Systems Engineering;Digital Twins;System Visualization;System Interactivity

Topics. 2. Aerospace; 3.3. Decision Analysis and/or Decision Management; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 6. Defense;

Abstract. Modern-day systems, supported by exploding advances in technology, are growing increasingly complex. This surge of expanding capabilities in modern systems reinforces the need for effective design management to lower the risk of detrimental architecture mistakes. Alongside this growth, the systems engineering community is undergoing its own digital transformation aimed at identifying gaps between unconnected artifacts created by rapid development cycles and siloed engineering disciplines. Digital twins, in combination with Model-Based Systems Engineering (MBSE), can fill these gaps by consolidating system aspects, enabling intuitive interactions, and aiding real-time relationship analysis.
MBSE methodologies are being widely adopted to address expanding system capabilities, combat architectural risks, and mitigate communication difficulties. MBSE has been proven to improve these issues; however, it can still exhibit a complicated view. The sheer number of interconnected files and diagrams may impede communication, but proper vetting of design needs can be simplified with the use of digital twins. The authors have created a coupled digital twin and MBSE system that can fill these gaps.
Since digital twins are a validated representation of a system, they can be used to guide MBSE models. This paper focuses on validating MBSE attributes within a game engine environment, where visuals add interaction to analysis and context for system behaviors. A study was conducted to validate the authors' hypothesis that capabilities offered by an MBSE-linked digital twin can facilitate collaboration on development, as well as promote understanding between analysts and stakeholders. The authors provide background research and results from the pilot project that show the benefits of digital twins and how they supplement MBSE methodologies today. This paper provides the results of the authors' research to explore the fusion of an MBSE-linked digital twin with MBSE representations to promote real-time relationship analysis, rapid comprehension of complex systems, and collaboration across multiple domains.

Paper#352

Case Study: Application of STPA in the development of a Fuel-Cell Propulsion System

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Presented on: Tuesday, 06:00-06:25 EDT

Keywords. System Design;Safety Requirements;STPA;Hydrogen Fuel Cell Propulsion

Topics. 1.1. Complexity; 10. Environmental Systems & Sustainability; 2. Aerospace; 2.3. Needs and Requirements Definition; 4.6. System Safety;

Abstract. To mitigate the impact of climate change caused by aviation, several states have committed to achieving the Net Zero 2050 goal for flight operations. Meeting this ambitious target requires the aviation industry to significantly reduce its emissions output, driving the development of zero-emission technologies such as electric or hydrogen propulsion systems. Project Fresson aims to demonstrate the feasibility of utilizing Hydrogen Fuel Cell technology to generate the electrical power necessary to drive an electric engine retrofitted onto a Britten-Norman BN-2B Islander aircraft.

While these technologies hold great promise for decarbonizing aviation, they also introduce new challenges. The integration of hydrogen propulsion systems comes with increased complexity, as these systems involve multiple interconnected subsystems, each with their own behaviours and dynamics. This complexity amplifies the potential for emergent risks, particularly in critical operational scenarios. Addressing these challenges is essential to ensuring safe and effective deployment of novel technologies.

This paper presents a case study on the application of System Theoretic Process Analysis (STPA) as a powerful methodology to address inherent challenges that arise when developing systems. By systematically identifying safety constraints and uncovering potential hazards, STPA enables the early detection of risks and emergent behaviours that may not be apparent through traditional safety processes. Unlike traditional approaches, STPA considers the system’s concept of operations, and how interactions within as well as beyond its boundaries, may lead to unsafe conditions. The aim is to demonstrate how STPA enables early identification and implementation of mitigations against undesirable emergent behaviours. By doing so, it enables the definition of a comprehensive set of functional safety requirements that ensures the safe and efficient integration of hydrogen propulsion technologies, ultimately advancing their viability as a solution for sustainable aviation.

Paper#159

ChatGPT Dilemma: Effects of Generative AI on Higher Education in Systems Engineering

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Presented on: Tuesday, 06:30-06:55 EDT

Keywords. Academic integrity;Generative AI;Higher education;Large language model (LLM);ChatGPT;AI-assisted learning;Systems engineering;Guidelines;Responsible use

Topics. 1.6. Systems Thinking; 5.11 Artificial Intelligence, Machine Learning; 5.9. Teaching and Training;

Abstract. This study explores the effects of ChatGPT on higher education in systems engineering. It focuses on how it influences student learning and academic honesty before and after the introduction of ChatGPT 3,5. Comprehensive research is limited in the literature. The research uses surveys, experiments, and case studies to understand the role of AI in education from a systems-thinking point of view. The results show that most students use AI tools in their homework, and it helps to improve grades. It also brings issues like plagiarism, critical thinking, and less effort during exams. The study points out the need for clear guidelines to provide responsible use of AI and sustain competency development. It may assist students and teachers in their learning and teaching pro-cesses and help them make ethical use of AI and find efficient ways in their professional lives.

Biography

Emin Simsek (University of Southeastern Norway) - eminsimsekm@gmail.com
He holds a Master of Science in Innovation and Technology Management with a specialization in Systems Engineering from the University of Southeastern Norway. He earned his bachelor’s degree in business administration from Ankara Yildirim Beyazit University, where he distinguished himself academically and participated in an international exchange program at Mondragon Uniberstitae. His research focuses on integrating emerging technologies with systems engineering, as exemplified by his master’s thesis, “Effects of Using Generative AI in Systems Engineering.” Emin’s interdisciplinary background is further enriched by professional experience as an Audit Associate at PwC and as a Retail Operations Associate at Inditex Norge, experiences that inform his commitment to bridging theoretical research and practical application.

Paper#92

Complexity in the Context of Systems Engineering

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Presented on: Tuesday, 06:00-06:25 EDT

Keywords. System;complex;bibliometric;complicated;systems engineering

Topics. 1.1. Complexity; 1.6. Systems Thinking;

Abstract. This paper analyses research papers from INCOSE’s journal articles and international symposium proceedings to understand how system complexity has been addressed in systems engineering. Using natural language processing (NLP) and topic modeling, relevant articles were categorized based on their research focus. Those associated with the topic of complexity were extracted and filtered to a refined set that aligns with the objective of this paper. The bibliographic analysis identified prominent authors on the topic of system complexity. Further analysis extracted definitions of complexity, tools, methodologies and evolving definitions of complexity. The main themes identified in the complexity definitions include emergent behavior, non-linear interactions, and adaptation. Key tools for managing complexity in systems engineering include Design Structure Matrices, System Dynamics, and Model-Based Systems Engineering. The analysis identified the challenges of traditional systems engineering methods in handling complexity, noting a shift towards holistic, adaptive approaches that consider technical, social, and contextual factors. This evolving perspective emphasizes stakeholder diversity, self-organization, and system adaptability, advocating for comprehensive, context-sensitive strategies in complex systems management.

Paper#233

CONFIGURATION MANAGEMENT AS A DRIVER FOR SUSTAINABILITY

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

Keywords. Configuration Management pillars;Sustainability Development Goals;traceability;sustainable standards compliance;certificates;product end-of-life;circularity and recycling

Topics. 10. Environmental Systems & Sustainability; 20. Industry 4.0 & Society 5.0; 3.2. Configuration Management; 4.3. Reliability, Availability, and/or Maintainability; 8. Energy (renewable, nuclear, etc.);

Abstract. In today's complex and ever-evolving world, the urgency for sustainability is unmistakable. The UN Sustainable Development Goals serve as our guiding framework. The critical question is: how can we effect meaningful change? We find ourselves in a dynamic cycle of continuous improvement, where we refine our systems and products to enhance functionality while prioritizing the reduction of emissions, costs, and environmental impact. By embracing sustainable design, circularity, and frugality, we can pave the way for a more resilient future. Configuration Management should serve as a key enhancer and become a decisive partner in our sustainability efforts. The proposed approach focuses on exploring how Configuration Management can actively contribute through adapting its practices and while providing the structure and visibility necessary for responsible resource management and reinforcing our commitment to sustainable development. This aligns with the INCOSE Systems Engineering Vision 2035, which emphasizes the importance of integrating sustainable practices into systems engineering to achieve the UN Sustainable Development Goals.

Paper#100

Creating Better System Models: A Method for Using Compositional Reasoning to Validate Architectures with Assumption/Guarantee Contracts

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Presented on: Monday, 11:30-12:10 EDT

Keywords. Compositional Reasoning;Architecture Modeling;System Composer;AADL;AGREE;Assume-Guarantee Reasoning;Architectural Analysis

Topics. 2. Aerospace; 2.6. Verification/Validation; 3. Automotive; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 6. Defense;

Abstract. Formal methods have proved to be a valuable tool for identifying defects early in the development of safety-critical systems. Despite that, several factors have impeded their adoption within the systems engineering community. Some of these include lack of commercially available solutions, poor integration of analysis functionality in existing model-based systems engineering (MBSE) tools, and difficulty interpreting the results of the formal analyses. One such analysis that is popular among pockets within the aerospace community is the Assume Guarantee Reasoning Environment (AGREE), based on the Architecture Analysis and Design Language (AADL). AGREE is an open-source property-proving model checker that uses compositional reasoning to prove the system composition is valid based on assumptions and guarantees associated with the system components. The goals of this work are to develop a method for using AGREE in a more widely adopted commercially available tool, and to take advantage of MBSE formalisms to better convey the analysis results, and especially counterexamples, with the hope that this will increase the use of formal methods by high-assurance systems developers.

Paper#187

Customer Needs Elicitation Method for Business Architecture Design In Space Industry

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Presented on: Wednesday, 16:00-16:25 EDT

Keywords. Systems Engineering;Business Architecture Design;Stakeholder Needs Analysis

Topics. 2. Aerospace; 2.1. Business or Mission Analysis; 2.3. Needs and Requirements Definition;

Abstract. In this paper, we introduce an overview of the methodology for eliciting one of the stakeholder needs in the customer identification process to define a system requirement that satisfies the customer expectations. We measure the effective results of the initial trial to extend Systems Engineering to the business layer, which is a higher layer than the system layer . The proposed method combines System Engineering methods with marketing and software requirements engineering methods to demonstrate that not only business designers but also modelers without domain knowledge can con-tribute to customer needs elicitation for businesses in the space industry.

Paper#110

Developing Competence in Competency Assessment and Development – Experiences from applying the INCOSE Systems Engineering Competency Framework from two Large Organizations

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Presented on: Thursday, 09:00-09:40 EDT

Keywords. Systems Engineering Competency Framework;Competency Management;Career Development

Topics. 2. Aerospace; 3.5. Technical Leadership; 4.5. Competency/Resource Management;

Abstract. Structured competency management is a key issue for all organizations. This paper presents an analysis on how two large aerospace organizations have introduced the INCOSE Systems Engi-neering Competency Framework for improving competency management. For both organizations, the purposes of introducing this framework are to be able to describe both the breadth and depth of skills within the Systems Engineering workforce, and to give an objective career guidance for Systems Engineers throughout their career. An outline is given of how the framework has been introduced, including adoptions to specific needs of each organization. Different areas of focus and priority are driving some distinct approaches being taken within each organization to achieve the end goals. Adopting and extending it is a low-cost route for introducing detailed Systems Engineering competence management in an organization.

Paper#331

Digital Engineering Testbed for T&E: Operation Safe Passage Status and Lessons Learned

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Presented on: Tuesday, 13:30-13:55 EDT

Keywords. Test & Evaluation;Systems Engineering;Digital Engineering;Digital Transformation

Topics. 1. Academia (curricula, course life cycle, etc.); 2. Aerospace; 2.6. Verification/Validation; 3.1. Acquisition and/or Supply; 5.3. MBSE; 6. Defense;

Abstract. The struggle to realize digital transformation persists, despite the release of the digital engineering strategy by the US Department of Defense (DoD) in 2018. In DoD, test & evaluation (T&E) is the government owned and conducted version of verification & validation (V&V) of systems. With the digital paradigm, many evaluations may be conducted through digital modeling and analysis as well as data fusion means that combine digital and physical test results. Our research aims to contribute to the digital transformation of T&E through creation of a framework and testbed to prove-in the methods and tools as we progress through a roadmap of tiers of T&E transformation. We present our vision and transformation status using a fictitious case study referred to as Operation Safe Passage and findings following the conduct of a mock interim design review.

Paper#186

Digital requirement management and exchange - a Case Study from the Energy Domain

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Presented on: Thursday, 09:45-10:25 EDT

Keywords. Digital requirement exchange;ReqIF;Energy industry;Requirement management;Supply chain

Topics. 15. Oil and Gas; 2.3. Needs and Requirements Definition; 3.4. Information Management Process;

Abstract. The energy industry is increasingly adopting digital tools to manage the requirements in systems development. To fully benefit from digital requirements, enhancing digital exchanges across the supply chain to improve traceability and reduce data loss is essential. This paper presents a supplier company's experience of implementing and using a requirement management system in a large organization from two perspectives. Firstly, we explore the internal experience with utilizing the requirement management tool and current initiatives to improve internal requirement handling. Secondly, we present our experience of exchanging digital requirements across the supply chain, highlighting the importance of collaboration and communication. This paper provides valuable insights into using requirement management tools in the energy domain. It emphasizes the importance of client and supplier relationships in exchanging digital requirements.

Paper#31

Digital Safety Analysis for Small Modular Nuclear Reactors (SMRs)

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Presented on: Wednesday, 13:30-13:55 EDT

Keywords. Model-Based Systems Engineering;Small Modular Reactors (SMRs);Microreactors;Safety Analysis;Nuclear Power Plants (NPPs)

Topics. 3.4. Information Management Process; 4.6. System Safety; 5.3. MBSE; 8. Energy (renewable, nuclear, etc.);

Abstract. A Documented Safety Analysis (DSA) is a Department of Energy (DOE) construct that defines the extent to which a nuclear facility can be operated safely. It includes a description of hazards, safe boundaries, and hazard controls.
The authors assert that a Digital Safety Analysis (DgSA) is far superior to a legacy DSA for several reasons:
• The underling database is structured such that it is possible to perform a comprehensive design review and safety analysis by iterating systematically across a hierarchy of linked objects versus a redundant and spotty review by entities of various abilities under unknown resource and schedule constraints.
• The analysis of a new design can discover elements that are similar to elements in previous designs. The discovery of similarities is made possible by using the same structure for the underlying database for each new DgSA. The “prior learning” from previous designs is then applied automatically to new designs.
• Outputs from the DgSA are from a single source to ensure consistency among various views of the same information. After the DgSA is released, the continued use of a single source implements a configuration management program to ensure consistency between the design basis, the design, the built system, and system procedures.
• The development of the DgSA is agile in that any change in a linked object triggers an analysis of impacts on other linked objects and updates of linked objects are made accordingly. After the DgSA is released, the continued maintenance of these links and objects automates the “unreviewed safety question” process.

Paper#180

Early-Stage Digital Engineering for Complex Energy Decarbonization Projects

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

Keywords. Energy Decarbonization;Digital Engineering;Feasibility Analysis;Design Assurance

Topics. 10. Environmental Systems & Sustainability; 12. Infrastructure (construction, maintenance, etc.); 3.3. Decision Analysis and/or Decision Management; 3.7. Project Planning, Project Assessment, and/or Project Control; 8. Energy (renewable, nuclear, etc.);

Abstract. The paper explores the application of digital engineering (DE) to model and analyze complex energy decarbonization (CED) systems and projects. It discusses the development of an economically viable analysis approach and integrated digital environment targeted at small to medium enterprises (SMEs) to enable them to provide high impact advice on the design, implementation, and risk reduction of CED projects. To address the challenges of climate change, efforts to implement energy decarbonization are rapidly growing. CED projects are often complex and span multiple industries, such as: energy generation, transportation, and mining. DE offers an opportunity to deliver enhanced systems engineering support. However, DE for complex systems can require significant resources and as such it is normally undertaken only by governments and large enterprises. The aim is to develop an economically viable approach and toolset able to undertake the modelling and analysis of CEDSs within the resources available to an SME. Using an underlying Design Science Research (DSR) methodology, a tailored DE approach for CED systems has been developed that leverages readily available and low-cost com-ponents. The resultant DE approach utilizes a commercial Model-Based Systems Engineering (MBSE) tool that can invoke analytical modelling using a variety of tools including OpenModelica, and open operations research (OR) tools. The modular approach enables rapid and adaptive development of tailored modelling and analysis. It applies module reuse to reduce costs and seek to minimize the level of modeling complexity consistent with the needs of the analysis. Two use cases are used to demonstrate the potential of the approach and its ability to be economically viable at SME scale.

Paper#54

Emotional Intelligence as a Tool for Sustainable Development: Insights from Student Projects

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

Keywords. Emotional Intelligence;Sustainability;Systems Thinking;Global Challenges;Engineering Education

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

Abstract. Addressing global challenges requires combining emotional intelligence (EI) and systems thinking to develop inclusive and sustainable solutions. Emotional intelligence is a skill that fosters self-aware-ness, empathy, and the ability to manage emotions, enhances collaboration, decision-making, and the capacity to address diverse perspectives. Systems thinking complements EI by providing a framework to analyze interconnected problems holistically, creating actionable strategies for complex global issues. This study explores how a systems-thinking approach influences the development of EI in engineering students, equipping them with the skills needed to tackle global challenges effectively. The research was conducted in a Spring 2024 undergraduate complex systems course in the USA, with 55 senior-level engineering students divided into 11 teams. Using a project-based learning approach, students worked on United Nations-defined global challenges such as hunger, water contamination, and migration. Each team produced a de-tailed report, including problem analysis, computational modeling, and proposed solutions. The data were analyzed through thematic classification to identify elements of EI, including empathy, trust-building, cultural sensitivity, and education-oriented approaches. The findings revealed that students demonstrated significant growth in emotional intelligence, particularly in understanding diverse perspectives and fostering collaboration. Reports highlighted empathy for vulnerable populations, trust-building in community engagement, and culturally sensitive solutions for global challenges. Education and awareness initiatives further showcased students' ability to integrate emotional intelligence and systems thinking skills. This study emphasizes the importance of integrating EI and systems thinking in engineering education to prepare students for addressing complex, interconnected global issues holistically and sustainably.

Paper#2

Enabling Enterprise Transformation Using Systems Principles and Concepts

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

Keywords. Enterprise Systems Engineering;Enterprise Architecture;Portfolio Management;Enterprise Transformation

Topics. 2. Aerospace; 2.4. System Architecture/Design Definition; 3.3. Decision Analysis and/or Decision Management; 3.9. Risk and Opportunity Management; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Systems Engineering as a profession is failing to keep pace with the rapidly changing world situation, and we need to embrace enterprise transformation as a way to address these challenges. Enterprise Systems Engineering (ESE) processes and methods can provide the ways and means that are essential for helping us manage increasing complexity, as well as improve the quality and time-liness of key decisions regarding enterprise capabilities, and adjust the portfolios of programs, pro-jects, systems, services, and organizations that underpin those capabilities. Enabling the cost-effective and timely resolution of strategic and operational capability gaps and shortfalls will ensure more efficient use of limited time and resources and it will increase the likelihood of achieving enterprise goals and objectives.

An ESE-enabled enterprise is better able to conduct trades across competing concerns about strategy, policy, capability, operations, and implementation, in a similar way that traditional SE practice per-forms tradeoff analyses among the functions, performance, physical parameters and structure to help realize more effective systems. This approach will result in more robust business and mission anal-yses, more balanced plans and deliveries, and more highly integrated collections of systems, prod-ucts, and services to rapidly meet evolving enterprise objectives. This paper explores the nature of Enterprise Systems Engineering, the various roles that ESE can play in enterprise transformation, and the value and application of Enterprise Architecture at the Enterprise level.

Paper#344

Engineering Hope via a Rapid Systems Engineering Approach to International Disaster Relief

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Presented on: Wednesday, 05:30-05:55 EDT

Keywords. Hackathon;Systems Engineering;Disaster Relief;International Collaboration;Damage Assessment;Computer Vision

Topics. 1.6. Systems Thinking; 5.10. Diversity (cultural boundaries, diverse engineering teams, training underserved groups, etc.); 7. Emergency Management Systems;

Abstract. Florida State University partnered with Taras Shevchenko National University of Kyiv (KNU) to host a five-day online Hackathon for students aimed at rapidly developed, cross-disciplinary, and business savvy responses to the rise of natural and human-caused disasters in the 21st century. The multinational student team codenamed ClearSight developed an innovative system-of-systems for assessing urban building damage after disasters or conflicts. Leveraging systems engineering techniques such as requirements analysis, concepts of operations (CONOPs), cost estimation, and more, their solution provides rapid and accurate damage assessments to enhance recovery efforts in affected areas. This paper outlines ClearSight’s system concept, hardware/software integration, and collaborative development process, highlighting its reliance on real-world data and computer vision for precise cost estimation. Key elements include drone deployment strategies and scalable, adaptable tools for stakeholders, emphasizing the solution’s potential for significant real-world impact. Despite the tight five-day timeline, the team successfully created a comprehensive system concept and software deliverables, showcasing how effective collaboration and systems engineering principles can drive meaningful, rapid, innovation. The paper explores the role of systems engineering in leading the team’s technical achievements, collaborative dynamics, competition experience, and broader lessons learned, demonstrating how ClearSight’s victory validated its approach and underscored the power of expedited, globally relevant solutions to address critical societal challenges.

Paper#120

Enhancing Healthcare Delivery through Systems of Systems Governance: A Multi-Layered Governance Framework

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Presented on: Wednesday, 16:00-16:25 EDT

Keywords. System of Systems;Governance;Meta-Governance;Healthcare Delivery;Fragmentation;Systems Engineering

Topics. 1.1. Complexity; 2.4. System Architecture/Design Definition; 22. Social/Sociotechnical and Economic Systems; 4. Biomed/Healthcare/Social Services; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Healthcare systems face increasing challenges such as fragmented care delivery, operational inefficien-cies, and escalating costs, highlighting the critical need for systems engineering approaches to reform and optimize healthcare delivery. The potential of systems engineering to address these challenges has gar-nered significant interest due to its ability to manage complexity and enhance performance in multifaceted environments through holistic frameworks and process optimization. This paper presents an enhanced governance framework for healthcare delivery systems, building upon previous research that examines healthcare through a System of Systems (SoS) lens. Based on findings from systematic analysis of 45 studies encompassing 37 governance frameworks, this research proposes a scalable approach that recog-nizes healthcare as a multi-layered SoS requiring tailored governance mechanisms at each level. The framework introducing a refined three-tiered governance structure comprising meta-governance (gov-ernment), governing system (Department of Health and Human Services), and governed system (healthcare delivery system). The study demonstrates how the Department of Health and Human Services' various agencies can effectively serve governance functions across different healthcare system strata, providing a comprehensive structure for addressing the complexity and fragmentation in modern healthcare delivery. This approach enables healthcare systems to maintain operational autonomy while ensuring alignment with overarching system goals and values.

Paper#151

Enhancing Shared Understanding in Multidisciplinary Teams

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

Keywords. Systems engineering;leadership;multidisciplinary;collaboration;shared understanding;technical leadership;TLI

Topics. 1.1. Complexity; 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. Modern complex projects increasingly rely on multidisciplinary teams, where members from diverse disciplines collaborate to address intricate challenges. Achieving a shared understanding and alignment in such teams remains an obstacle. This study conducted by INCOSE Technical Lead-ership Institute (TLI) Cohort 9 explores the role of systems engineering in facilitating shared un-derstanding within multidisciplinary teams.

The research employed a mixed-methods approach which included a literature review, interviewing industry and INCOSE leaders, and hosting interactive workshops. It identified five key challenges hindering shared understanding: communication breakdowns, organizational conflict, unconscious bias, microaggressions, and a lack of inclusive policies. To address these, the study proposed strat-egies such as structured communication frameworks, early stakeholder involvement, bias awareness, and inclusive workplace policies. The findings highlight systems engineering as a bridge of effective collaboration, bridging gaps across disciplines and promoting alignment. While the study offers insight, it also identifies the need for application into real world environments, further research on metrics of shared understanding, validation techniques, and leverage collaboration tools. This research advances the understanding of multidisciplinary teams and provides practical strategies for fostering collaboration and achieving shared goals in complex and global environments.

Paper#98

Enterprise Architecting to Advance Reliability and Maintainability Decision-Making

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Presented on: Monday, 14:15-14:55 EDT

Keywords. Enterprise Architectures;maintenance strategy;decision support;reliability;maintainability

Topics. 17. Sustainment (legacy systems, re-engineering, etc.); 3.3. Decision Analysis and/or Decision Management; 4.3. Reliability, Availability, and/or Maintainability; 5.3. MBSE; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Aircraft maintenance strategy, execution, and improvement decisions (i.e., solutions) are critical enterprise responses impacting a fleet's sustainment performance. Enterprise maintenance solutions are a key product support activity in the United States Department of Defense that must balance safety, economics, and operations. To guide and regulate enterprise reliability and maintainability decisions, several programs, policies, and standards govern various aspects of a system's product support and sustainment domain. While this body of enterprise knowledge prescribes what to do, it intentionally enables organizations to decide how they want to collaborate and organize to make enterprise-level reliability and maintainability decisions. In contrast, much of the academic literature focuses on how to make closed form organization-level reliability and maintainability decisions, but does not address the complexities and implications of involving multiple heterogeneous organizations.

To this end, this research seeks to develop enterprise architecture viewpoints and views to characterize the interdependencies, interactions, and integration of reliability and maintainability solutions across organizations. These architectures provide improved traceability and domain understanding of enterprise reliability and maintainability decisions to advance product support and sustainment outcomes. A notional United States Air Force commercial derivative aircraft serves as an exemplar of how these enterprise architectures identify enterprise actors and their exchanges to develop a reliability and maintainability decision-making framework. Together, this framework and its enterprise context guide the design of a decision support tool for enterprise reliability and maintainability solutions. Finally, applications of enterprise reliability and maintainability architectures are discussed to enable novel Digital Product Support strategies in the United States Department of Defense.

Paper#307

Ethical Human-AI Agent Interface Considerations

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Presented on: Wednesday, 14:00-14:25 EDT

Keywords. Human-AI Teaming;Decision-Making;Human Systems Integration;HSI;Combat Identification

Topics. 4.1. Human-Systems Integration; 5.11 Artificial Intelligence, Machine Learning; 6. Defense;

Abstract. The integration of Artificial Intelligence (AI) in safety critical workflows raises several ethical concerns. Human-Machine or Human-AI Teaming is one commonly discussed means to alleviate these concerns, as this method places the human in or on the decision loop. These systems intend to permit the human to either make a final decision based upon AI recommendations or to correct and override decisions performed by the AI, permitting the human to inject broader knowledge and ethical concerns into the decision-making process. Unfortunately, certain system designs involving automation or artificial intelligence prevent humans from operating in a truly autonomous fashion, preventing them from serving the role of an ethical governor. This research provides a discussion of design considerations that prevent humans from acting autonomously and discusses the conceptual design of an interface for an AI enhanced decision aid for combat identification. This interface design is intended to support human autonomy during an AI aided decision-making process. This interface is discussed to illustrate some important considerations for the design of ethical human-AI teaming interfaces in safety critical systems.

Paper#168

Explaining Model-Based Systems Engineering – Towards a Semiotic Perspective

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Presented on: Tuesday, 10:20-10:40 EDT

Keywords. Conceptual spaces;Model-Based;Systems Engineering;Semiotics

Topics. 1.1. Complexity; 1.5. Systems Science; 1.6. Systems Thinking;

Abstract. While the benefits of Model-Based System Engineering (MBSE) are recognized, its adoption is hampered by seemingly pragmatic problems, such as a harsh learning curve and lack of mature tooling and integration. While these perceived drawbacks are often described, they are only rarely explained – it is unclear what exactly about MBSE is challenging to use and learn, and how to determine whether new approaches mitigate this challenge. It this work, we propose a theory for explanation for three observations: (1) System engineers see less value in MBSE than other stakeholders, (2) models are used for communications between users, not automation, and (3) graphical notation is seen as both the major advantage of MBSE and a big drawback when learning it. We use a cognitive framework based on semiotics, conceptual spaces and naturalness and provide a first explanation of these observations: A graphical model can be interpreted either in terms of the domain it models, or in terms of the language it is expressed in. These two interpretations are in parallel when a user interprets a model and can interfere, which leads to problems in understanding.

Paper#185

Exploring the Use of SysMLv2 for Solution Architecture Development with the MagicGrid Framework

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Presented on: Monday, 11:30-12:10 EDT

Keywords. Model-Based Systems Engineering (MBSE);MagicGrid;SysMLv1;SysMLv2

Topics. 2.4. System Architecture/Design Definition; 5.3. MBSE; 5.9. Teaching and Training;

Abstract. The forthcoming release of SysMLv2 marks a transformative step in systems engineering. This paper examines the application of SysMLv2 concepts within the MagicGrid framework, a widely recognized methodology for model-based systems engineering. The purpose of this study is to explore how SysMLv2 aligns with MagicGrid and identify potential benefits and challenges compared to SysMLv1. The scope includes a comparative case study, focusing on developing solution architecture models using both language versions. This research provides an early evaluation, offering insights to practitioners as they prepare for the anticipated release of SysMLv2 in early 2025.

Paper#196

Extracting Information from System Model as Graph Structure by Large Language Model in MBSE

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

Keywords. MBSE;LLM;SysML;Neo4j;Cypher;Graph Database;Query

Topics. 2. Aerospace; 5.11 Artificial Intelligence, Machine Learning; 5.12 Automation; 5.3. MBSE;

Abstract. In Model-based systems engineering (MBSE), systems are represented as models, but modeling languages such as SysML are difficult to learn and engineers and reviewers are often not familiar with them. In such cases, it is difficult for them to extract the desired information from the system model in design and review. Therefore, we propose a method using large language model (LLM) that enables users who are not familiar with SysML to easily extract information through question-and-answer by natural language. Specifically, the system model is converted to Neo4j format, natural language questions are converted to Cypher queries by LLM, querying is performed, and the results are converted back to natural language by LLM. When we conducted a question-and-answer using this method on a system model that assumes a simple satellite, we found that the method was relatively successful in answering questions for full-text search and questions that require answering the attributes of elements, but the percentage of correct answers was relatively low for questions containing typographical errors or spelling inconsistencies and questions that trace the relationship between multiple elements. It is hoped that this method will increase the opportunities for more people to utilize the MBSE.

Paper#391

Faulted Agent Resilience in Multi-Agent Systems: An Exploration of Two Ant Inspired Strategies

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Presented on: Wednesday, 16:30-16:55 EDT

Keywords. Multi-agent systems;Autonomous Systems;Ad hoc networks;Bioinspired design;Faulted agent;Resilience

Topics. 4.4. Resilience; 4.7. System Security (cyber-attack, anti-tamper, etc.); 5.4. Modeling/Simulation/Analysis;

Abstract. Resilience is one of the key focal points of systems engineering research, especially in relation to multi-agent systems. This need for system resiliency is outlined by many sources, including the INCOSE Systems Vision 2035 document, as a part of the future of systems engineering and engi-neering in general. Finding solutions to improve systems resiliency, however, is often easier said than done. In the case of faulted and malicious agents the solutions in current literature lean towards consensus or identifying the source of a problem before it can become a problem. In this work we propose an approach that uses the behaviors identified in ant species to increase system resilience in spite of the presence of faults. The hypothesis is thus: “If insect inspired communication and spatial heterogeneity strategies are applied to a searching swarm, then the system’s overall resiliency to spreading faults will improve, because these strategies reduce the likelihood of communication be-tween faulted agents and those agents prone to encountering sources of faults.” In this work we present a simulated unmanned aerial vehicle (UAV) swarm that is tasked with randomly searching the simulation space with the goal of reaching 100% search success. Within the simulated space are Threat vectors that can induce a fault in agents within their connection range. Upon receiving a faulted message, an analog for malware, a receiving agent may become infected. If so, they will begin spreading the infection themselves, thus propagating the infection. Our findings suggest the strategies described within provide a massive increase to fault resilience compared to the control group that does not implement these strategies.

Paper#294

GenAi and RAG for Automated Traceability

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Presented on: Tuesday, 11:30-12:10 EDT

Keywords. GenAi;LLM;Requirements Traceability;NLP4RE;Retrieval Augmented Generation

Topics. 15. Oil and Gas; 2.3. Needs and Requirements Definition; 20. Industry 4.0 & Society 5.0; 3.4. Information Management Process; 5.11 Artificial Intelligence, Machine Learning; 8. Energy (renewable, nuclear, etc.);

Abstract. The US Department of Defense reportedly spends four percent of life cycle costs on requirements traceability (Powers & Stubbs, 1985) and GlobalData estimated that approximately $17.5 billion was spent on digital thread efforts in 2023 (GlobalData, 2023). Further, many organizations, including the US Food and Drug Administration, International Electrotechnical Commission (IEC), and the Capa-bility Maturity Model Integration (CMMI), now require bi-directional requirements traceability (US FDA, 2023), (US Government, 2022), (IEC 61508), (Vassilka Kirova, 2008).
Current methods for establishing and managing traceability during systems development are ineffective, prohibitively expensive, and do not scale for the future needs of managing complex systems inundated with hundreds of thousands of interrelated data artifacts across the engineering life cycle.
This paper investigates the feasibility of leveraging Generative AI, Large Language Models, Retrieval Augmented Generation to tackle the requirements traceability problem. We demonstrate that the new capabilities of LLMs effectively reduce the level of effort to identify traceability relationships while maintaining a higher level of quality compared to prior NLP methods alone.

Paper#248

Helping Future Nuclear Power Facilities Navigate Predatory & Hostile Environments: Insights from Systems Security Engineering

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Presented on: Wednesday, 14:00-14:25 EDT

Keywords. Security;systems security engineering;functional perseverance;lifecycle models

Topics. 4.7. System Security (cyber-attack, anti-tamper, etc.); 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 8. Energy (renewable, nuclear, etc.);

Abstract. Discussions at COP28 and COP29 emphasize that deploying advanced and small modular reactors (A/SMRs) with high safety and security standards can address energy security and climate change challenges. INCOSE's Vision 2035 advocates for systems-theoretic approaches to integrate security throughout the development lifecycle, ensuring system resilience in contested environments. The systems security engineering (SSE) domain aims to incorporate security solutions into complex design processes through requirements, trade space navigation, and systems architecture. Recent dialogues within INCOSE's SSE working group shift the security paradigm toward engineering for functional persistence in predatory and hostile environments. This perspective redirects the emphasis on security to highlight design decisions that enhance situational awareness, preparation, defense, and recovery capabilities and augment efforts to manifest "security-by-design" for A/SMRs. By applying systems-theoretic methods to integrate security early, frequently, and continuously, A/SMRs can improve their security performance and cost-effectiveness. This proactive approach is essential for navigating the evolving threat landscape while meeting global energy security and climate change objectives.

Paper#396

Hidden Beliefs in Verification Decisions: An Experimental Study with Practitioners

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Presented on: Tuesday, 14:30-14:55 EDT

Keywords. Verification;belief;expert performance;cognitive science;Bayesian network

Topics. 2.6. Verification/Validation; 3.3. Decision Analysis and/or Decision Management; 4.1. Human-Systems Integration;

Abstract. System verification is used to check that the system has been built in accordance with its requirements. In executing a verification strategy, each verification activity produces certain information artifacts that are then used as evidence in the assessment of the compliance of the system against its requirements. The process of reasoning through verification artifacts is cognitive and subjective, as the engineer combines their knowledge and expertise along with the information available in the evidence collected through verification activities. Through an experimental study with practitioners, this paper shows that engineers use some of this knowledge implicitly in their verification assessment and do not explicitly express it when formally articulating the justification to declare the compliance of a system.

Paper#251

Holistic Approach to Sustainability: A Comparative Life Cycle Assessment of Battery-Electric versus Biodiesel Transit Buses in Hawaii

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

Keywords. Sustainability;Sustainable Transportation;Life Cycle Assessment;Biodiesel;Biofuel;Electric Vehicles;Transit Buses;Urban Infrastructure;Energy Systems;Greenhouse Gas Emissions;Climate Change;Public Policy;Environmental Impact;Industrial Ecology

Topics. 1.6. Systems Thinking; 10. Environmental Systems & Sustainability; 21. Urban Transportation Systems; 4.2. Life-Cycle Costing and/or Economic Evaluation; 5. City Planning (smart cities, urban planning, etc.); 5.4. Modeling/Simulation/Analysis;

Abstract. The urgent global need to reduce greenhouse gas emissions has intensified efforts to develop sustainable transportation solutions. This study examines the environmental impacts of two transit bus technologies, battery-electric and 100% biodiesel (B100) internal combustion engine (ICE), within the context of Oahu, Hawaii, a region heavily dependent on imported fossil fuels with unique environmental and logistical challenges. Employing a comprehensive Life Cycle Assessment (LCA) methodology, the study evaluates both technologies across multiple environmental impact categories, including energy consumption, water use, and greenhouse gas emissions, over a vehicle lifespan. Data was modeled using the GREET model tailored to Hawaii's regional characteristics, including local biodiesel production and the island’s specific electricity grid mix. Results indicate that B100 biodiesel ICE buses currently have a lower environmental impact compared to battery-electric buses in terms of energy and water consumption, as well as greenhouse gas emissions, which are primarily driven by the high fossil fuel content in Hawaii’s electricity grid and the lifecycle impact of lithium-ion batteries. This analysis suggests that integrating locally sourced B100 biodiesel in Hawaii’s public transportation fleet may be a more immediate, sustainable option. In contrast, battery-electric buses could become more viable as Hawaii transitions to a renewable energy grid. The study underscores the importance of a regionalized, systems-level approach in evaluating sustainable transportation technologies and providing strategic recommendations to inform policy decisions. However, limitations of the study include reliance on generic component data and the exclusion of infrastructure impacts, highlighting areas for refined data in future analyses.

Paper#63

Innovation Engineering at Tesla – Agility as a Cultural Practice

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Presented on: Wednesday, 13:30-13:55 EDT

Keywords. Innovation;modularity;group engineering;opt-in teaming;agile systems engineering

Topics. 2. Aerospace; 3. Automotive; 5.1. Agile Systems Engineering;

Abstract. Tesla continues to pioneer innovations in automotive design, manufacturing, and product life cycle practices. Their engineering practice is equally pioneering, and radically unique in the automotive production environment. Though Tesla doesn’t have or recognize an agile systems engineering strategy, their pursuit of continual engineering innovation results in everything an agile systems en-gineering approach is expected to exhibit and provide. This article summarizes Tesla’s engineering practice, features an instructive graphic depiction of that practice, characterizes that practice as an agile systems engineering operations concept, and suggests how that practice can be employed in completely different system development environments.

Paper#363

Integrated Product Development shared management by Systems Engineers and Project Managers

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Presented on: Monday, 11:30-12:10 EDT

Keywords. Integrated Product Development;Systems Engineering;Project Manager

Topics. 3.3. Decision Analysis and/or Decision Management; 3.7. Project Planning, Project Assessment, and/or Project Control; 5.5. Processes;

Abstract. The development of a complex system is managed by Systems Engineering (SE) and Project Management (PM) practitioners. An integrated team is essential to take advantage of both disciplines and develop the product efficiently. This paper summarizes several models collected from literature and organizations that list SE and PM responsibilities and the overlap between the areas in which responsibilities are shared. The purpose is to analyze the processes classified by most of the models as shared responsibility in a matrix to propose levels of involvement of each specialist in these processes. The result is a beginning to document the processes and to establish roles and responsibilities in the development of a product and in which processes SE and PM should interact to properly manage the activities in the shared space.

Paper#3

Integrating concept of operations in prefabrication processes for effective construction projects: a case study on plumbing systems

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

Keywords. Prefabrication;Concept of Operations;Construction;Plumbing;Cost model

Topics. 12. Infrastructure (construction, maintenance, etc.); 2.2. Manufacturing Systems and Operational Aspects; 21. Urban Transportation Systems; 3.7. Project Planning, Project Assessment, and/or Project Control; 4.5. Competency/Resource Management; Other domain;

Abstract. This study examines how a Concept of Operations model integrated into a prefabrication process addresses the challenges of project cost and delivery time in plumbing operations from a technical contractor's perspective. First, we analyzed the process flow to identify the pain points faced in the plumbing process and developed an As-Is Concept of operation model. We identified the factors affecting prefabrication of cost, labor, time, and logistics as provided by the state-of-the-art. Second, we mapped out the workflow and proposed an improved model that addresses the challenges, with findings showing improvements in both time and cost savings for projects. Finally, we supported the findings with a cost model and evaluated the proposed Concept of the operations model with industry experts. These experts foresee the proposed model as a good recommendation for rethinking the process and setting up a streamlined prefabrication line. With the proposed model, we made an estimation for a selected building site, which reveals time saving of 1911 hours translating to 573 kNoK. To verify our results, we suggest further testing for verification before full-scale implementation on a construction project

Paper#178

Integrating configurator and model-based verification and validation to streamline the design process of large-scale ETO systems

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Presented on: Thursday, 13:30-13:55 EDT

Keywords. product configurator;v&v process;model-based systems engineering;model-based development;engineering-to-order product;pump system;motor design

Topics. 10. Environmental Systems & Sustainability; 12. Infrastructure (construction, maintenance, etc.); 2.2. Manufacturing Systems and Operational Aspects; 2.5. System Integration; 2.6. Verification/Validation; 3.2. Configuration Management; 3.7. Project Planning, Project Assessment, and/or Project Control; 5.12 Automation; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 5.5. Processes; 5.6. Product Line Engineering;

Abstract. This paper presents the current model-based systems engineering efforts at Toshiba Corporation. It de-scribes the background that has led us to these efforts as well as the approach that we have adopted on Design Configurator and Model Based Systems Engineering (MBSE) in the development of engi-neer-to-order (ETO) products. To improve the efficiency of engineering process and to construct a more proposal-based sales process (sales process that proposes high-value product systems to customers by verifying performance feasibility at the customer requirements inquiry and quotation phase), we proposed a standard process which integrate top-level design process with low level design process targeting ETO systems with high design loads. To implement the proposed standard process, we have built a configurator enhanced with mode-based development (MBD) interface to meet large scale customization (requiring major change to design) such as customization involving design mold modification. We have added to the configurator functions to optimize key design parameters in collaboration with external simulators as well as optimization tools, addressing the major change requirements from customers. This configurator en-hancement applied a flexible concept of modular design to propose an approximate configuration as a baseline to accommodate higher levels of customization and estimate costs more accurately. Sequentially, proposed baseline configurations' design parameters are transferred swiftly to verification and valida-tion(V&V) phase with smooth integration between the configurator and Model-based V&V tools for op-timization, to ensure the optimal customization that meets customers' requirements. The preliminary evaluation with a Proof-of -concept for pump system design showed that the proposed process and tools return substantial improvement in engineering lead time, design cost and design quality.

Paper#343

Integrating Digital Engineering Needs into Physics-based Modeling and Simulation for Aircraft Power and Thermal Systems

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Presented on: Wednesday, 14:30-14:55 EDT

Keywords. digital engineering;digital transformation;model-based systems engineering;modeling and simulation;INCOSE model-based capabilities matrix

Topics. 2. Aerospace; 3.4. Information Management Process; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. As organizations look towards their digital engineering future, many different strategies exist to realize new and more effective model-based capabilities and digital ecosystem enablers. Of interest in this paper is understanding and meeting the digital engineering needs for physics-based modeling and simulation (M&S) within a larger enterprise specializing in the research and development activities of aircraft power and thermal (PT) systems. First, the organizational context and key stakeholder considerations are described in order to understand how the digital engineering ecosystem is developed. Then, the INCOSE Model-Based Capabilities Matrix (MBCM) is utilized to provide a self-assessment of the state of the model-based digital transformation effort and provides context for further advancement of the digital engineering strategy. Many of the assessed MBCs started at low stage numbers (0 or 1) and rose significantly, especially in the areas of Model Tool Access, Model Based Tool Licensing and Access, Model Configuration Management, and Modeling Roles and Responsibilities. Two other MBCs (Simulation Capability and Model Libraries) were assessed at an already advanced stage for this M&S organization, and a key emphasis was to ensure no regression on these MBCs. Expected outcomes include better collaboration with other disciplines regarding aircraft power and thermal concerns and modeling and design capabilities, as well as the ability to explore and respond to a broader range of potential aircraft technologies and solutions faster.

Paper#193

Integrating PLE To Enhance MBSE Education In Emerging Engineering Countries: The Singapore SIT Example

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

Keywords. MBSE education;Emerging Engineering Countries;PLE;Singapore

Topics. 1. Academia (curricula, course life cycle, etc.); 5.3. MBSE; 5.6. Product Line Engineering; 5.9. Teaching and Training;

Abstract. This paper explores the integration of Model-Based Systems Engineering (MBSE) education with Product Line Engineering (PLE) principles to address challenges in teaching MBSE in contexts where complex, safety-critical systems are not predominant. Using insights from a two-year teaching experience at the Singapore Institute of Technology (SIT), it investigates how the teaching of PLE theory and practice enhances learners' understanding of MBSE's practical value. The findings aim to provide a foundation for advancing MBSE education in emerging engineering regions like Southeast Asia, where industrial and academic adoption faces unique barriers.

Paper#177

Integrating system dynamics with systems modelling language for resilient system design

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Presented on: Tuesday, 11:20-11:40 EDT

Keywords. Resilience Engineering;System Dynamics;Systems Modeling Language;Dynamic Simulation;Structural Modeling

Topics. 1.4. Systems Dynamics; 2.4. System Architecture/Design Definition; 4.4. Resilience;

Abstract. Resilience engineering requires robust methodologies to model and predict system behaviour under adverse conditions. While the Systems Modelling Language (SysML) is excellent for designing system structures, it cannot simulate dynamic behaviour over time. System Dynamics (SD), focusing on feedback loops, stocks, and flows, offers a deterministic approach to modelling such behaviour. This paper explores the integration of System Dynamics with SysML to enhance resil-ience modelling. It emphasizes potential benefits, challenges, and future research opportunities. By examining the methodologies, mapping their elements, and considering implementation strategies, the paper aims to provide a framework for engineers seeking to design resilient systems capable of adapting to, withstanding, and recovering from adversities.

Paper#274

IntelliFactory: Intelligent Software Factory for Embedded System Generation

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

Keywords. Embedded Software Factory;Multi-Agent;MagicGrid;Model-Driven

Topics. 5.2. Lean Systems Engineering; 5.4. Modeling/Simulation/Analysis; 5.5. Processes;

Abstract. The design of embedded systems usually involves complex requirements analysis, system modeling, and control implementation, and traditional manual modeling methods often face the risk of ineffi-ciency and human error when dealing with large-scale systems. In this paper, we propose Intelli-Factory, an embedded intelligent software factory methodology based on Multi-Agent systems, which extends the classic MagicGrid process to automatically generate SysML v2 and SCADE models, achieving full lifecycle automation management from requirements to embedded code. This ap-proach significantly shortens the development cycle and reduces the risk of human errors. Intelli-Factory is requirements-driven and supports the entire process from high-level system architecture design to the underlying control model implementation and embedded code generation through a unified development framework and automated toolchain. The effectiveness and practicality of the method is verified through the case of UAV flight control system. Experimental results show that IntelliFactory is significantly better than the traditional manual modeling method in terms of modeling efficiency, and is able to generate high-quality models in a shorter period of time. The method pro-vides a new automated modeling solution for embedded software development with a wide range of application prospects.

Paper#213

Intelligent Exploration

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Presented on: Tuesday, 15:30-15:55 EDT

Keywords. Space;Optical Communications;Artificial Intelligence (AI);Extraterrestrial Environments

Topics. 1.4. Systems Dynamics; 1.5. Systems Science; 11. Information Technology/Telecommunication; 14. Autonomous Systems; 2. Aerospace; 2.2. Manufacturing Systems and Operational Aspects; 2.4. System Architecture/Design Definition; 2.5. System Integration; 3.7. Project Planning, Project Assessment, and/or Project Control; 5.11 Artificial Intelligence, Machine Learning; 5.12 Automation; 5.5. Processes; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.);

Abstract. Abstract. This paper investigates the application of systems engineering to integrate optical communications with Artificial Intelligence (AI) for autonomous exploration of extraterrestrial environments. Focusing on deep-space missions, it examines AI-enabled robotic systems sup-ported by high-bandwidth, low-latency optical communication to assess planetary habitability. Using systems engineering methodologies, the research addresses key challenges, including inte-gration feasibility, scalability, and robustness under interplanetary constraints.
This research hypothesizes that a systems engineering framework can effectively integrate AI software, optical communication infrastructure, and robotic platforms into a cohesive and scal-able solution for space exploration. It addresses three key questions: (1) What systems engineer-ing methodologies are needed to design and manage this integration? (2) What factors influence the feasibility of implementing such systems, considering technological, operational, and envi-ronmental challenges? (3) Can systems engineering approaches ensure robustness and scalability under interplanetary constraints? By applying these principles, this study seeks to identify critical design considerations for creating efficient and resilient solutions for future space missions.

Paper#22

Into the Unknown!

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Presented on: Monday, 14:15-14:55 EDT

Keywords. Uncertainty;Unknowns;Detection;Sources;Reserve;Plausible Worst Case

Topics. 2. Aerospace; 22. Social/Sociotechnical and Economic Systems; 3.3. Decision Analysis and/or Decision Management; 3.7. Project Planning, Project Assessment, and/or Project Control; 3.9. Risk and Opportunity Management; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. When working a project, the one thing we can be confident about, is that there will be uncertainties and unknowns. It’s hard enough to plan a car journey and guarantee an arrival time. Complex or novel projects will only be more challenging. On a project, late change can impact budgets and schedules. A Systems Engineer will consider the Known-Knowns and the Known-Unknowns. These are things they know. But what about the Unknown-Knowns and the Unknown-Unknowns? How can we determine what we don’t know we don’t know? Are there ways to improve their detection or protect ourselves from them? This paper looks at a range of studies to uncover the sources of Unknowns. Then we shall explore ways to improve the detection of them. Based on a study of over five hundred projects, we can begin to predict a likely level of unknowns. A project planner or budget owner can then protect themselves with Reserve for a Plausible Worst-Case outcome. Detect what you can, and protect yourself from what you don’t yet know.

Paper#71

Large Language Model-based Generation of Use Case Diagrams from Requirements Specifications

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Presented on: Monday, 15:30-16:10 EDT

Keywords. Use case diagrams;Large Language Models;Prompt engineering;Model-Based Systems Engineering;Requirements engineering

Topics. 3. Automotive; 5.11 Artificial Intelligence, Machine Learning;

Abstract. Model-based formalization of natural language requirements is a promising approach to cope with the ever-increasing complexity of technical systems and the resulting increase in requirements. Use case diagrams typically are the first step towards model-based requirements in terms of Model-Based Systems Engineering. As manual modeling is perceived as time-consuming for large requirements specifications, there is a need for modeling assistance with artificial intelligence. To allow for an industrial application, certain demands must be met. This comprises working with multiple requirements per use case as well as dealing with inhomogeneous natural language requirements. Recent advances in the field of Large Language Models open new possibilities to support the manual modeling task. Therefore, this contribution proposes a comprehensive method based on two sequential prompting pipelines, namely intra-use case and inter-use case pipeline. Both utilize advanced prompting techniques like one-shot prompting to improve the quality of the results. Semi-structured expert interviews were conducted to assess the quality of the resulting use case diagrams. This revealed a general applicability and semantic integrity of the results especially with consideration of the industrial application scenario. Thus, the method can effectively support the creation of use case diagrams and contributes to a clear model basis for subsequent behavior modeling.

Paper#382

Lifecycle Switching Costs

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Presented on: Tuesday, 16:00-16:25 EDT

Keywords. adaptability;switching cost;systems engineering;software tool

Topics. 3.7. Project Planning, Project Assessment, and/or Project Control; 4.2. Life-Cycle Costing and/or Economic Evaluation; 5.2. Lean Systems Engineering;

Abstract. Switching costs, an important topic in adaptive systems, are the costs incurred by modifying a product design to another. Most previous works focused on development switching costs. However, design switching can trigger different production costs and operational costs too. Also, for development costs, only two methods, process-based and parametric, are available. For open-source tools, only one tool is available, COSYSMO (parametric). However, parametric methods require large sets of historic cost data, and cannot support small or medium size products, which leaves the problem still unresolved. This paper addressed these gaps. Its contributions are: first, it analyzed the whole lifecycle switching cost and revealed that some mathematical properties from development switching costs no longer hold. Second, it identified and proved the new mathematical properties for lifecycle switching costs, and also developed a new useful concept, vendor switching cost. Third, it presented a new tool for estimating these costs, which does not rely on product sizes, making it the first open-source tool that supports all systems. Finally, we demonstrated its effectiveness through an example use case of office area design, and made the tool available online, with a manual and this detailed example.

Paper#263

MBPLE Adoption in the European Aviation, Defense and Automotive Industries

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Presented on: Monday, 11:30-12:10 EDT

Keywords. Feature-based PLE;MBPLE;ISO/IEC 26580;European Industries;Aviation;Defense;Automotive;Real-world Adoption

Topics. 2. Aerospace; 3. Automotive; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 5.6. Product Line Engineering; 6. Defense;

Abstract. This paper focuses on the adoption of Model-Based Product Line Engineering (MBPLE) across three European industries, showcasing its potential to address system's complexity and variability. MBPLE, as combination of feature based PLE and Model-Based Systems Engineering (MBSE), leverages standards like ISO/IEC 26580 to enable machine-readable models for managing variants and supporting the digital thread across multiple domain-specific assets. The work highlights a common pattern in MBPLE adoption, from initial motivation to practical implementation, in terms of process, methods, information model, toolchain and organization, while noting differences driven by industry-specific contexts.

Paper#214

Methodology for Model-Based Certification

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Presented on: Tuesday, 11:00-11:20 EDT

Keywords. MBSE;Certification;Model-based certification;Model-based systems engineering;System validation

Topics. 1.6. Systems Thinking; 14. Autonomous Systems; 2.3. Needs and Requirements Definition; 2.6. Verification/Validation; 3. Automotive; 3.8. Quality Management Process; 5.3. MBSE; 5.5. Processes; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 6. Defense;

Abstract. This paper presents a methodology for Model-Based Certification (MBC). As Model-Based Systems Engineering (MBSE) gains acceptance in industry, efficiencies can be realized by including more aspects of the systems engineering Vee model within the MBSE system model. This paper proposes a process for Model-Based Certification, wherein all aspects of a system of interest and the data needed for certification can be contained within a Systems Modeling Language (SysML) based model.

Paper#226

Methods for Quantifying Rework Risk to Make Efficient Schedule for a Project

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Presented on: Tuesday, 13:30-13:55 EDT

Keywords. Project Scheduling;Rework Risk Quantification;Multi-Agent System (MAS);Design Structure Matrix (DSM);Resource Allocation Optimization

Topics. 1. Academia (curricula, course life cycle, etc.); 3.7. Project Planning, Project Assessment, and/or Project Control;

Abstract. This research paper presents a novel methodology for quantifying rework risk and creating effi-cient project schedules. The study addresses the challenge of rework in project management, which often lacks explicit planning despite its significant impact on later project stages. The authors propose a two-step simulation model that combines DSM (Design Structure Matrix) clustering algorithms and MAS (Multi-Agent System) simulation with Fuzzy Logic Inference Systems to overcome challenges in impact assessment, task dependencies, and human resource skill varia-bility. The methodology was validated through a case study of a train control system design project with 26 subsystems. Results showed significant improvements in project efficiency, achieving 82.9% overall resource utilization, with senior workers reaching 89.7% utilization. The study demonstrated potential for up to 40% reduction in total make span through optimized execution order and resource allocation. Through 50 rounds of simulation, the results showed rework percentages ranging from 30.7% to 40%, while resource utilization varied between 63.3% and 90.3%, indicating the model's effectiveness in optimizing resource allocation and minimizing rework impact. The research makes a significant contribution to project management by integrating rework risk quantification with resource allocation optimization, providing a systematic approach for handling complex project dependencies. The methodology enables efficient scheduling through early-stage rework risk reduction and comprehensive consideration of project planning elements including scope, resources, and cost. Future research directions include application to more complex projects, development of nuanced resource categorization systems, and integration with critical path analysis. The methodology represents a valuable tool for project managers seeking to improve efficiency and reduce project duration and cost while effectively managing rework risks.

Paper#354

MilliSwarm: Leveraging Emergence for Energy Efficient Robotic Swarm Movement

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Presented on: Wednesday, 15:30-15:55 EDT

Keywords. Emergence;Energy Efficiency;Multi-Agent Systems;Swarms;Bio-Inspired Design

Topics. 1.3. Natural Systems; 5.4. Modeling/Simulation/Analysis; Other domain;

Abstract. Abstract. INCOSE Systems Vision 2035 outlines the need for greater understanding of both complex system dynamics and efficient systems. Energy efficiency and coordination in multi-agent systems is a key focal point of current research. Finding solutions to group movement that balance energy savings and group cohesion provide unique benefits to the system. While current approaches focus on improving the efficiency of individual swarm members (a reductionist approach), we approach this challenge through using biologically inspired design to harness emergence. Thus, the hypothesis examine is: “If rolling swarm inspired movement is applied to ground swarms encoun-tering obstacles, then the system's overall energy efficiency will improve because cooperation in both climbing and moving reduces the energy required to operate in these environments.” In this article a method for moving groups of agents together as a team is presented, inspired by the behaviors of millipede swarms. The individual agents represent robots that are abstracted into uniform sliding blocks. Using simple behaviors based on individual knowledge, rather than global information sharing, we present a new efficient way to travel in groups. Initial data shows up to a 96% decrease in energy spent in certain scenarios for systems using the proposed MilliSwarm movement design. Additionally, this algorithm proves to be increasingly efficient at larger swarm sizes, while not re-quiring additional computing resources for coordination. Future work in this project will work on applying these functions to 3D environments, real-world case studies, and additional non-physical system implementation.

Paper#182

MissionDE: A Distributed Process Engine for Automated Mission Execution

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Presented on: Wednesday, 15:30-15:55 EDT

Keywords. Automated Mission Execution;Dynamic Mission Scheduling;Resource-Based Execution;Real-Time Process Adaptation

Topics. 14. Autonomous Systems; 5.12 Automation; 5.5. Processes; 7. Emergency Management Systems;

Abstract. As automated task execution scenarios become increasingly complex, there is a pressing need for systems capable of managing intricate operations efficiently. While current models support the construction of complex tasks, a gap remains in the availability of engines that can automate task execution effectively. This paper presents a distributed process scheduling engine tailored to the needs of automated mission schedules and execution across multiple platforms. The engine enables efficient resource allocation, task distribution, and inter-platform communication, enhancing real-time responsiveness, reliability, and adaptability within a dynamic operational environment. The engine supports modular and distributed execution of processes. Key functionalities include automated parsing of process definitions, real-time task status monitoring, fail-safe mechanisms, and dynamic task orchestration, allowing for responsive adjustments to changing conditions or task requirements. The scheduling engine integrates seamlessly with external modules and offers a robust API for managing task dependencies, life cycles, and system states. Compared to existing engines, such as Activiti, Camunda, and Flowable, this engine has unique strengths in dynamic task orchestration and resource allocation. It allows real-time process modifications without scheduling, aligning closely with real-world requirements for automating complex operations. We consider resource factors in task scheduling and reduce task execution failures caused by insufficient resources. With high reliability and scalability, the distributed architecture ensures local adaptability in network disruptions, enhancing overall system stability and extensibility. These features position the engine as a robust solution for large-scale, automated task-scheduling applications.

Paper#278

Model-Based Maintenance Planning and Analytics for Oil & Gas Offshore Systems

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Presented on: Tuesday, 16:30-16:55 EDT

Keywords. Model-Based Systems Engineering;Maintenance Planning;On Off Valves;Failure Rates;Analytics

Topics. 15. Oil and Gas; 2.2. Manufacturing Systems and Operational Aspects; 4.3. Reliability, Availability, and/or Maintainability;

Abstract. Good planning and data management have become increasingly essential for companies in the oil and gas industry and other complex and task-dependent industries. Digitalization has, for that reason, be-come more prevalent. It has allowed businesses to reevaluate how they operate and set up their goals and strategies, allowing them to build resilience that has helped them harness data to gain better in-sights and analytics. The oil and gas industry could use a more holistic model-based approach to planning integrated maintenance. This may be accomplished using model-based systems engineering (MBSE) principles adapted to the oil
and gas industry.

MBSE usage for maintenance and test concepts can be further enhanced by using analytics to deal with failure rates of different types of components. Calculations based on design and operational experience data can improve overall maintenance planning and management. On/off valves, as defined in (ISO 14224,2016), have various applications in industrial processes and are commonly used in safety sys-tems. Therefore, on/off valves have been selected for the scope of this manuscript.

The analysis presented in this paper indicates that utilizing MBSE in maintenance planning and man-agement, together with data-driven analysis, could make maintenance more efficient and streamline the process

Paper#381

Model-Based System Verification Applied to Spanish Navy's S80 Class Submarine Sustainment Case Study

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Presented on: Tuesday, 14:30-14:55 EDT

Keywords. MBSE;verification;RAMS;multiphysics simulation;mission engineering;sustainment.

Topics. 2.4. System Architecture/Design Definition; 3.1. Acquisition and/or Supply; 5.3. MBSE; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 6. Defense;

Abstract. The emergence of model-based methods in systems engineering has been at the forefront of the discourse in complex system development in recent years. While MBSE is seen as a model-based approach to systems engineering, its implementations across industries have varied in terms of the usability of the models themselves and the scope of the SE process covered by employing these models to use. Generally, MBSE methodologies promote using models to capture and allocate requirements, describe system's functional and structural definition, associated parametric constraints and in some cases- localized simulation capabilities. While such approaches have proven beneficial, there exist significant scalability challenges of MBSE across the system development lifecycle, especially in the naval and maritime industries. In this study, we explore a model-based system verification approach that focuses on developing system models that capture safe-ty-critical functional behavior required to deliver mission capabilities while using those as orchestrators of functional failure assessment across multiple stakeholders through a cross-domain lifecycle collaboration platform. Using multiphysics control models, functional failures are analyzed, and results are captured in a configurable verification dataset that can be shared across the enterprise stakeholders. In a submarine program, such an approach can have significant benefits such as granular model development, model-based communication across stakeholders, early detection of functional flaws and agility in complex system development programs to name a few.

Paper#273

Model-Driven Engineering for Modeling and Simulating Satellite Power Systems: A Case Study

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Presented on: Wednesday, 11:30-12:10 EDT

Keywords. Satellite System;Model Driven;SysML;MagicGrid

Topics. 5.3. MBSE; 5.4. Modeling/Simulation/Analysis;

Abstract. Model-Based System Engineering (MBSE) accurately defines different models for specifying system requirements, architecture, and design. Moreover, it supports traceability between different levels of abstraction and refinement, as well as direct verification models through simulation without imple-mentation. However, it is still a lack of practical guidelines and a complete case study to help domain experts and system engineers to learn and use in academic and industry settings. In this paper, we present a comprehensive case study that uses the System Modeling Language (SysML) and the modeling approach MagicGrid to analyze, specify, simulate, and verify the satellite power supply system. By starting from analyzing stakeholder needs in the problem domain, identifying system context, describing system use cases, transitioning to the system requirements, modeling system ar-chitecture and behavior, simulating and verifying the correctness of the system, the model-driven approach shows the advantages of precise system definition, automatic traceability detection, and lower verification costs in practice. Finally, we summarize the guidelines and best practices of the MBSE approach for domain experts and system engineers.

Paper#353

Modular Design Method Considering System Architecture in Maritime Radar System for Autonomous Ship

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Presented on: Wednesday, 16:00-16:25 EDT

Keywords. Modular Design;Maritime Radar System;System Architecture;Performance Optimization;Au-tonomous Ships

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

Abstract. This research proposes a novel methodology for modular design of maritime radar systems for autonomous ships, specifically focusing on X-band and S-band radars. The study addresses the challenge of creating efficient modular designs while considering system architecture character-istics and performance requirements. Utilizing Capella modeling tool for system decomposition, the research first identifies 17 key components of radar systems. A comprehensive evaluation framework is then developed, incorporating four metrics: design inner difficulty, design outer difficulty, design gap, and design conflict. These metrics assess module relationships, interface complexities, performance variations, and alignment with existing radar designs. The methodology integrates random module generation with Non-dominated Sorting Genetic Algorithm III (NSGA-III) for optimization, evaluating 5,000 potential designs to identify optimal modular configurations. The resultant designs for both X-band and S-band radars feature two distinct module types: shared modules for minimizing system complexity and customizable modules for performance variation. For X-band radars, four modules are identified with 22 effective variations, while S-band radars comprise three modules with 24 variations. The research demonstrates that modularizing transmitter components enhances customization capabilities while managing system complexity. The proposed designs align closely with existing radar architectures, minimizing implementation costs and changes. The study validates the effectiveness of the methodology in creating practical modular designs that balance customization with system complexity, though further research is needed to address software modularization and expand performance variations.

Paper#351

NASA’s Hopes and Fears of Digital Engineering

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Presented on: Thursday, 14:00-14:25 EDT

Keywords. Digital engineering;MBSE;group model building;GMB;community-based system dynamics;CBSD

Topics. 2. Aerospace; 5.3. MBSE;

Abstract. Missions and research objectives at the National Aeronautics and Space Administration (NASA) continue to increase in scope and complexity while under significant schedule and budget pressure. Digital transformation is a key enabler for NASA to do more with less. But as many large and storied organizations are experiencing, the rate of digital transformation is as much a social problem than a technical one. Contributing social factors include the distribution of the inherent willingness of individuals to adopt new technologies and the natural tendencies of like-minded individuals to form echo chambers. A team of NASA systems engineers recently attempted to smooth over those tendencies and kick-start more productive dialog in the area of digital engineering by leading a group model building session using community-based system dynamics approaches at the 2024 NASA Systems Engineering Workshop, which included over 400 participants. This paper captures the approach, results, and findings of this ambitious experiment.

Paper#265

Navigating Complex Systems: A review of Systems Practice Frameworks

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Presented on: Thursday, 13:00-13:25 EDT

Keywords. Complex Systems;Systems Engineering Practices;Systems Engineering tools;Approach Selection;Critical Thinking

Topics. 1.1. Complexity; 1.6. Systems Thinking; 3.3. Decision Analysis and/or Decision Management; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Systems engineering methodologies are complex and interconnected, reflecting various philosophies and problem-solving approaches. Practitioners often question their suitability for all contexts, especially complex adaptive systems. This has led to the need for meta-methodologies” which could help in the selection of appropriate methodologies. Michael C. Jackson’s “Critical Systems Thinking: A Practitioners Guide” introduces a more pluralistic approach, exploring different systemic perspectives to inform the selection and combination of methodologies, replacing the term meta-methodology with the “Practice” term as in Critical Systems Practice (CSP). Taking this lead this paper reviews a set of similarly constructed publications, termed Systems Practice Frameworks (SPF), that all seek to aid the reader in characterizing their unique problem and proposing pointers to tools, techniques, heuristics or methodologies. It compares and contrast these approaches to assess their suitability to guide readers in selecting suitable approaches to address Complex Adaptive Systems and identify recommendations for improving SPFs. It concludes that SPFs are increasingly pivotal in helping Systems Engineers face their unique complex challenges. CSP is identified as the most useful SPF, but the other SPF’s indicate improvements that can be made, such as simplification of the advice, and pointing towards a wider accessible range of practices.

Paper#30

Navigating Innovation: MBSE Adoption at Turkish Aerospace Industries

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Presented on: Wednesday, 16:00-16:25 EDT

Keywords. Model-Based Systems Engineering (MBSE);Systems Engineering (SE);SysML;Digital Transformation

Topics. 2. Aerospace; 5.3. MBSE; 5.5. Processes;

Abstract. Turkish Aerospace has been developing indigenous aircraft design for 30 years with a well-defined systems engineering methodology in line with guidelines of INCOSE. However, in parallel to the improvements in technology, the aircraft systems evolve to be more complex which requires new solutions to support the complexity and increasing demand to reduce the time to deliver. Complex Aircraft design contains lots of system designs, including advanced avionics, communicating with each other through integrated network systems and communicating with other assets outside of the aircraft. The development of this complex system pushes the limits of traditional Systems Engineering approaches, necessitating new methods to manage the increasing complexity. Model-Based Systems Engineering (MBSE) represents a modern approach to Systems Engineering, shifting the focus to using models as the primary source of information for developing complex systems. As MBSE helps to tackle the intricate challenges inherent with the advanced technologies, Turkish Aerospace has decided to transition to MBSE, for the new starting complex Aircraft Design Project. Turkish Aerospace traditionally relied on conventional Systems Engineering practices, where standalone documents served as the primary artifacts for system development. As a result, the organization had limited experience with MBSE and how to effectively implement it in practice. This lack of familiarity created challenges in adopting the new approach within the organization. In this paper, we will share our experiences transitioning from a document-centric Systems Engineering to an MBSE approach, discussing the transformation process, issues, and practical insights.

Paper#212

Next Generation MBPLE with SysML v2: Feature Modeling, Variability Modeling and API Potentials

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Presented on: Thursday, 11:20-11:50 EDT

Keywords. MBPLE;PLE;MBSE;SysML v2;Variability Modeling;Feature Modeling;Interoperability

Topics. 5.3. MBSE; 5.6. Product Line Engineering;

Abstract. This paper explores using SysML v2 for Model-Based Product Line Engineering (MBPLE), focusing on how it improves variability management compared to SysML v1. It highlights SysML v2's built-in support for variations and variants in requirements, structures, and behaviors, showcasing its capabilities through a drone product line example. The authors also propose a SysML v2 extension for feature modeling, leveraging the language's API for tool integration. The paper emphasizes the importance of consistency and traceability across shared assets and the potential of SysML v2 as a central hub in MBPLE toolchains. Finally, it concludes that SysML v2 offers a robust framework for managing variability in complex product lines.

Paper#238

OMG's Approach to Developing its SysMLv2 Certification Program

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Presented on: Tuesday, 10:00-10:20 EDT

Keywords. SysML;SysMLv2;Certification

Topics. 5.3. MBSE; 5.9. Teaching and Training;

Abstract. The imminent adoption of the Object Management Group's (OMG's) Systems Modeling Lan- guage version 2.0 (SysMLv2)1 has created an immediate industry-wide need for personal knowledge certi- fication in this new and powerful language. However, the unique features of SysMLv2 have made it more challenging than its predecessor (SysMLv1.x)2 in creating a certification program. This paper provides an overview of the history, challenges experienced, and innovative approaches taken by the SysMLv2 Certi- fication Working Group (SCWG) in the ongoing development of the upcoming certification exams.

Paper#23

On The Importance of Being Able to Hold a Stake

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Presented on: Monday, 15:30-16:10 EDT

Keywords. Stakeholders;needs;decomposition;roles;stakeholder integrator role;Belbin;Graves;Myers-Briggs

Topics. 1.6. Systems Thinking; 2. Aerospace; 2.1. Business or Mission Analysis; 2.3. Needs and Requirements Definition; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. The consideration of stakeholders as an input to a Systems Engineering approach is well-known and well-documented. What is not considered or discussed as much are the times a Systems Engineer developing a solution must become a stakeholder, defining and distributing needs derived from the system solution to its sub-element systems and other realization systems. This paper describes the importance of a Systems Engineer being able to act as a stakeholder, and how important the partnership and cooperation between a system developer (Systems Engineer) and the stakeholders is. Both interacting with and being a stakeholder are important skills for a Systems Engineer to have – this paper gives an introduction to both why and how to do this.

Paper#401

Ontological definition of seamless digital engineering based on ISO/IEC 25000-series SQuaRE product quality model

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Presented on: Tuesday, 11:30-12:10 EDT

Keywords. digital engineering;ontology engineering;digital transformation;model-based systems engineering

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

Abstract. Since the introduction of Digital Engineering (DE) in 2018, enterprises and standards working groups have been interpreting the DE strategy to create meta-models of those interrelated concepts for integration into their processes and tools. Ontology development is underway and requires the import of other international standard sources such as ISO/IEC/IEEE 15288, 42000-series, 27000-series, and 25000-series to effectively model the knowledge domain where digital engineering applies. The harmonization of the concepts used in these standards continues to improve with each revision, but can more effectively be accomplished when relying on the descriptive logic formalized in the Web Ontology Language (OWL 2 DL). This paper presents a fully-verified ontology based on the Basic Formal Ontology (BFO) and Common Core Ontologies (CCO) that is used to define Seamless Digital Engineering: a digital tooling paradigm that relies on formal verification of digital interfaces to provide a system-level qualification of the assured integrity of a Digital Engineering Environment. The present work defines classes and equivalence axioms, while using only the BFO- and CCO-defined object properties that relate them, to provide a baseline analysis that may inform future DE-related ontology development, using a case study to formally-define the `seamless' quality in relation to the updated 25010 SQuaRE product quality model. We identified ISO meta-model inconsistencies that are resolvable using the BFO/CCO ontological framework, and define `seamless' as both a system integration quality and a Human-Computer Interface quality-in-use, working to disambiguate this concept in the context of DE.

Paper#379

Outcome-Driven Product Development: An enabling system for complex system development projects

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Presented on: Tuesday, 05:30-05:55 EDT

Keywords. Complexity;Product Development;Outcome Driven;Process Application

Topics. 1.1. Complexity; 22. Social/Sociotechnical and Economic Systems; 3.7. Project Planning, Project Assessment, and/or Project Control; 5.5. Processes; 5.7. Software-Intensive Systems; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Not all complexities are equal; complex projects are more complex than the complex products they are developing due to the interaction of a project's social dimensions and its technical dimensions. Standards are intended to manage project risk by mitigating the impacts of complexity; however these standards are often applied in an approach that fixates on project activities for the complex product but obscures the need to manage the total risk of the complex project. Such an approach assumes that the desired project outcomes will be achieved if project activities, inputs, and outputs are properly controlled. When applied to a complex project this approach, which we refer to as "activity-driven" product development, can result in waste (e.g. excessive up-front documentation or unnecessary revision), project delays, project inflation, or other disruptions of the desired project goal.
We propose an approach for the application of standards to product or system development that addresses the total complexity of the development project: the complex product under development along with the complexity of its enabling project system. This approach, which we refer to as "outcome-driven" product development, positions outcomes explicitly as the purpose of the project and driving comparisons of the current state of work products vs. the desired outcome. Project activities, inputs, and outputs are then shaped by the results of these comparisons.
Key characteristics of activity-driven and outcome-driven project approaches are identified; key differences between activity-driven and outcome-driven project approaches are defined; and relevant supporting terms are disambiguated within their sources from their respective standards bodies.
Examples of both activity-driven and outcome-driven approaches, using standards from PMI, ISO/IEC/IEEE, and INCOSE, are presented in illustrative scenarios for development of a simple hardware product item, a complicated software product item, and a complex software-enabled system product item.

Paper#52

PBSE Data Initialization Framework and Practive by Using LLM

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Presented on: Thursday, 10:10-10:40 EDT

Keywords. PBSE;AI4SE;Artificial Intelligence;Large Language Models

Topics. 2. Aerospace; 5.1. Agile Systems Engineering; 5.11 Artificial Intelligence, Machine Learning; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis;

Abstract. With the increasing complexity of commercial aircraft and the rapidly changing market demands, the system engineering development pattern extensively adopted by aircraft OEM has evolved from the traditional "Document-Based Systems Engineering (DBSE)" to "Model-Based Systems Engineering (MBSE)" and "Pattern-Based Systems Engineering (PBSE)." MBSE employs models to describe products, while PBSE builds upon MBSE by utilizing engineering patterns, which are validated in advance, to enhance the efficiency and quality of data production in both MBSE and DBSE. However, during PBSE engineering practices, we have observed certain challenges, such as the barriers to initializing product S* model and the low efficiency in generating instance. AI4SE is an emerging concept aimed at creating a more efficient and user-friendly systems engineering implementation environment through the integration of Artificial Intelligence (AI), Machine Learning (ML), and related technologies.This paper explores the application of AI4SE in real-world engineering projects by leveraging "Large Language Models (LLMs)" to develop a methodology that reduces the deployment threshold of PBSE for enterprises and enhances the efficiency of instance generation.

Paper#129

Performing verification and validation activities in a model-based environment

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Keywords. Model-based Systems Engineering;Verification;Validation;INCOSE;Needs and Requirements

Topics. 1. Academia (curricula, course life cycle, etc.); 17. Sustainment (legacy systems, re-engineering, etc.); 2. Aerospace; 2.3. Needs and Requirements Definition; 2.6. Verification/Validation; 5.3. MBSE; 5.5. Processes; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Verification and Validation (V&V) are critical processes of systems engineering, ensuring alignment between stakeholder needs and system realization. As industry transitions from document-centric to model-based systems engineering (MBSE), limited guidance exists for implementing V&V in a model-based environment, particularly for early lifecycle activities. This paper presents an adaptable methodology leveraging Cameo Systems Modeler and a SysML-derived Meta-Model to perform V&V across needs, requirements, design, and system levels. By aligning with the INCOSE Needs and Requirements Manual (NRM) (INCOSE Needs and Requirements Manual, Needs, Requirements, Verification, Validation across the Lifecycle, 2024), the proposed approach is split into two major processes: needs and requirements V&V and design and system V&V. Needs and requirements V&V integrates automated and manual methods for ensuring need and requirement sets are written in compliance with the INCOSE NRM through the instantiation of structured attributes and text validation rules. Design and system V&V uses a custom profile to define system V&V attributes and activities used for verification and validation planning in order to ensure that the system design and realized system meets the intent of the requirements and needs. This model-based framework enhances the efficiency and accuracy of both needs and requirements V&V and system and design V&V activities throughout the system development lifecycle.

Paper#163

Redesigning Systems Architecture for AWS Platform Migration: A Case Study of an Energy Monitoring System

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Presented on: Tuesday, 15:30-15:55 EDT

Keywords. Energy Mapping;Energy Monitoring;Platform Migration;System Architecture;System Engineering

Topics. 2.4. System Architecture/Design Definition; 3.3. Decision Analysis and/or Decision Management; 5.5. Processes;

Abstract. Monitoring activities play an important role in increasing the effectiveness of the energy adopted in the industry. Accurate tracking in combination with analytical usage patterns helps to identify potential inefficiency in the adopted setting. Cloud-based services are adopted to help these monitoring activities. Energy companies adopt these platforms to leverage real-time energy data. Recent advancements in this field have led companies to continuously evolve and develop their energy platforms. Platform migration is important for improving scalability, flexibility, and advanced analytics. This paper presents an industrial case study on redesigning system architecture for platform migration. The case company aims to modify its actual Energy Monitoring System (EMS) by shifting from its current EMS to a novel platform. The case study shows how platform migration requires technical and organizational challenges related to the integration of the novel platform in the existing system architecture. This work proposed a strategy to minimize stakeholder's resistance and ensure an easy platform migration aligned with the company's objectives. Potential risks associated with the platform migration are analysed. Potential risks associated with the platform migration are analysed.

Paper#364

Relationship between Adaptability and Resilience

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Presented on: Thursday, 13:30-13:55 EDT

Keywords. System Adaptability;Resilient Systems;Adaptable Systems Engineering;Systems Engineering

Topics. 2.3. Needs and Requirements Definition; 4.4. Resilience;

Abstract. This paper addresses an important topic and a frequently asked question on the differences, relationships, and causality of system adaptability and system resilience. It discusses areas that are unique to each concept, and the significant common areas. We depict the relationship through a comparison chart and Venn Diagram that addresses both the unique areas and areas of synergy. We present different types and representative case studies/examples for both adaptive systems and resilient systems. This is a comprehensive study for a year between the Resilient System working group and System Adaptability working group in INCOSE for answering the frequent question on the difference and relationship between adaptability and resilience, and will be useful to help the systems engineering community to understand each concept and apply techniques accordingly. We also identify the value of applicable resilience and adaptability techniques for stakeholders and show directions for further investigations and subsequent studies.

Paper#192

Scar Tissue in a Sophomore Course: SE Experience Acceleration in a Safe Environment

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

Keywords. education;experiential learning;art of systems engineering;undergraduate education

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

Abstract. This paper presents an innovative educational approach used in a sophomore systems engineering course, where LEGO Mindstorms robots are integrated to accelerate the understanding of complex systems engineering concepts. While hands-on learning tools like LEGO Mindstorms are often used in engineering education, our approach uniquely emphasizes the unpredictability and complexity inherent in real-world systems engineering. Rather than focusing solely on technology or project completion, we incorporate controlled disruptions during exercises, such as modifying project requirements, changing team compositions, or removing key components from the kits. These disruptions simulate dynamic environments, requiring students to adapt, manage resource limitations, and navigate evolving constraints. This approach bridges the gap between theory and practice, allowing students to rapidly prototype, test, and observe the impacts of their engineering decisions in real time. This paper describes in detail the instructional approach and presents the different experiences that mimic real-life projects that emerge during the learning activities.

Paper#318

Semantically-Enabled Dashboards to Support Systems Engineers

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Presented on: Wednesday, 14:00-14:25 EDT

Keywords. Digital engineering;Model-based systems engineering;Semantic web technologies;Ontologies

Topics. 1. Academia (curricula, course life cycle, etc.); 2. Aerospace; 3.4. Information Management Process; 5.3. MBSE; 6. Defense;

Abstract. Modern digital ecosystems require aggregating data from multiple tools, but ensuring seam-less integration without replicating data across these tools remains a challenge. Dynamic dashboards address this issue by enabling real-time visualization and interaction with aggregated data. Ontologies, as formalized representations of domain knowledge, offer a robust foundation for achieving this integration. They enable the structuring, querying, and reasoning over complex datasets, ensuring semantic consistency and interoperability across domains. Building on the University of XXX Ontology Stack (UXOS), a layered, modular ontology system developed to support digital engineering, we explore its application in dynamic dashboard generation. The UXOS leverages the Basic Formal Ontology (BFO) and includes core ontologies based on the Common Core Ontologies and Provenance Notation (PROV-N), as well as domain-specific ontologies such as the System Architecture Ontology and the Orbits and Trajectories Ontology. By federating knowledge across these ontologies, the UXOS enables dynamic mapping of heterogeneous data to reusable, semantically coherent structures. This capability facilitates the creation of dashboards that adapt to evolving user needs and data contexts in a tool-agnostic manner. In this paper, we present a methodology for leveraging the UXOS in the generation of dynamic dash-boards. We demonstrate how the integration of ontologies, reasoners, and SPARQL queries supports the automated configuration of dashboard components. Use cases from digital engineering research are discussed to illustrate the approach. Additionally, we address challenges, including real-time performance and ontology alignment, and identify opportunities for future enhancements in dynamic visualization systems.

Paper#260

Stakeholders Harmonization Initiative: An UAF Approach to System Dynamics in Enterprise Architecture and Product Service Systems

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Presented on: Tuesday, 16:00-16:25 EDT

Keywords. Energy Transition;Hydrogen Supply Business;Enterprise Architecture;UAF;System Dynamics;Product Service System

Topics. 1.4. Systems Dynamics; 10. Environmental Systems & Sustainability; 2.1. Business or Mission Analysis; 4.2. Life-Cycle Costing and/or Economic Evaluation; 8. Energy (renewable, nuclear, etc.);

Abstract. Mitsubishi Heavy Industries is working on the energy transition to achieve Carbon Neutral, which can be achieved by collaborating with multiple stakeholders. While it is of course important to achieve Carbon Neutral as a social issue through the energy transition, it is also important to consider the business viability of stakeholders, including clients, the company itself, and partners. This paper shows assessment how the manufacturer's development activity of liquid hydrogen solutions can contribute to the energy transition and the client's hydrogen supply business.
The purpose of this paper is to provide a method for describing and evaluating enterprise architectures to support consensus necessary for future business progress by harmonizing the stakeholder's concerns.
This paper proposes an approach that combines Unified Architecture Framework, system dynamics, and a product service system approach. Causal loops are described in the manner of system dynamics approach to capture the strategic business issues, considering future business environment change. Based on the business strategic issues, enterprise architecture is described to capture how the company's business contributes to the client's business, using the UAF's domain of strategy, operations, and resources. Then service business analysis was conducted to identify a product service system as a new business. It examined the key operational activity extracted from the enterprise architecture and identified a new service centered business candidate to solve the strategic business issues. In addition to that, multiple patterns of resource combinations to implement operational architecture were described. Two patterns of them were evaluated how they impact on the enterprise goals which are defined based on the causal loops. The evaluation was conducted in the manner of calculation by formulation.

Paper#60

Standards Gaps for Enabling Model Interoperability for MBSE in a Digital Engineering Context

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

Keywords. Descriptive models;interoperability;model interoperability;MBSE;DE;digital engineering

Topics. 5.3. MBSE;

Abstract. Model-Based Systems Engineering (MBSE) is the modern practice of systems engineering in which descriptive models supplant documents as the formal embodiment of SE knowledge. MBSE is often per-formed within very localized contexts, creating models that inform their immediate stakeholders but not necessarily suitable for broader use or reuse. However, if the models are intended to serve wider purposes—-e.g., to be more broadly used, reused, and federated to enable sharing of the information they contain—-standards are needed to advance the quality, value, usability, and interoperability of those models, particularly when the intent is for the MBSE activity to contribute to and participate in a more comprehensive digital engineering (DE) ecosystem. This paper describes the problem of model interoperability in MBSE within a DE context and the role that standards play in facilitating broader use, reuse, and federation of models to achieve greater value from those models. It also describes standards for model quality, content, usability, and interoperability that are needed to advance the MBSE integration maturity not only of individual organizations but also of the broader MBSE community at large.

Paper#269

Streamlining Engineering in Growing SMEs: A Framework of Guidelines and Checksheets for Knowledge and Project Improvement

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Presented on: Tuesday, 14:30-14:55 EDT

Keywords. Project Management;Process Improvement;Guidelines;Checksheets;Knowledge Management

Topics. 13. Maritime (surface and sub-surface); 3.4. Information Management Process; 5.2. Lean Systems Engineering; 5.5. Processes;

Abstract. In the rapidly evolving marine automation industry, project-based small-to-medium-sized enter-prises (SMEs) in the engineering field face the dual challenges of managing complex projects and fostering innovation amidst intense competition. This research focuses on a case study, improving and streamlining the knowledge management (KM) and project management (PM) processes in a small growth-oriented company in Norway through the development of a project guideline and checksheets.
The project began with a critical evaluation of existing documentation practices and challenges perceived by the employees, identifying the need for a more adaptable and accessible set of tools. Through surveys and interviews with stakeholders, including engineers and project managers, insights were gathered on current work practices and the organisation's needs in these areas. This stakeholder engagement highlighted a preference for straightforward, easily navigable tools that support diverse project activities while enhancing efficiency and quality, whilst not consuming the time of the user.
The outcome is a proposed set of a guideline and checksheets designed to enhance PM and knowledge sharing. Developed through a collaborative process, these tools simplify complex tasks, gives the user an overview of the entire process, ensure documentation consistency, and provide intuitive access to key information, directly addressing the organisation's operational needs. The approach not only aligns with the organisation's strategic goals and engineering pro-cesses, but is expected to significantly improve daily operations, facilitating more effective team alignment and process efficiency.

Paper#210

Successfully Integrating Early Validation and Verification in Industrial MBSE

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Presented on: Thursday, 13:00-13:25 EDT

Keywords. MBSE;Simulation;Verification;Validation;Success factors

Topics. 2.6. Verification/Validation; 3. Automotive; 3.6. Measurement and Metrics; 5.3. MBSE; Other domain;

Abstract. Model-Based Systems Engineering (MBSE) is being adopted and integrated in industrial settings. Through MBSE several capabilities are unlocked and made available during development, especially in the earlier stages of development where there is historical use of document-based artefacts. A notable capability enabled by a primarily model-based development is Validation and Verification (V&V). Enabling early V&V is potentially a strong enabler for improving development efficiency, particularly through reducing the need for later prototyping stages. In fact, through MBSE virtual prototyping can be enabled through the early and continuous use of models. While virtual prototyping provides a significant value proposition, it is often confirmed to be challenging to adopt MBSE and integrate approaches in specific industrial contexts. In this article, we analyze existing approaches to understand what made them successful when applied in industry. From these findings we develop a set of criteria that positively influences the integration process, and reason about how to concretely achieve successful industrial integration. From the identified criteria a discussion on existing barriers is also provided, reasoning for why these successful factors is missing from a majority of MBSE disseminated work. Our final contribution is a set of recommendations that could steer published research towards more successful application of early V&V in industry through various incentives.

Paper#254

Sustainment of Navy Assets: A Case study of Post-Production Design Change Process and Documentation of Archetypical Sources of Inefficiency

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Presented on: Tuesday, 14:00-14:25 EDT

Keywords. Systems Engineering;Systems of Systems;Post-production Change;Sustainment;Naval Engineering

Topics. 13. Maritime (surface and sub-surface); 17. Sustainment (legacy systems, re-engineering, etc.); 2.4. System Architecture/Design Definition; 3.3. Decision Analysis and/or Decision Management; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 6. Defense;

Abstract. Complex systems-of-systems (SoS) such as Navy platforms are designed to execute counterbalancing mission objectives; and are operated for uncertain, and often extended lifecycles that may exceed fifty years. This necessitates numerous post-production design changes over-time to facilitate new technological developments or to counter emerging threats. However, system engineering (SE) research prioritizes earlier design studies, and research on post-production design change of SoS is nascent. This study presents findings from a case study of a Navy SE team that is tasked with executing the post-production design projects for a diverse set of Navy assets. More specifically, we focus on the preliminary design phase, and document the socio-technical complexity of these projects through interviews and on-site observations. We find that these projects necessitate careful management of a diverse set of external and internal stakeholders; along with an array of disciplinary analyses in conjunction with each other. We then analyze our findings to characterize four archetypical inefficiency modes that might be generalizable to all post-production design change projects for SoS. These include loss of configuration control, volatile requirements, handoffs between disciplinary analysis, and lack of digital authoritative source of truth. Although neither of these inefficiency modes are surprising, this study documents the intricate nature of how these mechanisms influence the process, and why they are difficult to counter.

Paper#270

SysML4Sec – Methodology for Security modeling in the context of large-scale product development with multiple design levels

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Presented on: Tuesday, 14:00-14:25 EDT

Keywords. Model-based Security Engineering;SysML4Sec;Security Engineering Method;Aircraft System Development;RAAML;DO-326;ED-202 set

Topics. 2. Aerospace; 21. Urban Transportation Systems; 4.7. System Security (cyber-attack, anti-tamper, etc.); 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 6. Defense;

Abstract. Increasing functionalities and the rising complexity of aircraft systems used by flight and cabin crews, passengers, maintenance staff, and other stakeholders necessitate a reconsideration of system development methodologies. This paper presents SysML4Sec, a model-based security engineering method that integrates the systems engineering process (SEP) with the security engineering process (SecEP). Both processes operate concurrently and interactively within the same system model across all development levels. We detail SysML4Sec for model-based security engineering using a consistent SysML approach and demonstrate SEP-SecEP interactions in developing a passenger seat connectivity function with the SysML4Sec supporting 'CATIA Magic Systems of Systems Architect' tool. The 'Magic Systems of Systems Architect' tool provides a single source of truth where a system and security engineers could collaborate to design the system architecture and the associated preliminary security assessments as per the DO 326A aviation standard. It enables to define Assets to be protected, the Threat Conditions (TC), the Threat Scenarios (TS) and Security Measures (SM) which are specified in terms of effectiveness to reduce the risk.

Paper#26

Systematic Risk Analysis: FMEA and FTA Approaches for Multi-Level System Architectures

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Presented on: Tuesday, 13:30-13:55 EDT

Keywords. MBSE;MBSRA;System Architecture;Reliability Analysis;SysML;FMEA;FTA

Topics. 2.4. System Architecture/Design Definition; 4.3. Reliability, Availability, and/or Maintainability; 5.3. MBSE;

Abstract. This paper explores the advantages of Model-Based Systems Engineering (MBSE) and Model-Based Safety & Reliability Analysis (MBSRA) compared to traditional approaches in the context of mul-ti-level complex system architecture. It outlines a comprehensive approach to developing multilayer architectures while integrating reliability analysis and ensuring traceability of design elements. Uti-lizing Failure Mode Effects Analysis (FMEA) and Fault Tree Analysis (FTA), the study demonstrates how these reliability analyses yield actionable insights for modifying system design. The iterative process of refining both architecture and reliability assessments throughout the product lifecycle underscores the dynamic interplay between design evolution and safety considerations. The findings highlight the effectiveness of MBSE and MBSRA in enhancing the reliability and robustness of complex systems, ultimately contributing to more resilient engineering practices.

Paper#378

Systems Engineering Automation Through Artificial Intelligence (AI) and Natural Language Processing (NLP)-Based Software

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

Keywords. AI;NLP;artificial intelligence;natural language processing;software;systems engineering;generative ai;large language models;llm;requirements

Topics. 3.8. Quality Management Process; 5.11 Artificial Intelligence, Machine Learning; 5.12 Automation;

Abstract. In the field of both traditional and Agile systems engineering, engineers manually perform a variety of tasks to derive, decompose, trace, rewrite, and evolve large numbers of engineering artifacts – work that is time-consuming and prone to human error. Mistakes made during the project lifecycle have compounding negative impacts on product efficacy and remediation costs grow exponentially problems go unchecked. Thus, improving requirements work through the adoption of modern technologies and methodologies is of significant importance to increase turnaround time and quality of products.

In 2012, Army Training and Doctrine Command (TRADOC) Combined Arms Center for Training (CAC-T) and the MITRE Corporation developed software to accelerate common and repeatable engineering tasks to improve the quality of capability development and acquisition working group efforts. Recent advances in artificial intelligence (AI) natural language processing (NLP) have modernized this software into a web application known as the Requirements Analysis using Artificial Intelligence for Mapping (RAAM), which provides a case study in the automation of language-related tasks such as generating requirements, improving requirements quality, and performing traceability analysis. In the past two years, the tool has been used by multiple government organizations to accelerate initial requirements generation by 9,000%, reduce traceability analysis times by 84%, and to improve requirements quality based on International Counsel on Systems Engineering (INCOSE) and Institute of Electrical and Electronics Engineers (IEEE) writing standards.

This paper will discuss several distinct stages of the digital engineering workflow that involve tedious manual work but are essential to project success. It will propose how certain NLP technologies and techniques can be used to accelerate and improve those tasks through software automation. To further illustrate these time-saving capabilities, the paper will focus on the RAAM tool as a case study for real-world application of NLP to digital engineering.

Paper#394

Systems engineering practices and enabling future AI for fluoros-copy complexity

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Presented on: Tuesday, 16:30-16:55 EDT

Keywords. System Engineering;Fluoroscopy;AI Artificial Intelligence;System Approach;System Practices

Topics. 1.6. Systems Thinking; 2.5. System Integration; 3.9. Risk and Opportunity Management; 4. Biomed/Healthcare/Social Services; 5.11 Artificial Intelligence, Machine Learning;

Abstract. In the rapidly evolving field of medical imaging, the integration of systems engineering practices and artificial intelligence (AI) holds significant promise for enhancing fluoroscopy procedures. This paper explores the application of systems engineering methodologies to optimize the design, implementation, and management of AI-driven fluoroscopy systems. By examining current trends, technological ad-vancements, and regulatory considerations, we highlight the potential of AI to improve diagnostic ac-curacy, reduce radiation exposure, and streamline clinical workflows. Key strategies include the devel-opment of robust AI algorithms, the integration of real-time data analytics, and the implementation of user-centric design principles. This paper demonstrates how a systems engineering approach can facilitate the successful deployment of AI in fluoroscopy, ultimately leading to improved patient outcomes and more efficient healthcare delivery.

Paper#49

Systems Engineering Role Evolution and the Right Stuff

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Presented on: Tuesday, 13:30-13:55 EDT

Keywords. Roles;sociotechnical systems;modeling;Large Language Model Artificial Intelligence;Belbin;Myers-Briggs;DISC

Topics. 22. Social/Sociotechnical and Economic Systems; 4.5. Competency/Resource Management; 5.11 Artificial Intelligence, Machine Learning; 5.4. Modeling/Simulation/Analysis; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Systems engineering has been defined in many ways since before INCOSE (or even NCOSE) existed. A 1996 paper categorizing the definitions into buckets called roles has become widely known and used in many universities as a primer into what systems engineering is. However, in the nearly thirty years since its publication, almost an entire generation of systems engineers has turned over. Model-based systems engineering has gone from a novelty to a baseline. Maturity models have been invented, peaked, and faded into the background. Cyber-physical and sociotechnical systems have dominated discussions for ten years. How is it possible that the paper is still being cited or even read? This paper provides a new set of 9 primary systems engineering roles and 9 support roles that are appropriate for complex sociotechnical systems. These roles are then assessed against standard Team Roles and Personality Types using Large Language Model Artificial Intelligence to assess the relative suitability of each Team Role and Personality Type for the new 18 primary and support Systems Engineering roles. Some examples are presented where assuming “All Systems Engineers are the same” can lead to poor outcomes.

Paper#40

Systems Engineering Roles for a New Era

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

Keywords. Systems engineering roles;digital engineering;artificial intelligence;value of roles;systems engineering challenges.

Topics. 3.5. Technical Leadership; 5.11 Artificial Intelligence, Machine Learning; 5.5. Processes; 5.7. Software-Intensive Systems; Other domain;

Abstract. Nearly thirty years ago, a classic paper was written that described systems engineering in terms of twelve roles. That paper is still being cited today, and the ResearchGate site reported it surpassed 20,000 reads on their site alone, and 46 citations since 2020. Are these authors not citing a seriously outdated paper? After all, Google was not invented when the paper was published. Nonexistent at the time, or at best newborn, were model based systems engineering, digital engineering, ubiquitous agile, DevSecOps, intense sociotechnical systems, and global systems of distributed architectures. Furthermore, an easily adopted kind of artificial intelligence appeared on the systems engineering stage around 2015 but exploded beginning in about 2020. It is the premise of this paper that it is well past time for the 1996 paper to be updated to account for these.
This paper provides eighteen roles for a new era, ten primary and eight secondary or support.

Paper#340

Systems Engineering with Attitude

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Presented on: Monday, 13:30-14:10 EDT

Keywords. Predatory;Hostility;Evolution;Perseverance;Innovation

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

Abstract. This article explores the role of systems engineering in creating perseverant systems, ones made to endure and prevail in an environment of constantly evolving, intelligently-directed, predatory hos-tility. Security as a collection of intents, methods, and techniques attempts improvement by broad-ening and extending a legacy mindset. And that’s not working. Here we propose a different mindset and a different approach compatible with, and enabled by, systems engineering.

Paper#243

Systems Engineering – A Matter of Perspectives

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

Keywords. Systems Thinking;Systems Principles;Capability Systems Engineering

Topics. 1.4. Systems Dynamics; 1.6. Systems Thinking; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. This paper presents a “8 degrees of Systems Engineering” framework, encouraging readers to think beyond simply thinking of “nested” systems and consider the wider environment in its fullest sense. It draws upon the work of Meadows, Martin, Sillitto and Salado, amongst others, to create a simple framework with potentially far-reaching exploitation.

The aim of the framework is to break out of traditional mindsets that seek to understand the wider system context by simply drawing a boundary around the contracted for system and treating everything as either inside or outside. It is also a rebuttal to models which perpetuate the single system boundary myth and then seek to surround it with further layers of delivery and development “systems” rather than properly separating the concerns.

It has been used in several “awareness” level courses on Systems Thinking, where it has proved to be easily digestible by students and gives a much richer point of departure for exploring Systems En-gineering techniques than simply using a “poached egg” type model. In particular, the ability to use the framework to focus discussion into specific areas of concern enables students to more thoroughly explore the techniques that can be used to understand options, uncertainties and issues.

Paper#160

Systems-of-Systems Engineering Challenges: Experiences from the Road Construction Domain

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Presented on: Wednesday, 06:00-06:25 EDT

Keywords. Systems-of-systems;Construction;Digitalization

Topics. 1.5. Systems Science; 1.6. Systems Thinking; 12. Infrastructure (construction, maintenance, etc.); 20. Industry 4.0 & Society 5.0; 3. Automotive; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.);

Abstract. Many sectors of society are in the middle of a digital transformation aiming at improvements in operation and new or improved services. A key part of this transformation is a digital exchange of information between different independent systems, which can be viewed as a system-of-systems (SoS) situation. However, most of the knowledge on SoS comes from the defense sector, and this may not be applicable in other, more commercial, situations. This paper investigates digital transformation activities through a case study of an SoS in the construction domain. Based on the findings from that case, a set of generic challenges for SoS engineering are identified, which differ in several respects from what has previously been described for defense SoS. Those challenges relate to the SoS structure; information representation and exchange; and business models and incentives. The challenges are described in detail and illustrated with examples from the case study.

Paper#166

Teaching Systems Engineering for Students – Experiences from the Swedish Education System

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

Keywords. Education;Systems Engineering;Experiences;Lessons Learned

Topics. 1. Academia (curricula, course life cycle, etc.); 1.6. Systems Thinking; 5.9. Teaching and Training;

Abstract. Swedish industry perceives a need for systems engineers due to the useful skillset they develop. However, teaching and providing educational paths for undergraduate and graduate students is a challenge in the Systems Engineering (SE) field. There are several structural and practical challenges to enable education in SE, related to the wide scope and emphasis on thinking as opposed to doing. Additionally, managing broad engineering programs from a faculty perspective is challenging to incorporate due to the multi-disciplinary nature of teaching. In this article we discuss the nuances of providing educational opportunities for SE based on our experiences in implementing a 5-year Integrated Master of Science in Engineering Program in Sweden. We provide our experiences and lessons learned from managing the SE program, while providing an overview of the program and its rationale. These findings can be used to strengthen future educational initiatives to support the development of SE knowledge while transferring experiences from the Swedish system to a wider audience. We discuss our findings through the lens of the future education of systems engineering, emphasizing what changes are expected to meet the needs of the future and the principles we will strive for going forward.

Paper#150

The Cost of Expertise: Performance Trade-Offs in LLMs for Systems Engineering

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Presented on: Thursday, 09:00-09:30 EDT

Keywords. Large Language Model;LLM;Performance Benchmarking;Systems Engineering;SysMLv2;Fine-tuning;RAG;prompt engineering;MBSE

Topics. 1. Academia (curricula, course life cycle, etc.); 3.6. Measurement and Metrics; 5.11 Artificial Intelligence, Machine Learning; 5.3. MBSE; Other domain;

Abstract. In the systems engineering (SE) community, generative artificial intelligence (GenAI), such as large language models (LLMs), continues to grow in popularity with applications varying from help with writing requirements, to creating traditional text-based documents, and to generating models. Furthermore, the text-based format of the Systems Modeling Language version 2 (SysMLv2) gives rise to wide ranging possibilities when combined with LLMs. It is common to specialize LLMs on specific task, such as SE; which may be achieved by a number of means. Fine-tuning and retrieval augmented generation (RAG) are example methods to teaching a model how to act and what the model needs to know, respectively. Typical practice evaluates LLMs relative to one-another through the use of benchmarks. Benchmarks are tasks that use a common scoring-based method where the LLM either answers a set of multiple-choice questions or textual queries to verified, correct answers. A domain specific benchmark for SE, SysEngBench, was developed over the last year and will be leveraged for the domain specific needs of SE evaluation. With many in the SE community developing custom language models, the usage of a standard benchmark is essential for relative performance comparison. We have conducted a limited experiment using SysEngBench to compare performance between ChatGPT4o, fine-tuned ChatGPT4o, and fine-tuned ChatGPT4o with RAG; results being what many in the SE community may find intuitively unexpected.

Paper#242

The Need for Systems Thinking in Digital Health Transformation

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Presented on: Wednesday, 06:30-06:55 EDT

Keywords. systems thinking;digital health transformation;AI;systems modeling;digital engineering

Topics. 1.6. Systems Thinking; 18. Service Systems; 4. Biomed/Healthcare/Social Services; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); Other domain;

Abstract. A few decades ago, digital health was primarily limited to business-to-customer-facing wellness apps. The trajectory of the digital health transformation was significantly boosted and bolstered by significant growth in venture capital funding following the COVID-19 pandemic. Digital health venture capital funding mirrored that of siloed biomedical venture capital growth. However, the value of digital health transformation in healthcare delivery (a system of systems) goes beyond the focus on technology. For digital health transformation to realize its unique opportunity to address the fragmentation of healthcare delivery systems and to truly build digital health systems that address interoperability for healthcare systems and patients, there needs to be a systemic (systems thinking) approach to digital health transformation. It is worth noting that digital health here includes Artificial Intelligence (AI). While this paper focuses on digital transformation in the healthcare space, it is worth noting the recognized importance of digital engineering in systems engineering. And yet, there has been minimal integration of systems engineering and systems thinking into digital health transformation. Through two illustrative examples, we apply systems thinking to analyze the systemic focus of digital health companies to illustrate by juxtaposition the differences between technology-focused and system-focused digital health companies. In doing so, we highlight the pressing need to integrate systems thinking and systems engineering into a fast-paced digital health transformation climate at this critical stage of growth.

Paper#217

The Three Fundamental Questions: A Minimal Complete Framework of Systems Engineering

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Presented on: Thursday, 09:45-10:25 EDT

Keywords. Systems Engineering Foundations;Methodology;Framework Analysis;Process Improvement;Cross-Scale Integration

Topics. 1.5. Systems Science; 22. Social/Sociotechnical and Economic Systems; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Systems engineering has grown into an increasingly sprawling discipline with numerous frameworks and methodologies, complicating the fundamental task of transforming stakeholder needs into operational systems. While many existing frameworks provide valuable guidance, they fragment rather than unify understanding of core systems engineering activities. This paper argues that three fundamental questions - "What are we making?", "How are we making it?", and "What has been made?" - provide a minimal and complete framework for describing systems engineering efforts across all scales and contexts. Through analysis of major frameworks and methodologies, we demonstrate these three fundamental questions (3FQ) are both necessary and sufficient to encompass all systems engineering activities across different scales and contexts. The framework's utility is illustrated through applications in process improvement, framework selection, and cross-scale integration. This unifying perspective offers immediate practical value while suggesting promising directions for theoretical development, potentially transforming how organizations understand, approach, and optimize their systems engineering practices.

Paper#143

The TRA Tool: Modeling and Projecting Readiness Levels with MBSE

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Presented on: Monday, 13:30-14:10 EDT

Keywords. TRL;TRA;SRL;SRA;IRL;MBSE;DE;SE

Topics. 2. Aerospace; 2.1. Business or Mission Analysis; 5.3. MBSE; 5.5. Processes; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. In this document, we discuss the state of the art for technology readiness assessments through the use of established metrics, we propose a Model-Based Systems Engineering (MBSE) approach that streamlines the process, and we provide a specific implementation of this approach with our TRA Tool.

The TRA Tool provides a methodology for completing a Technology and System Readiness Assessment in a model-based environment. The tool allows for the efficient collection and management of data on the maturation schedule of each technology and integration of a complex system design in a SysML based architecture model. It produces numerous useful diagram views and metrics to support analysis of a design's maturity.

Paper#62

Toward Quantitative Assessments of Cybersecurity Countermeasure Efficacy

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Presented on: Thursday, 09:45-10:25 EDT

Keywords. Cybersecurity;D3FEND;ATT&CK;Efficacy;Prioritization;Countermeasures;Security Requirements

Topics. 3.3. Decision Analysis and/or Decision Management; 3.6. Measurement and Metrics; 4.7. System Security (cyber-attack, anti-tamper, etc.);

Abstract. Most organizations have limited cybersecurity budgets, but there is no standard methodology for prioritizing cyber countermeasure investment. Without a rigorous, quantitative methodology for measuring efficacy, organizations can never hope to allocate countermeasure investment effectively. Other industries such as medicine measure efficacy by combining multiple metrics into a single figure of merit. We seek to address the question of countermeasure efficacy measurement by reporting properties that can measure efficacy, aligning these properties to the high-level tactics laid out in the MITRE D3FEND framework, and proposing the combination of these properties with qualitative organizational priorities via a weight matrix. The resulting score for a given countermeasure (within a D3FEND tactic) begins to answer the question of quantitative prioritization of security countermeasures.

Paper#320

Towards a Digital Engineering Ontology to Support Information Exchange

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Presented on: Monday, 11:30-12:10 EDT

Keywords. Digital engineering;Model-based engineering;Ontology;Semantic web technologies

Topics. 2. Aerospace; 20. Industry 4.0 & Society 5.0; 3.4. Information Management Process; 5.3. MBSE; 6. Defense;

Abstract. To support the transition to model-based engineering (MBE) through the system development lifecycle, Digital Engineering (DE) initiatives have become priorities, focusing on data integration, exchange, and management for tool and data interoperability. However, a lack of consensus on terminology impedes standardization efforts. The Digital Engineering Information Exchange (DEIX) Working Group is creating a framework for digital information exchange. Their activities include reviewing existing standards, surveying DE practitioners to refine terminology, identifying necessary standards through use cases, and developing a model of defined terms and relationships within digital engineering. In particular, the DEIX Ontology Working Group is tasked with consolidating complex, varied DE terminology into a unified ontology to ensure consistency and interoperability across system lifecycles and across relevant domains. Following Noy's ontology development approach, the DEIX Ontology Working Group (WG) has scoped relevant domains and established initial use cases. These use cases, aligned with DEIX WG goals, help define DE terms for the DE Primer, the DE Guide and the Digital Viewpoint Model (DVM). Terminology is being organized from relevant standards to sup-port digital information exchange. This paper describes the DE ontology's current status, the standards used for term extraction, and classification decisions influenced by INCOSE workshop outcomes. Through example use cases, it demonstrates how the ontology enables consistent, interoperable digital engineering terminology across diverse contexts.

Paper#146

Towards a greater understanding of Systems Design and Interoperability between Airbus Commercial and its Suppliers

Maxime Varoqui (AIRBUS) - maxime.varoqui@airbus.com

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

Keywords. MBSE;Model-Based Specification;Collaborative Modeling;Assisted Design Reviews;User-Interface

Topics. 2. Aerospace; 2.4. System Architecture/Design Definition; 2.6. Verification/Validation; 5.3. MBSE; 5.6. Product Line Engineering;

Abstract. As Systems Engineering is now widely developed within our organization, the introduction of Model-Based Systems Engineering (MBSE) methods and tools is still a gradual process that Airbus approaches incrementally. In that view, the knowledge and training on the usage of systems modeling tools is still being developed. This paper takes a look into the ways Airbus plans to make MBSE usable and understandable both internally to its engineers and externally to its suppliers. This work presents how Airbus managed a collaboration use case with a supplier from the delivery of a new model-based specifications to the supplier, to the interpretation of a joint modeling effort through a User Interface. This new process has been tested on a passenger seats system and at the time of writing, maturity is still in progress. This paper introduces the different technical concepts necessary to set up such a collaborative model-based environment, the difficulties encountered along the way as well as future research segments and ways to improve the process.

Paper#319

TurboArch: Towards Automating System Architecture Decisions with a CoPilot

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Marcell Padilla (CRL Technologies, Inc.)

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

Keywords. System architecture;CoPilot;cognitive assistant;Large Language Models;ilities

Topics. 2. Aerospace; 2.4. System Architecture/Design Definition; 5.11 Artificial Intelligence, Machine Learning; 6. Defense;

Abstract. Architectural decision-making often requires navigating a wide array of disparate evidence sources, from heuristic lists to empirical studies, to anticipate how choices will impact the exhibition of future ilities. This paper a proof-of-concept utilizing Large Language Models (LLMs) as a CoPilot to assist engineers in synthesizing architectural evidence efficiently. By automating evidence retrieval and analysis from diverse data pools, the proposed approach enables a more informed, streamlined decision-making process for system architects, much like how TurboTax aids individuals in generating accurate tax returns. This novel approach aims to improve accessibility to architectural insights, bridging the gap between human expertise and the vast reservoirs of knowledge available at organizations, ultimately enhancing the effectiveness of architectural choices in complex systems.

Paper#264

Universal Systems Engineering Lifecycle Framework (USELIFE): An Integrated MBSE Approach For Managing System Lifecycle Complexity

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Presented on: Wednesday, 06:30-06:55 EDT

Keywords. Model Based Systems Engineering (MBSE);Systems Engineering;Enterprise Architecture;Framework & Method;Views & Viewpoints;Lifecycle Processes;System Modeling Language (SysML);Arcadia;OOSEM;MBSE Adoption;Complex Systems;System Integration;System Architecture/Design Definition

Topics. 2. Aerospace; 2.4. System Architecture/Design Definition; 2.5. System Integration; 3. Automotive; 5.3. MBSE; 6. Defense;

Abstract. In the realm of Model-Based Systems Engineering (MBSE), the effective framework is paramount for streamlining complex system development processes. Over the years, various frameworks and methodologies related to MBSE have been developed and adopted. Many of these originated with a focus on industry-specific needs, while others are closely tied to particular tools and systems engineering languages. As organizations transition into increasingly heterogeneous environments, characterized by a growing ecosystem of diverse stakeholders, it becomes imperative to establish a framework that is agnostic to tools, industry sectors, and languages while catering to System of Systems (SoS). The framework should be comprehensive, integrated across the entire system lifecycle, and aligned with industry-leading practices and standards.

This research paper delves into the creation of a new MBSE framework viz. Universal Systems Engineering Lifecycle Framework (USELIFE) by conducting a comprehensive study and comparison of the most utilized frameworks and methods in the field, addressing their limitations, and introducing some new concepts.

The proposed framework provides a structured approach to system modeling, based on key standards & guides such as the INCOSE Handbook, ISO/IEC/IEEE 15288:2023 (System Lifecycle Processes), and ISO/IEC/IEEE 29148:2018 (Requirements Engineering). It provides a common platform for stakeholder collaboration, focusing on model-centric end-to-end lifecycle modeling for consistency, traceability, and reusability of system information.

The framework is presented through two intersecting perspectives: (a) providing a comprehensive overview of the interconnected aspects of the systems engineering lifecycle, and (b) a layered approach that analyzes and demystifies systems engineering challenges using multiple derivatives. This framework is demonstrated through a case study of an e-bike, facilitating the understanding of different perspectives and the process of building system models. It assists engineers in capturing and managing system requirements, design iterations, verification, validation, and operational factors throughout the system lifecycle.

Paper#101

What would I see in court? A survey analysis of who americans would blame for self-driving vehicle crashes and traffic violations

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Presented on: Tuesday, 13:30-13:55 EDT

Keywords. Self-Driving Vehicle;Autonomous Vehicle;Legal Culpability;Advertising Impacts;Risk Tolerance

Topics. 14. Autonomous Systems; 3. Automotive; 3.9. Risk and Opportunity Management; 4.1. Human-Systems Integration; 5.12 Automation;

Abstract. Self-Driving Vehicles (SDVs) are rapidly transitioning from science fiction to viable commercial products, bringing with them the promise of safer roads, less traffic congestion, and greater transportation efficiency. Numerous automotive companies are pursuing the development of SDVs, and several prototypes and pilot programs have been initiated to evaluate the safety, reliability, and acceptability of these designs. Some of the SDVs participating in these pilot programs have been involved in traffic crashes involving injuries and property damage, while other SDVs have committed moving violations. These incidents have exposed manufacturers to legal culpability, requiring manufacturers to understand how potential jurors may assign blame for these collisions and moving violations. This paper looks at how individual risk tolerance, SDV comfort level, and SDV familiarity impacts assignment of blame for SDV failures, and how SDV manufacturer advertising campaigns can influence these blame assignments.

Paper#21

Why Systems Engineering Skills Are Critical for Successful Leadership of Large Complex Projects

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

Keywords. megaproject;leadership;skills;competencies;project complexity;enterprise leadership;skills development

Topics. 1.1. Complexity; 3.5. Technical Leadership;

Abstract. This article explores the critical leadership competencies required for the successful management of megaprojects—large-scale, complex ventures exceeding $1 billion in cost and spanning multiple years. Given that only 8.5% of megaprojects are completed on time, within budget, and with intended benefits, effective leadership is vital. Successful megaproject leaders combine technical expertise with systems thinking, transformational leadership, and the ability to navigate complexity and uncertainty. They prioritize stakeholder management, communication, and people leadership, while maintaining a strong foundation in project management. Drawing from existing frameworks, including the HELIX systems engineering model, the article proposes a new framework for developing the unique skills needed for megaproject leadership. This framework emphasizes the integration of technical, interpersonal, and enterprise leadership skills, which are crucial for managing the challenges inherent in these large, multi-stakeholder projects. The paper advocates for a shift in how leaders are selected and developed, focusing on their adaptability, strategic thinking, and ability to lead in uncertain environments. The goal is to improve the success rate of megaprojects through more effective leadership development and selection strategies.

Presentations

Presentation#106

"Reclaiming the Engineering in Model-Based Systems Engineering: Refocusing MBSE on Practical System Engineering Outcomes

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Presented on: Thursday, 13:00-13:25 EDT

Keywords. MBSE;V-Model;INCOSE Standards

Topics. 1.6. Systems Thinking; 13. Maritime (surface and sub-surface); 5.3. MBSE; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Model-Based Systems Engineering (MBSE) has revolutionized the way systems are designed, analyzed, and verified, offering a structured approach to managing complexity and improving communication across interdisciplinary teams. However, the recent drive toward "perfect" SysML models has, in many cases, overshadowed the true purpose of MBSE: to support sound, effective, and practical systems engineering (SE). Too often, MBSE practitioners prioritize model syntax and adherence to SysML semantics at the expense of using the model to enhance decision-making, traceability, and overall engineering rigor.
Reflecting on the industry's evolution from traditional document-based SE, centered on the V-model, it's clear we may have overcorrected. The V-model—rooted in answering the fundamental questions, "Are you building the right thing?" and "Are you building it correctly?"—emphasizes traceability, verification, and validation at every stage. While MBSE has helped us move beyond document-centric approaches, it has, in many cases, failed to maintain clarity in addressing these essential questions, creating a gap in its ability to demonstrate engineering rigor in the modern age.
This session seeks to realign MBSE practices with the core principles of the V-model, bridging the gap between traditional SE foundations and modern modeling approaches. Attendees will learn practical strategies to ensure MBSE supports genuine engineering outcomes, such as creating a model-based Systems Engineering Management Plan (SEMP), developing INCOSE-compliant requirements directly within the model, and using the model to drive technical milestone reviews with rigor and transparency.
We will provide real-world examples and actionable methods for using SysML and MBSE frameworks to address V-model fundamentals, delivering better engineering artifacts, improving requirements quality, and streamlining program review processes. The session will explore how MBSE can evolve to answer the "right thing" and "correctly" questions more explicitly, integrating traditional SE principles with the power of modeling.
By the end of the session, attendees will be equipped to:
• Develop a model-based SEMP that aligns with both INCOSE and project-specific requirements.
• Write and validate requirements within the model that meet INCOSE standards and avoid common pitfalls.
• Use the model to plan and execute technical milestone reviews, ensuring traceability and completeness of engineering decisions.
• Close the knowledge gap between modeling and SE by improving modelers’ proficiency in SE principles, enabling them to confidently pursue and achieve their Certified Systems Engineering Professional (CSEP)

credential.
This session is designed for systems engineers, MBSE practitioners, and project leads looking to bring the "engineering" back into MBSE while honoring the enduring relevance of the V-model. Join us to explore how we can evolve MBSE practices to maintain engineering rigor, address fundamental SE principles, and ensure modeling enhances, rather than detracts from, the primary goals of systems engineering.

Presentation#153

A Knowledge Graph Framework for Failure Analysis and Prevention

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

Keywords. Systems Engineering;Aerospace Engineering;MBSE;Digital Engineering;Mission Assurance;Vulnerabilities;Data Visualization;Analysis;Human Computer Interaction

Topics. 17. Sustainment (legacy systems, re-engineering, etc.); 2. Aerospace; 3. Automotive; 3.3. Decision Analysis and/or Decision Management; 4.1. Human-Systems Integration; 5.3. MBSE;

Abstract. Effective failure analysis requires that systems engineers understand which systems or events have had a failure, the type(s) of failure, the existence of concurrent or related failures, and the causes of the failure. Once we have a better understanding of the failures, then root causes can be determined and be addressed. Furthermore, future failures can be prevented by looking for similar pre-failure patterns in systems data. The growing size and complexity of systems plus the vast amounts of collected data from systems can obfuscate the existence of concurrent or related failures, and make it more difficult to discover deeper and inter-related root causes of system failures in addition to hiding the frequency of failures.

Knowledge graphs provide effective models for systems and for data collected from simulations, digital twin management, and field data. For example, we can use knowledge graphs to model complex systems of systems such as spacecraft, airplanes, or automobiles. These models can be used to represent parts, the relationships between those parts, and the actions that can occur between model elements or actors. These models can be created and evaluated through review and simulation, then updated to incorporate improvements. In addition, the same knowledge graph can be expanded with collected data which evaluates the effectiveness and stability of the model. The resulting knowledge graph can contain many thousands of data points for a systems model and its performance. Not only must the knowledge graph be appropriately created to support project objectives, the knowledge graph must be effectively analyzed to discover deeper insights. Graph analysis is especially effective at finding deeper, multi-hop path connections in complex data. This type of analysis leads to the discovery of additional root causes of failure. Furthermore, the analysis will search for the connectedness of failures and their related root causes that were previously unknown. In addition, graph analyses can be combined with AI / ML techniques to understand similarities and predict future points and causes of failure.

In this presentation, we will introduce a knowledge graph framework for failure analysis and prevention. First, we discuss the competent creation of a knowledge graph with model, simulation, digital twin, and field data. Next, we will discuss effective analytics to discover points and causes of failure, as well as the use of effective graph pattern searches to discover the additional failures and the connections between them. Furthermore, some failures occur sequentially or have multiple root causes which must simultaneously exist in order for the failure to occur: analysis of the knowledge graph will lead to an understanding of the AND, OR, and XOR relationships between related failures and root causes.

In addition to providing event analysis and better understanding of current failures, the combined use of

graph analysis with advanced graph pattern searches will indicate potential points and root causes of failure before failures occur through the recognition of emerging patterns of failure. This error prediction will allow time for corrective actions which can prevent or reduce the impact of the failure. Also, these results indicate which failures are caused by the unique design of the system and which are caused by industry standards or expectations. These analyses can be applied to both historic data and to on-going telemetry data. Comparison of telemetry data with known failure patterns indicates to the operator whether or not there is an emerging trend that matches previous failures, and whether or not it may be beneficial to take corrective actions.

In addition to using the knowledge graph for the modeling and analysis of system data, we will discuss how the knowledge graph can be used for communication of key findings to decision makers and stakeholders. Dashboards with interactive visualizations of the knowledge graph will provide not only a summary of key failures and their interrelated causes, they also provide a way to usefully navigate and abstract the complex data. This combination of data-driven visualization and analysis with human interaction supports stakeholders in benefiting more fully from the failure analysis and prevention. For example, a human expert can see and interact with a knowledge graph visualization and say “there is something interesting here, let’s look further,” or “I have seen this pattern in another situation, a similar solution may be helpful here as well.” Of special importance, the knowledge graph visualization and interaction provides a way for humans to discover more “almost-patterns:” an almost-failure, an almost-root-cause, an almost-connection between failures. And, by discovering more of these “almost patterns,” which can be very difficult or impossible to find through traditional analyses and AI / ML techniques alone, we can prevent more failures.

In this presentation, we will use data from the aerospace industry with an emphasis on digital engineering objectives, however this framework also can be applied to the automotive, biomedical, and energy domains, as well as other domains which benefit from the modeling, analysis, and prevention of failure.

Presentation#148

A Maturity and Cost Model for Systems Engineering with Generative AI

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

Keywords. Generative AI;Large Language Models;Maturity Model;Cost Modeling;COSYSMO;Systems Engineering Process

Topics. 3.7. Project Planning, Project Assessment, and/or Project Control; 5.11 Artificial Intelligence, Machine Learning; 5.5. Processes; 9. Enterprise SE (organization, policies, knowledge, etc.); Other domain;

Abstract. Abstract
Generative Artificial Intelligence (AI) is rapidly transforming systems engineering processes in numerous ways, including automating tasks, generating architecture and design options, tradeoff analysis, implementation, testing, and improving decision-making processes. We introduce a harmonized maturity and cost model for using generative AI in systems engineering. Understanding the maturity levels with defined key practices and their associated cost implications allows organizations to develop strategies for effectively leveraging generative AI in their engineering workflows, ensuring continuous improvement, cost reductions, and strategic technology integration. The cohesive framework will provide participants insights into optimizing generative AI across systems development activities, enabling evaluation of the financial impacts of AI adoption and improving systems engineering cost predictions.

Introduction
Generative AI tools are transforming how systems engineering teams develop, deliver, and sustain systems. These tools support all non-hardware production processes, including concept development, analysis of alternatives, architecture, requirements, design, software, verification, testing, and validation. Significant reductions in effort are possible using AI assistant tools that utilize large language models (LLMs), a type of generative AI driven by deep learning algorithms responding to user queries.

Effective integration of generative AI into systems engineering requires a structured approach to assess readiness, plan adoption, and track progress. To address these needs, we propose a process maturity and cost modeling framework that provides a comprehensive view of the technological, organizational, and financial aspects of AI adoption. The maturity model provides a roadmap for integrating generative AI, while the cost model quantifies costs and benefits for data-driven decision-making. This approach draws upon existing maturity models and cost modeling research to update parametric cost models for AI assistance usage.

The 5-level maturity and cost model offers advantages such as standardized evaluation, strategic planning, risk management, cost estimation, improved process prediction, and process optimization based on empirical data.

Framework Overview
The framework consists of five maturity levels: Initial, Developing, Competent, Advanced, and Optimized. Each level represents a stage of generative AI integration, characterized by increasing sophistication in AI usage, organizational readiness, and automation. Each maturity level is aligned with an AI Assistant Usage cost factor rating scale to assess the cost implications of AI adoption.

Our cost modeling research is calibrating the AI Assistant Usage cost factor to update the Constructive Systems Engineering Cost Model (COSYSMO) and the Constructive Cost Model (COCOMO) for software development. The established COCOMO II and COSYSMO models are also precedents for having harmonized cost factor rating scales and maturity model levels.

Aligned cost factor ratings and maturity levels provide a comprehensive view of capability progression and cost implications, helping organizations align technological advancements with strategic cost planning. This harmonized model ensures that cost factor settings and maturity levels are fully integrated.

Maturity Level Key Practices

The integration of AI into systems engineering involves several key practices that contribute to overall maturity. These practices, which describe organizational activities and infrastructure, evolve as an organization progresses through maturity levels and serve as critical factors influencing the success of AI integration.

Investment in Hardware and Infrastructure addresses the technological resources required for AI adoption, ranging from basic infrastructure to highly scalable, robust systems. LLM Customization and Fine-Tuning describes the depth of AI model customization, from using a generic model to extensive fine-tuning with specialized datasets. Knowledge Integration and Data Management highlights how AI systems evolve from limited context awareness to fully indexed and dynamically managed knowledge bases. LLM Retraining indicates the frequency and adaptiveness of model updates, evolving from minimal retraining to real-time adaptive learning with Reinforcement Learning from Human Feedback (RLHF). People training addresses the specific skills necessary for applying generative AI at each maturity level.

Project Cost Modeling of AI Assistance Usage

Our cost modeling research aims to quantify the impact of generative AI in systems and software engineering, using a framework containing model definitions, lifecycle standards, and data calibration processes. It incorporates a new factor for AI Assistance Usage, defined using the COSYSMO framework. This rating scale, aligned with the maturity levels, ranges from Very Low to Very High, corresponding to the degree of AI assistant usage on a project. Empirical data collection is ongoing aligned with these levels.

Conclusions and Future Work

Generative AI is transforming systems engineering by enabling greater efficiency, creativity, and decision support. The integrated maturity and cost modeling framework offers a structured pathway for adopting generative AI. By progressing through the maturity levels and using the AI Assistance Usage cost factor to assess financial impacts, organizations can enhance their capabilities, optimize costs, and remain competitive.

The framework will be further elaborated in our research, and the levels will be used for collecting empirical cost data aligned with generative AI practices in the development lifecycle for standardized activities.

Further analysis of AI tool impacts will be conducted across the lifecycle, aligning artifacts and effort data with ISO/IEC/IEEE 15288 systems and software engineering phases. This lifecycle standard harmonization will help address large-scale team and enterprise processes assisted by AI.

We will refine the cost model, calibrate the AI Assistance Usage cost factor based on empirical data, and evaluate the long-term financial and operational impacts of AI adoption.

Future research will develop assessment tools to help organizations determine their maturity level and identify actions for advancement. Case studies of successful generative AI integration will provide valuable insights into best practices and challenges.

Presentation#81

A Model-Based Framework for Assessing MOSA Value Delivery in DoD Acquisitions

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Presented on: Wednesday, 11:30-12:10 EDT

Keywords. Model-Based Acquisition;Digital Engineering;Model-Based Systems Engineering;Unified Architecture Framework;Modular Open Systems Approach;Business Architecture;Compliance Assessment;Value Delivery;Project Assessment

Topics. 3.6. Measurement and Metrics; 3.7. Project Planning, Project Assessment, and/or Project Control; 5.3. MBSE; 6. Defense;

Abstract. Overview. Various agencies in the Department of Defense (DoD) are supplementing or transforming their acquisition process to a model-based approach, specifically submission of a Model-Based Request for Proposal (RFP) Package by a DoD program office and response from a supplier in the form of a Model-Based Proposal. However, there is no standard approach for creating either. The Model-Based Acquisition User Group Community within the Object Management Group (OMG) is addressing this gap by standardizing approaches, patterns, and reference architectures in the context of Model-Based Acquisitions to aid in the creation of Model-Based RFPs and Model-Based Proposals. Additionally, this effort includes the assessment or evaluation of a solution architecture description as part of a Model-Based Proposal. This assessment, known as a Domain Overlay, addresses various engineering domain concerns, such as Modular Open Systems Approach (MOSA), Cyber Security, and Nuclear Surety. The first concern to be standardized through a Domain Overlay is assessing the compliance of an architecture with MOSA statutes, policies, and regulations.

Problem. Developing a system architecture that embodies MOSA principles is not an easy task. MOSA is defined as “an integrated business and technical strategy to achieve competitive and affordable acquisition and sustainment over the system lifecycle.”
DoD programs must comply with U.S.C Title 10 §4401, which codifies MOSA into law, as well as many other related and derived statutes, policies, and guidance. The blessing and the curse of how the law is written results in the determination of “maximum extent practicable” and how to assess compliance of an architecture being left up to the program.

MOSA principles, such as design modularity and interface standardization and openness, are key in assessing MOSA compliance of an architecture. However, an architecture with higher modularity and openness isn’t always better. The technical decisions made to achieve high modularity and interface openness can sometimes compromise competitive and affordable lifecycle sustainment. Conversely, a pragmatic MOSA approach that balances technical and business decisions can result in effective, affordable, and sustainable systems. Therefore, compliance depends on transparent business and technical decisions that achieve and sustain the desired MOSA benefits. Acquisition programs need a clear approach to measure success and ensure compliance with MOSA law.

Approach and Methods. In collaboration with the Model-Based Acquisition User Group Community and the NDIA Systems Engineering Division Architecture Committee, work is underway in the development of a MOSA Domain Overlay to aid acquisition programs in the assessment of how well a program, inclusive of RFP and solution architecture models, applies MOSA principles and ultimately complies with U.S.C Title 10 §4401 by leveraging business architecture concepts and principles. From this perspective, any assessment of MOSA compliance is specific to how the program and its organization wants to optimize the value proposition, i.e. benefit against cost, of a MOSA. The selection of the specific types of metrics and assignment of target values to assess how effectively an organization is in delivering the MOSA value proposition is highly contextual and

requires defensible justification meaning a framework is needed that unifies business and technical considerations.

The MOSA Domain Overlay is a repeatable model-based framework compatible with MBSE languages and practices. Key components of the framework include:
* An ontology defining business and technical concepts and their relationships necessary for measuring value delivery.
* A project assessment model pattern based on the Unified Architecture Framework (UAF), implementing the ontology as a business architecture.
* A library pattern for reusable elements such as objectives, benefits, capabilities, and resources, and traceability relationships between them.
* Methods for normalizing program artifacts, such as architecture models, cost estimates, and risk registers, into common, unambiguous views.
* Algorithms for calculating MOSA value delivery across organizational levels.
* Guided workflows, accessible via fit-for-purpose views, to support program-specific overlay development.
* Tool-specific validation rules to ensure consistent creation and application of the overlay.
* Dashboards for monitoring and sustaining MOSA value delivery, with drill-down insights.

This presentation will demonstrate the framework’s utility through a notional acquisition scenario and show how it addresses the challenges of MOSA compliance within DoD acquisition programs.

Presentation#24

A Proposed Capability Package for Preventing Hardware-Specific Cyber Attacks in Critical Infrastructure

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Presented on: Thursday, 09:00-09:40 EDT

Keywords. Industry 4.0;Cybersecurity;Smart factories;Robotics and automation;Supply chain security;Hardware vulnerabilities;Critical infrastructure;Programmable logic controllers;Defense manufacturing

Topics. 1.6. Systems Thinking; 12. Infrastructure (construction, maintenance, etc.); 2.2. Manufacturing Systems and Operational Aspects; 20. Industry 4.0 & Society 5.0; 4.7. System Security (cyber-attack, anti-tamper, etc.); 6. Defense;

Abstract. Thanks to the rapid evolution brought about by Industry 4.0 technologies, the pace of technological adoption in smart factories, robotics, and automation has outpaced the development of corresponding cybersecurity measures, particularly in industries that prioritize efficiency over security. This misalignment poses a serious risk to the integrity of interconnected supply chains and manufacturing systems, exacerbated further when considering that traditional cybersecurity efforts have largely focused on software vulnerabilities, neglecting hardware, which is now increasingly targeted by cyberattacks. Systems engineering (SE), then, faces the challenge of creating an integrated framework that protects both hardware and software in critical infrastructure, such as industrial control systems (ICS) and programmable logic controllers (PLCs). This is essential to prevent large-scale disruptions in operations, financial loss, and national security risks, all of which are particularly dangerous in defense-related manufacturing where compromised hardware can lead to severe consequences for military readiness and classified information security.

Attendees of this presentation will gain preliminary insights into developing a hardware-focused SE cybersecurity framework, modeled on the Department of Defense’s (DoD) guidelines, known as Capability Packages, imposed on trusted integrators of classified technology solutions for the United States Government. The presentation will discuss potential methods such as hardware monitoring and lifecycle management, while exploring ways systems engineers might mitigate risks introduced by Industry 4.0 technologies. Initial analyses of high-profile hardware-based cybersecurity attacks will provide emerging considerations for securing critical infrastructure. The audience will gain an introductory understanding of integrated cybersecurity strategies, informed by best practices from leading organizations like Microsoft and guidelines from the DoD and other U.S. policymakers. The presenter, who holds a Bachelor’s in Computer Engineering and Computational Mathematics and a Master’s in Product Development, is a Ph.D. candidate at The George Washington University. She has 15 years of experience in industrial software and hardware supply chains. Her expertise spans advanced equipment and systems used in the supply chains and mass-production environments of major technology producers such as Apple, Microsoft, and Meta. She is deeply interested in addressing the potential for catastrophic supply chain disruptions arising from hardware-specific cybersecurity vulnerabilities.

Presentation#405

A State of the System Analysis of the world's energy transformation towards net zero

Thomas Manley (Decision Analysis Services (DAS) Australia) - incose@thomas.manley.name

Presented on: Thursday, 09:00-09:40 EDT

Keywords. Energy transformation;Renewable energy;Battery storage;Solar;Wind;Electrification;Net Zero

Topics. 1.1. Complexity; 1.6. Systems Thinking; 10. Environmental Systems & Sustainability; 8. Energy (renewable, nuclear, etc.);

Abstract. An energy transformation is underway, with the underlying intent of achieving 'net zero' by 2050. Whilst politics has muddied the waters, many parts of the world are now substantially along the journey towards net zero, such that their efforts are more than just theoretical, and lessons can be learned. Electrification, distributed renewable generation, grid scale battery storage, and a resurgence in nuclear are all elements of this fundamental shift. A systems approach is crucial.

Striping away all subjective bias, it is the technical knowledge, and the economics modelling, along with some Human Systems Integration, that are fundamental to engineering our way towards a net zero energy system. It is clear how vastly more complex the new energy system of systems will be (is already) with shifts from:

- Centralised generation ⇨ Distributed generation
- Increased demand through electrification of everything (EVs, Cooking, Heating)
- Passive end users ⇨ Consumer Energy Resources (CER)
- One-directional distribution ⇨ Two-way distribution
- Baseload demand profile ⇨ ‘duck’-shaped time-of-day demand profile
- Time arbitrage through battery storage
- Greater grid interconnectivity (interconnectors)

Systems Thinking is a core discipline within the INCOSE Systems Engineering Competency Framework, and yet its coverage in the Systems Engineering Handbook, and in standards more broadly, is minimal. It is also a key element of the new Sustainability Engineering Area of Practice (AoP) being developed by Engineers Australia. The emerging energy system of systems is becoming increasingly complex, with the exponential increase in the number of generation ‘nodes’, and the addition of substantial ‘storage’ nodes. Architecture, and management, of the future electricity grids will require substantial systems thinking skills to build a reliable, resilient, cost-effective system.

This presentation is a catalyst for this necessary work. It will cover the current state of different generation technologies (solar, wind, coal, gas, nuclear), different markets (US, China, Australia), Electric Vehicles (EVs) and the controversial topic of nuclear energy, which is in the midst of a potential renaissance. It will also cover S-curves and their importance, and provide some insight into the new thinking that will be required to successfully reach net zero.

Presentation#78

A Systems Engineering Approach to Standards Development

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

Presented on: Tuesday, 16:00-16:25 EDT

Keywords. Standards;Digital standards;SysML;Model-based systems engineering;MBSE;Systems engineering process;ISO/IEC/IEEE 15228;Authoring standards

Topics. 1.6. Systems Thinking; 2. Aerospace; 20. Industry 4.0 & Society 5.0; 5.4. Modeling/Simulation/Analysis; 5.5. Processes; 6. Defense;

Abstract. SAE International has done a lot of research around digital standards, talking with manufacturers, government, and academia about how they want to use the various types of information contained in standards. Part of the challenge to implement digital standards is rooted in how standards are written in the first place. Some of our findings are highlighting inadequacies in how standards are written today. Standards are written as text documents, and many standards have multiple authors working on different sections of a document. Text does not enforce consistency of information across sections, and it does not prohibit standards authors from including contradictory statements in standards. Text does not help standards authors determine if a standard is complete or whether some parts of a standard are subject to multiple interpretations.

SAE has presented some editorial guidance on how to write more digital-ready standards. This is a good start, but SAE believes that standards development organizations can do more. If standards authors use MBSE tools to author standards, this will help to programmatically enforce the development of more complete and consistent standards. However, there is often a knowledge gap between standards authors and the expertise to use these tools. It is unrealistic to expect all standards authors to be experts in SysML, OPL, and other systems engineering languages. However, it is not unrealistic to train some standards authors to think like systems engineers and apply this methodology to authoring standards.

This presentation describes how standards authors can use a systematic approach to authoring standards, resulting in standards that are more complete, accurate, and clear. Applying well-established analysis techniques at the initiation of a standard could positively transform the content irrespective of whether the then-authored standard is digital or not. Then, it is more likely to generate reliable interoperable data when it is captured/authored/transformed into a data model or other digital object. This presentation will describe how standards authors can apply the systems engineering methodology to various steps of the standards development process to write better standards.

Presentation#280

Accelerating agile MBSE deployment for next gen automotive architecture with gen AI based SysML V2

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Presented on: Wednesday, 05:30-05:55 EDT

Keywords. Model based systems engineering (MBSE);Gen AI;SYSML V2;CI/CD;Automotive;Next Gen Architecture

Topics. 1.1. Complexity; 1.6. Systems Thinking; 2.4. System Architecture/Design Definition; 2.5. System Integration; 3. Automotive; 3.6. Measurement and Metrics; 3.7. Project Planning, Project Assessment, and/or Project Control; 4.3. Reliability, Availability, and/or Maintainability; 5.1. Agile Systems Engineering; 5.11 Artificial Intelligence, Machine Learning; 5.3. MBSE; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.);

Abstract. Technological transformations are evident in this era where industries are being driven by goals centered towards sustainability, automation, enhancing user experience etc., powered with data and artificial intelligence. We can see automotive industry amid massive transformation with vehicle ecosystem extending to off-board elements like cloud and external infrastructures- e.g. chargers, mobiles and GPS. It also must meet emerging business models like feature subscriptions. Hence the vehicle use-cases and supporting architecture are increasingly software driven and complex. This is leading to more cross functional stakeholders getting involved in the end-to-end vehicle lifecycle. This emerging complexity can be well-managed by adapting systems engineering best practices viz model based systems engineering, which help in integrating various work-products seamlessly, earlier in the lifecycle thus optimizing development time and improving KPIs -e.g. quality and time to market. It is appropriate time when auto industry players can utilize the benefits of model systems engineering practices.
However, although many Auto OEMs may be convinced of the importance of systems engineering, the deployment of model-based systems engineering is not gearing up significantly. This may be a result of –
• Unawareness or ignorance towards using model-based systems engineering.
• OEMs being uncertain of the Return of Investment (ROI) w.r.t. the initial investment needed to deploy MBSE, in the form of-
o Upskilled engineers to use MBSE e.g. SysML and toolchain training.
o Time and efforts needed to model the systems.
o Initial investment in the toolchain, which will eventually prove itself the right choice.
This presentation focusses on the advent in Model based Systems Engineering through SysML V2, Gen AI practices and agile practices through CI/CD pipeline and how these can be used to improve return of investment in deploying MBSE practices in an effective way.

With the advent of SysML V2 some of the challenges stated above can be mitigated. SysML V2 is getting used for Auto generation of model where only text driven, simple, understandable format will be capable of generating a SysML diagram as a representation of that text. These generated diagrams will be directly considered as Model artifacts. SysML V2 can be used in CI/CD pipeline which will accelerate the integration of systems engineering artifacts as input to software development lifecycle (SDLC) and reduce development time, with its collaborative capability. Agile practice can be effective because of usage of SysML V2 together in CICD pipeline. SysML V2 is relatively easy to learn, additionally Gen AI models can be deployed to create SysML V2 textual representation, which is further reducing the time and cost for modeling a system. As tool vendors are bringing up SysML V2 standard interfaces, the need for tool specific skill and tool dependency is reduced. The risk due to investing in a toolchain is significantly reduced due to SysML V2 interface standardization. This will also lead to having an open room adapting future changes flexibly.

We are deploying these newer MBSE practices, viz. Gen AI based SysML V2 models, in cloud environment CI/CD pipeline on use case of actual feature development in software defined vehicle architecture context. This paper elaborates comparative study on the approaches where manual tool based SysML modeling and newer way of modeling with SysMLv2 are deployed on similar use cases. Further enablement of CI/CD pipeline and its benefits are evaluated. This presentation will help not only Auto industry but any other organizations which are hesitant on deployment of MBSE due to ROI hurdles.

Presentation#42

Achieving Harmony in System Design: Balancing Optimal

Performance Across the Engineering Specialties in a Solution

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

Presented on: Monday, 15:30-16:10 EDT

Keywords. Engineering Specialties;Integrating specialties;SE Skills Model;Balanced systems;Digital challenges;Future of Systems Engineering;Agility;AI;Methods

Topics. 1.1. Complexity; 2.4. System Architecture/Design Definition; 21. Urban Transportation Systems; 22. Social/Sociotechnical and Economic Systems; 4.5. Competency/Resource Management; 6. Defense;

Abstract. The systems workforce is in growing worldwide demand. As technology, economics, innovations, societal needs and perceptions, to name a few, continually evolve, so will the breadth and depth of system competencies of the workforce to meet these opportunities and challenges. The current foundational skills are not to be tossed aside, but rather built upon with the additional mastering of new skills.

In addition to new competencies, time and resource constrained environments are major challenges. Innovation and targeted trajectories needed to respond as quickly as possible to threats and opportunities is critical. Mental agility will be required to best utilise new technology advancements, to work with a growing and potentially complicated toolset necessary for digitalisation, in order to respond within expected timeframes with systems that are safe, secure, user-friendly, sustainable and resilient. However, these systems will increasingly be challenged by society. Societal acceptance largely will drive the architecture of a system through the engineering specialties.

The system architect/engineer will be required to learn, adapt and adopt the newer and evolving technologies and engineering specialties such as AI, autonomy , robotics, data analytics, virtual reality, modelling and simulation, deployability, cybersecurity, serviceability, ecodesign, and agility, to name a few. Still, just learning and applying the appropriate engineering specialties is not enough. Each specialty seeks to be optimised, however this is impossible to achieve across all specialties in the system solution. Is it more than carrying out multi-criteria decisions across the applicable engineering specialties of a system solution?
The growing challenge to be addressed is “how can the system architect/engineer develop a “balanced system” when all applicable engineering specialties are expected to be optimised?”

This presentation will explore this challenge across three themes –
1. The demise of the “T-shaped skills model” replaced with a “stalactite skills model”. Collaboration across more specialties will be required but more importantly the specialised skills required will be across more than one core area. Potential new competencies and technology enablers of the future systems workforce will be named.
2. Technique for identifying the applicable engineering specialties for the system under design, and classifying the importance across this set. Consideration on which specialties provide value and be nurtured in view of global competition will be presented.
3. Applying a number of methods and techniques to develop a harmonised system solution across the applicable engineering specialties. This will be the primary focus of this presentation. It will aid system architects/engineers in describing a potential new approach(es) to address harmonisation in future complex systems. Variations will also be described based on -
a. Minimal viable capability projects
b. Software intensive solutions
c. System of Systems considerations
d. Industry specificities
e. Commercial vs defence related domains.

The presentation will conclude with a summary sheet for the audience to take away and adopt on their projects. The information provided in this presentation is the ongoing work and refinement across multiple projects to provide the best balanced system solution under the increasing pressure to integrate more and more engineering specialties.

Presentation#329

Agile Systems Engineering of an Astronaut Digital Twin to Optimize Human Space Exploration

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Presented on: Tuesday, 16:00-16:25 EDT

Keywords. spaceflight;systems engineering;agile;digital twin;systems biology;space medicine;precision medicine;Bayesian inference;computational systems physiology

Topics. 1.4. Systems Dynamics; 2. Aerospace; 22. Social/Sociotechnical and Economic Systems; 4. Biomed/Healthcare/Social Services; 5.1. Agile Systems Engineering; 5.11 Artificial Intelligence, Machine Learning; 5.4. Modeling/Simulation/Analysis;

Abstract. The vigorous pace of innovation in the spaceflight engineering community has left a growing gap in the readiness of medical solutions to help humans thrive in space long-term. For example, how will the human body and psyche cope with the more than a year of weightlessness, radiation, isolation and confinement in the hostile, closed spaceship environment, and significant, increasing distance from Earth present on a trip to Mars and back to Earth? Further, how would the health of that crew fair long-term, years after the mission? To adequately answer these types of questions and promote astronaut adaptability, resiliency, and performance, the spaceflight medicine community is in need of readily deployable solutions to rapidly increase the pace of innovation. The biodigital twin is one such tool. The Astronaut Digital Twin (ADT) is a biodigital twin specifically designed to emulate the behavior of the astronaut entering the spaceflight environment and represent it virtually. It incorporates real time data, simulates outcomes, and catalogs probable trajectories through "what-if" simulations. Its goal is to help humans thrive in space by moving everyone up the adaptation curve – striving to convert poor adapters into good adapters by promoting performance, health, and safety pre-, in-, and post-mission.

The ADT is developed through a hybrid agile systems engineering framework that fosters responsiveness to critical data needs during development. That is, the process of biodigital twin creation is a structured six stage process, where the movement to and from stages must be nimble, and is heavily dependent upon data needs and how the data is recreating the objective function (i.e., the phenotype of interest). At its core, the ADT is a set of computational systems physiology models, based on systems of differential equations, which are in dynamic equilibrium with each other. Further, through deep mechanistic insight, these models define the positive and negative feedback inherent in the system, which is a critical feature when trying to adequately project that system into the future. In the initial embodiment, it animates the dynamic equilibrium that exists between the bone, skeletal muscle, and cardiovascular systems and the alternate parameterizations that exist on the Earth and in space. To adequately represent the variability that exists within the human population, a virtual astronaut population is constructed and 'ground truthed' (i.e. anchored on calibration data from the same biological systems). This population is then used to build the functional digital twin, which is a full representation of how the coupled bone, skeletal muscle, and cardiovascular systems respond in unison to spaceflight.

Layered within the six step agile systems engineering process are a series of optimization activities to ensure the objective of the ADT is accurately being met. This serves as a form of quality control to include: 1) using a Validation and Verification (V-Model) during the initial development and final development to make sure the context, objectives, and requirements of the system are understood and tracked over time; 2) understanding model topologies through dynamic analysis as the scope of the model becomes further defined mathematically; 3) using global and local sensitivity analysis, continued dynamical analysis, model reduction, and parameter estimation to capture behaviors and build confidence in the models by calibrating reference

subjects; and, 4) using robust simulations to predict biological outcomes while accounting for natural variations and uncertainties, then explaining how these predictions align with existing biological knowledge and experimental data.

A fully functional ADT has multiple clinical and research applications that can be leveraged for innovation and to rapidly progress human space exploration. Clinically, it affords astronauts, flight surgeons, and commercial flight providers the ability to offer risk assessment and prediction for major spaceflight risks, coupled with precision and personalization in clinical decision support when recommending effective countermeasures. When applied to spaceflight research, the ADT can help by analyzing existing and novel data to create and test theories, design experiments, and simulate virtual countermeasure trials. All this data (from both clinical and research activities) is leveraged to help the ADT to learn on an individual or population level for iterative model development.

A spacefaring civilization will require considerable advancements in the ability to enhance astronaut performance, health, safety, and survival. Within this context, the ADT is one critical tool to shorten the development cycle, pose complex questions about any unique environment, and test hypothetical countermeasures before entering those environments. This is expected to provide an advanced capability to the spaceflight medicine community and help them keep pace with the spaceflight engineering community, as they collectively grapple with these highly complex operations.

Presentation#132

Applying Systems Engineering to Develop a Management Operating System at a National Laboratory

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Presented on: Thursday, 13:30-13:55 EDT

Keywords. Engineering management;Change management;Learning Organization;Organizational knowledge

Topics. 2.1. Business or Mission Analysis; 22. Social/Sociotechnical and Economic Systems; 3.5. Technical Leadership; 5.5. Processes; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Sandia National Laboratories is undergoing a transformative effort to accelerate project and product delivery in its nuclear deterrence portfolio. Using a systems engineering approach, Sandia is developing a learning system where knowledge management and change management are central to an engineering management strategy that accelerates the delivery of technical projects, with knowledge as a key component. In this presentation, the author—a Systems Engineer and Change Management Practitioner—demonstrates how a team at Sandia is applying systems engineering methodology to this transformation effort and explains the importance of effective change management in this context.

Technical projects for nuclear deterrence applications face significant engineering management challenges, including long development engineering cycles, outdated or incomplete information, risk aversion, reluctance to adopt new technologies, and changes in regulation. The compounding effect of these challenges can delay projects that are crucial to national security. To address these challenges in a large organization, a coordinated and systematic effort to transform engineering management practices is essential for changing how decisions are made and risks are managed. This transformation must focus on equipping technical teams with the knowledge they need to perform their jobs effectively and improve their decision-making and problem-solving skills by understanding their project's knowledge gaps (the difference between what is currently known and what is necessary to complete a task). Effective engineering management—particularly in knowledge management, availability of technical expertise, oversight, strategic planning, and team development—can ensure that teams have access to the knowledge and resources they need to close knowledge gaps and make timely, informed decisions.

This presentation outlines how Sandia's nuclear deterrence portfolio has adopted a systems engineering approach to improve its engineering management system by addressing knowledge gaps. The goal is to evolve into a learning organization that embodies core disciplines such as Systems Thinking, Personal Mastery, Challenge to Mental Models, Shared Vision, and Team Learning. In alignment with Sandia's strategic vision, a transformation team at Sandia has developed a series of interrelated initiatives—including tools, practices, processes, and procedures—based on this set of core disciplines to help teams close their knowledge gaps. Examples of these initiatives include independent technical peer review, risk management, technical authority, and digital engineering. These initiatives serve as the foundation of the improvement system the transformation team is examining to identify the system components, the interactions among the initiatives, and the relationships between the processes and the engineering teams.

Sandia is currently implementing these initiatives using a change management framework. This is important in such a large transformative effort to ensure that the results of the initiatives are long-lasting and reduce change fatigue.

This presentation intends to help other organizations with similar challenges to improve their engineering management practices by using systems engineering as a framework to transform their operations.

Presentation#97

Architecting the Future through Natural Language Processing

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

Keywords. Artificial Intelligence (AI);Natural Language Processing (NLP);Model-Based Systems Engineering;Requirements engineering

Topics. 2. Aerospace; 2.3. Needs and Requirements Definition; 5.11 Artificial Intelligence, Machine Learning; 5.3. MBSE; 6. Defense;

Abstract. The world is currently undergoing a digital transformation. System engineers have embraced digital, model-based methods leveraging great leaps in computing power to manage the ever-increasing complexity of systems. Model-Based Systems Engineering (MBSE) allows for creation and maintenance of a single source of truth on a system throughout its lifetime. The MBSE method creates a holistic model via rigorous requirements engineering, which includes creation, quality, management, verification, and validation of requirements. Failure to capture system requirements and specifications accurately can lead to either outright system failure or the accumulation of technical debt in the design. As systems continue to become more complex, the likelihood of these mistakes increases, and the implications are often more severe and less well understood. It is, therefore, critical that there is a robustly created, easily maintained, and simple to navigate single source of truth for a system.

Through a combination of diagrams with written language, MBSE extends the effectiveness of systems engineering. As systems progressively become more complex, the traditional document-based systems engineering approach begins to fall short in its ability to reach various stakeholders. MBSE models provide a visual representation of a system that promotes collaboration and understanding of complex systems amongst diverse development teams. While MBSE is an effective way to promote conversation and understanding between different system stakeholders, it, too, is reaching capacity to contain, communicate, and effectively architect enterprise product architectures. In addition, to remain competitive, systems are being developed at a faster pace. These factors coupled with the fact that MBSE relies on volumes of written language and diagrams to thoroughly explain a system hinder the effectiveness of solely employing MBSE techniques to evaluate and design complex systems.

Natural Language Processing (NLP), a sub-discipline of AI focused on evaluating written language, can be used to further improve the MBSE capability. NLP is used to comprehend written language, including contextual nuances, styles, patterns, similarities, and semantics Historically, NLP largely consisted of classifying parts of speech and building out rulesets for those Parts of Speech. Though recently, the field progressed to more general methods such as Latent Dirichlet Allocation (LDA) incorporating research from the field of information retrieval. In its current state, NLP has evolved further to include heavily computational methods such as embeddings and Large Language Models (LLMs). An embedding is a collection of numbers representing the meaning of text that can be used to compare texts that have been "learned". Using the concept of embeddings, it is possible to use the embedding of a piece of text to predict the most likely next word that would appear in that sequence. At a high level this is how LLMs function. Therefore, LLMs have some understanding of sentence structure and grammar, making them useful for text-heavy systems and architectures in the engineering community.

The inclusion of NLP techniques in the systems engineering process is not new, and researchers are applying innovative NLP techniques and practices to benefit the systems engineering community. Over the past three years, research and experimentation has primarily focused on the use of NLP techniques to automatically

create systems diagrams from system documentation, detect ambiguity in requirements, automatically linking similar documents, and increasing the quality of metrics used to evaluate systems.

Previously, the authors performed a use case study on the application of NLP technology to aid in requirements tracing activities. The primary goal of this study was to evaluate if an NLP algorithm could trace similarities between two sets of requirements, how well the NLP algorithm performed these tasks, and how much time was spent performing the trace activity. In that study, the authors trained an NLP algorithm and chose two related requirements documents from an internal project. The results showed that the algorithm was able to cover 53.97% of the requirements traces identified by the Subject Matter Expert (SME). While all the traces were not found, this NLP enabled trace and evaluation activity was performed in about two working days while traditional manual trace activities took almost a week. This experiment showed the NLP algorithm will not fully replace a human analyst but can aid humans to perform trace activities more quickly.

Currently systems engineers spend many hours doing the manual labor of requirement categorization and comparison. Automation, even if not complete, can provide a dramatic speed up during the requirement discovery process and allow engineers to focus on the smaller number of requirements that may be tricky for an automated system. Industry is currently evaluating powerful LLMs for applications within system design as well as proper safeguards to ensure system design integrity. Focusing on requirements processing, it is possible to apply LLMs in a variety of situations. These include requirement categorization, comparison, and Quality Assurance (QA) all in an automated manner. Categorization and comparison can be achieved through direct querying of the LLM in a purely text-based approach, clustering embeddings extracted from the LLM, and then applying summaries. QA, or determining whether the requirement itself is high-quality, will leverage the semantic capabilities of LLMS with prompts engineered to refine and point out flaws in the input requirements. LLM implementation for QA, improving readability, enforcing standards, and making sure there is a cohesive voice in technical documentation, without additional overhead not only increases throughput in the present but ensures higher-quality material to work from for future engineers.

The authors’ presentation will address the problem of efficiently handling and systematically interpreting extensive verbiage and documentation in the systems engineering domain. The presentation will demonstrate the use of NLP technologies including LLMs to augment common requirements engineering pitfalls. The presentation will outline the authors’ research and applications of NLP techniques to increase comprehension and effectiveness of the technical and systematic written language methods used within systems engineering. In addition, the presentation will also detail a methodology for the inclusion of LLM in the MBSE workflow to promote requirement comprehension in innovative ways.

Presentation#341

Beyond Traditional Engineering: Transformative Approaches for a Changing World

Elena Gallego Palacios (Spain - AEIS) - elena.egp@gmail.com

Presented on: Wednesday, 14:30-14:55 EDT

Keywords. Systems Engineering (SE);Complexity;Transformation;Model-Based Systems Engineering (MBSE);Artificial Intelligence (AI);Product Line Engineering (PLE);Agility;Digital Infrastructure;Interoperability;Collaboration;Systems-of-Systems

Topics. 1.1. Complexity; 2. Aerospace; 5.5. Processes; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. The ever-increasing complexity of modern systems demands a paradigm shift in engineering approaches. Systems Engineering (SE), with its transdisciplinary and integrative nature, is well-suited to address these challenges. In this presentation, we will focus on how to transform traditional engineering processes to adapt to the rising complexity of systems and solutions.

When we look back only around 60 years, most defense systems onboard a ship were manually operated and purely mechanical. Communication was slow, messages were handwritten, and too many links were in the chain. Today, these same defense systems have evolved into unmanned and autonomous systems with strong components in electronic warfare, AI software, and the passing and exchange of data across remotely connected resources. This shift illustrates the rapid pace at which complexity is increasing, requiring organizations to meet demands for affordability, agility, efficiency, and quality. These demands must be addressed while managing factors like more complex organizational structures, growing customer requirements, systems of systems with different development life cycles, co-development, and knowledge management.

The more traditional engineering approaches need transformation due to various factors:
- The evolution of systems from standalone assets to complex systems-of-systems. Defense systems historically exemplify this shift, such as NATO's collaborative exercises involving diverse technologies, nations, and requirements.
- The rise of complexities coming from more demanding customer needs, integration of multiple disciplines (e.g., software, hardware, UX, cybersecurity, eco-design), and faster technological advancements.
- The imperative to maintain affordability, agility, and sustainability to deliver operable capabilities to users.

In order to successfully overcome these challenges, engineering must be transformed, leveraging the current corporate infrastructure. This transformation requires innovative thinking, new behaviors, and more resilient teams. Systems that once were built to last must now be built to evolve. This shift means that system functional architectures must grow over time, necessitating a digital infrastructure that supports configuration management and reuse. Interoperability and integration of tools are critical to secure delivery, facilitate rapid decision-making, and optimize collaboration.

This growing complexity impacts multiple industries, highlighting the critical role of SE in managing and orchestrating these demands. During this presentation we will see examples on how advanced defense systems demonstrate the need for interoperability and adaptability. NATO exercises, for example, require coordinating hundreds of personnel, aircraft, ships, and ballistic missile targets remotely distributed. These systems demand real-time data sharing and robust SE processes to ensure optimal solutions.

These examples emphasize that as complexity increases, traditional engineering practices struggle to meet industry and government standards for cost, quality, and speed. Addressing this issue is vital to maintaining competitiveness and ensuring success across sectors.

The presentation outlines methods to address these challenges, focusing on transitioning from traditional to

modern SE practices, such as:
- Model-Based Systems Engineering (MBSE): MBSE emphasizes unified modeling, enabling multidisciplinary collaboration and iterative validation. Incorporating Artificial Intelligence (AI) enhances MBSE by automating model validation, optimizing system configurations, and providing predictive insights to identify potential risks earlier in the development lifecycle.
- Product Line Engineering (PLE): PLE streamlines the development of product families, allowing organizations to maximize reuse of shared features and manage variants efficiently. AI-driven analysis can support PLE by identifying reusable components and optimizing product variations based on performance data and customer needs.
- Agile Systems Engineering: By applying Agile principles, SE can adapt to dynamic requirements, foster rapid prototyping, and facilitate early-stage validation.
- Digital Infrastructure: Modern engineering tools like integrated ontologies, predictive analytics, and collaborative platforms are critical for managing data, ensuring configuration accuracy, and enhancing decision-making.

A practical example of transformation in Defense is NATO's "At Sea Demonstration," which highlights the necessity of interoperable systems and the adoption of predictive analytics to coordinate between subsystems.

The presentation will also walk through a number of realistic objectives that can be achieved by the engineering community for business success. We will specifically analyze what processes, methods, and tools need to be transformed. Traditional engineering practices will be compared with modern enabling systems such as collaborative environments, data accessibility, reuse of information, and predictive algorithms. Additionally, we will explore which elements of the development lifecycle must evolve and how the appropriate tool landscape can be established to support these processes and methods.

Participants will discover the real definition and application of the steps to manage the increasing complexity of developing systems from an engineering transformation perspective. This session will provide practical guidance on aligning SE processes with organizational goals, focusing on agility, affordability, and quality, while also highlighting the importance of organizational readiness for change.

Through enhanced SE processes, businesses can address not only technical demands but also cultural and structural changes essential for long-term success. This focus on sustainable transformation ensures relevance to INCOSE's goal of improving the state of the practice globally.

In conclusion, the increasing complexity of modern systems makes engineering transformation a necessity rather than an option. This presentation outlines practical approaches, grounded in SE principles, to help industries manage this complexity effectively. Attendees will leave with actionable insights, concrete examples, and a deeper understanding of the methodologies—including AI enhancements—needed to foster innovation and maintain competitiveness in an ever-evolving landscape

Presentation#65

Case Studies for Querying the Model - SysML V2

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

Keywords. SysML V2;Model Queries;Model Analysis;Query;MBSE;CATIA Magic;Simulation Toolkit

Topics. 2. Aerospace; 2.6. Verification/Validation; 3. Automotive; 3.6. Measurement and Metrics; 5.3. MBSE; 6. Defense;

Abstract. As the excitement for SysML V2 grows, industry begins to discover its benefits and push its limits. One of the promises of V2 is the ability to use textual notation to manipulate the model. This brings additional capabilities beyond what was available in V1. This presentation will explore a number of popular use cases on querying data within the model that will provide a foundation for model based systems engineers to implore and improve on. Such case studies are to include, but are not limited to: number of specific elements within the model, number of satisfied requirements, element filtering, and actions allocated to performers.

Presentation#311

Configuration Management Challenges in Multi-Team Collaboration Using Linked Models

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Presented on: Wednesday, 16:30-16:55 EDT

Keywords. MBSE;Model-Based Systems Engineering;Configuration Management;Digital Engineering

Topics. 3. Automotive; 3.2. Configuration Management; 5.3. MBSE; 5.5. Processes; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. The growing prominence of Model-Based Systems Engineering (MBSE) as a key methodology in systems development brings unique challenges to the forefront, particularly in the context of configuration management (CM). While CM principles have been well established over decades in software engineering (SWE), their application to MBSE, with its reliance on highly interconnected and evolving digital models, demands a tailored approach. This presentation seeks to outline these challenges through specific real-life use cases, highlighting how SWE-inspired CM practices can be adapted and extended to address the underlying complexities of MBSE.
Central to the discussion are the structural and operational complexities inherent in digital engineering

networks—interconnected systems of models that span multiple teams, organizations, and tools. These networks, often characterized by their high coupling and intricate dependencies, present a range of issues, including versioning inconsistencies, diamond dependencies, and circular pathologies. Such problems are most clearly seen when multiple parties (e.g. OEM/Suppliers, Primes/Subcontractors) exchange and co-develop models, requiring robust mechanisms for model integrity, immutability, and synchronization.
Key use cases addressed include:
1. Dependency Management in Model Networks: Drawing parallels to software systems managed by tools like Maven, this use case explores strategies for managing interdependencies within large-scale MBSE projects. Proposed solutions include adopting immutable model versions, introducing pull-based dependency resolution, and leveraging continuous integration/continuous deployment (CI/CD) pipelines for automated updates and validation.
2. Complexity Analysis of Model Networks: This examines metrics and methodologies for analyzing and mitigating complexity at three levels: inter-model networks, intra-model element cohesion, and inter-model element coupling. Strategies for simplifying network structures and ensuring scalability are presented, informed by SWE practices.
3. Model-Based Exchange Across Teams and Tools: The process of sharing, updating, and reintegrating models among diverse stakeholders introduces challenges akin to "round-trip" consistency in software version control. The presentation discusses approaches to maintaining model fidelity during transfers, achieving stable baselines, and automating exchange workflows, drawing on SWE solutions like Git-based repositories for release management.
4. Visualization and Traceability of Model Networks: Effective visualization tools for understanding and managing dependencies are critical. The presentation explores current limitations in MBSE toolchains and proposes enhancements inspired by SWE tools that facilitate greater transparency in dependency trees and network flows.
5. Configuration Management for Linked Models: Managing linked models across teams poses distinct challenges, particularly when addressing issues like overlapping dependencies, partial model cloning, and version mismatch. The use of modular, supplier-neutral CM practices to resolve such issues is explored.
The proposed solutions advocate a shift in MBSE CM practices towards a DevOps-inspired paradigm. This includes integrating unit testing for model validation, developing centralized repositories for model discovery and reuse, and automating dependency management workflows. The importance of establishing clear standards for baselines in model exchange is also emphasized to mitigate the problem of propagating immature “engine is in pieces on the garage floor” versions from team-to-team which can often cause escalating program instability in dynamic multi-team environments.

Furthermore, the presentation highlights the potential of incorporating SWE-native concepts, such as patching, into MBSE to tackle inherent scalability challenges, particularly in multi-iteration model exchange workflows. It showcases how applying this concept can enhance the efficiency of model exchange and outlines the necessary methodological preconditions for its successful implementation in practice.

Through the above use cases and their associated solutions, the presentation aims to provide a roadmap for advancing CM practices in MBSE. By bridging the gap between SWE and MBSE, it seeks to foster a more scalable and resilient approach to managing the lifecycle of interconnected models, ultimately enhancing productivity and reducing errors in complex systems engineering projects.

Presentation#105

Curiosity-Centered AI Engineering

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Presented on: Monday, 14:15-14:55 EDT

Keywords. Artificial intelligence;Innovative approaches;Human systems integration (HSI)

Topics. 4.1. Human-Systems Integration; 5.11 Artificial Intelligence, Machine Learning;

Abstract. The swift and ubiquitous integration of artificial intelligence (AI) into everything – with its reliance on data, and its dynamic nature - has revealed weaknesses in software practices. Engineering programs do not incentivize students to gain a deep understanding of data and context or encourage their natural curiosity about the people who will use the systems they build. Engineers are taught math and programming and expected to create algorithms, with data and the user interface often being an afterthought. Exploratory Data Analysis (EDA) is a necessary step to evaluate data, but it is not sufficient to reduce risk for AI-enabled systems.

Curiosity-centered engineering brings the focus back to the data and people who will use the system and reduces risk across the system. AI-enabled systems can make unexpected connections and find patterns in data that are not helpful. A curious and intense exploration of the data supports the identification of errors that would otherwise go unnoticed during development. Reliance only on accuracy or F1 scores can belie the inadequacy of systems, whereas understanding how end-users will use the system outputs supports better test, evaluation, verification, and validation practices.

It is time for engineers to rediscover their curiosity. To successfully build a curiosity-centered culture AI engineering teams need guidance and support. This session builds upon decades of practices to make systems that work with, and for, humans. Incentivizing curiosity about the subject matter, the needs of end-users, and the overall use case will result in better and more trustworthy systems. Attendees will learn when and how they can integrate curiosity-centered AI engineering practices into their development cycles.

Presentation#16

Darth Vader's Personal Library: Models, Models, and More Models

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Presented on: Monday, 13:30-14:10 EDT

Keywords. Model Libraries;Model Management;MBSE;Mission Models;System Models;Product Line Engineering

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

Abstract. The Galactic Empire is constantly trying to develop systems under compressed schedules. Additionally, the struggle for power within the Empire has driven project managers to refrain from sharing product designs and specifications, resulting in design silos that duplicate product lines, common systems, sub-systems, acquisition processes, and mission planning. However, this has resulted in extended development cycles, as well as key system failures, beyond what is acceptable to the Empire's Sith leaders, and has forced the early "retirement" of project managers. In an effort to resolve this, Lord Vader has demanded that an official Empire Library of Models be developed to be used across the Empire's development and acquisition workforce to reduce product development times and cost, while improving product capability and consistency. This effort is focused around the following modeling efforts: Product Development, System Development, Product Line Engineering (PLE), Mission Engineering (ME), and Model based Acquisition (MBAcq). This presentation will use a novel example (Star Wars) to identify some of the key concepts for defining models, and their libraries, such that they enable integration into other models and hence, reuse.

Presentation#348

Data Visualization of MBSE Models for Systems Engineering Baseline Assessments

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Presented on: Monday, 14:15-14:55 EDT

Keywords. MBSE;PowerBI;Cameo;Data visualization;Systems engineering baseline;Systems engineering technical reviews

Topics. 2.4. System Architecture/Design Definition; 3.6. Measurement and Metrics; 5.3. MBSE; 6. Defense;

Abstract. Systems engineering baseline assessments are essential for the defense industry as they establish

a foundational understanding of a system's current state and its performance against the government’s defined requirements. These assessments help identify gaps or deficiencies early in the development process, enabling timely corrective actions and ensuring that the system meets mission-critical objectives. To effectively conduct these assessments, decision-makers must be able to understand and analyze the Model-Based Systems Engineering (MBSE) models that define the system baseline. As systems become increasingly complex, MBSE models also become large and difficult to navigate and understand. Barriers such as Systems Modeling Language (SysML) knowledge, tool proficiency, tool access, and tool limitations hinder effective utilization of the data in MBSE models. Consequently, decision-makers often struggle to leverage MBSE models to make informed decisions during systems engineering technical reviews.

This presentation explores an approach for using PowerBI to create data visualizations from Cameo-based SysML models, helping stakeholders assess their system baseline. These visualizations make MBSE model data more approachable, easier to understand, and more accessible to all stakeholders, even those without access to the modeling tool. While an MBSE model may be complex and difficult to navigate, PowerBI data visualizations can transform model data into simple, tailored views that show each stakeholder only the information they care about. Filtering, search, sorting, and drill-down features in PowerBI make it easy for users to dig into areas of interest without needing significant training or advanced Cameo skills. This presentation will focus on tool setup, configuration, lessons learned, and best practices in building these data visualizations.

First, we will explore methods for extracting data from Cameo models into a PowerBI-readable format. Although a live data connection is ideal, periodic exports can suffice for visualizations updated on a weekly or monthly basis. Current tool limitations necessitate using Excel spreadsheet exports to extract model data. By creating custom tables in Cameo, we can tailor the data for PowerBI visualizations, using custom columns to query element properties and relationships of interest. Metachains can be leveraged to pull complex multi-level relationships into simple formats that can be processed by PowerBI. The presentation will cover lessons learned and optimal table configurations for PowerBI import.

We will also demonstrate various data analytics and visualizations achievable with PowerBI. While creating metric suites in Cameo requires advanced tool knowledge, similar analytics can be achieved in PowerBI by users with beginner to intermediate skills. Once data structures and links are established, PowerBI facilitates easy creation and modification of dashboards. These flexible and modular visualizations can be quickly updated and reconfigured to create different views customized to particular stakeholders.

PowerBI dashboards are powerful tools for understanding and communicating data in MBSE models. Overcoming initial challenges in extracting information from Cameo models paves the way for building a wide variety of PowerBI visualizations tailored to different stakeholders. This methodology enabled a large defense program to quickly assess system baseline completeness and identify gaps and risks. Managers who struggled to navigate and make sense of large, complex MBSE models were able to easily access and interact with the PowerBI dashboards. At a quick glance, they could see the current status of the model and check key metrics. These dashboards were updated every few weeks whenever new vendor MBSE models were delivered, giving leadership the ability to stay up-to-date with the current state of the system baseline, instead of just reviewing it for major Systems Engineering Technical Reviews. By making MBSE model data more approachable and accessible to non-modelers, decision-makers can stay better engaged with the model data to more effectively assess gaps and risks affecting their program.

Presentation#383

Digital Engineering Adoption at Small Manufacturers: Learning from Digital Thread and Model-Based Definition Adoption at SMMs from a Prototype Project and Study

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Presented on: Tuesday, 16:00-16:25 EDT

Keywords. model-based definition (MBD);digital engineering;small manufacturers and business;digital technology adoption;education and training

Topics. 19. Very Small Enterprises; 2.2. Manufacturing Systems and Operational Aspects; 20. Industry 4.0 & Society 5.0;

Abstract. Large engineering and manufacturing companies need small and medium-sized manufacturers in their supply chain to adopt digital thread and model-based definition (MBD) practice to achieve their own higher levels of MBD capability and digital thread implementation across their enterprise. The digital thread cannot stop at the walls of an enterprise. Although small and medium-sized manufacturing companies (SMMs) may not often produce what systems engineers would consider complex systems, their high technology operations to produce highly complex parts for key industrial bases in aerospace, naval, and defense industries drive a need to adopt systems thinking, systems engineering, and digital engineering practices.

At the systems level, digital thread and model-based engineering approaches are used to handle and mitigate complexity and provide information in a way that aids in design and development decision making across silos and lifecycle stages. At the part level, model-based approaches are used to make better decisions during design, costing, manufacturing, and inspection. In addition to improved decision across the operation, adopting MBD at an SMM can support the automation of workflows for digital costing, advanced manufacturing system and machine programming, improving first articles inspection practices, automating inspection machine programming, and facilitating digital twin (DT), artificial intelligence (AI), and industrial internet of things (IIoT) use and adoption improving real time decision making in manufacturing. These improved levels of operational efficiencies and effectiveness can lead to shorter lead times, greater levels of efficiency, lower levels of scrap, and can increase production capacity. In many ways, MBD adoption can finally break down the walls between design, manufacturing, and inspection at a manufacturer, but the breaking down of the walls is a barrier itself to MBD adoption.

For SMMs to adopt MBD and digital engineering practice, the organization must assess their MBD maturity, adopt new technologies, acquire new MBD skills, plan technology adoption financial resources, and often must conduct and manage organizational change that goes along with the adoption of digital thread practice that inherently effects many parts of the organization.

This presentation proposes an Integrated MBD Adoption (IMBDA) Framework and strategy for SMMs to start, grow, and maintain their MBD adoption journey. The IMBDA Framework presents and discusses key elements unique to business aspects of small businesses and how using a combination strategy of technical skills training, business and value proposition training, leadership training, technology adoption strategies, and investment strategies for small businesses can effect change and move SMMs towards higher levels of MBD readiness. The IMBDA Framework proposes a competency and skills model for SMM adoption of MBD technical skills developed based upon results from a Scaling Model Based Definition project conducted over several years between OEMs and SMMs to prove out best MBD practices. The IMBDA Framework also proposes new methods of cooperation and coordination between customers and suppliers in large and complex industrial supply chains that have proven effective in sending correct supply and demand signals that can lead to wider spread adoption in important supply chains. The IMBDA Framework was developed based upon feedback collected from SMM and OEM technology adoption and training program participants during their participation in 2024. This study explores barriers and challenges to adoption, technical skills needed, and the value proposition for MBD adoption and the program’s experience developing cooperative MBD engagement models with OEMs and their suppliers. This program, work, and results can enable a paradigm shift for SMMs in key industrial supply chains and enable their ability to adopt MBD.

Presentation#218

Driving the Future of MBSE: SysMLv2 and Simulation-Driven Verification for the example of an Electric Vehicle ePowertrain Battery System

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Presented on: Wednesday, 16:30-16:55 EDT

Keywords. SysMLv2;MBSE;Architecture;Analysis;Modeling;Simulation;Verification

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

Abstract. The emergence of SysMLv2 marks a transformative leap in how Systems Engineer define, model, and analyze/verify complex systems. Concepts such as Definition and Usage introduced in SysMLv2 simplify and streamline the reuse of model elements. The standardized SysMLv2 API has the potential to significantly enhance analysis, verification, and trade studies through simulation as it allows to query and modify the architecture in a standardized manner. But how can these capabilities be harnessed to ensure the design and performance of critical systems in real-world applications?
In this presentation, we delve into the practical application of SysMLv2 and demonstrate how its API can be leveraged to conduct Trade Studies and perform Verification by Modeling & Simulation (M&S). Using the example of an electric vehicle's ePowertrain battery system, we show how new SysMLV2 concepts can be consistently applied across all hierarchy levels - from the vehicle (system context), via the ePowertrain (System of Interest) to the battery cell (the lowest relevant system element in the architecture). This approach facilitates the creation of modular, self-contained, and reusable model entities, enabling the development of complex, variant-rich systems with repeated subcomponents across multiple architecture levels. Furthermore, we illustrate how the SysMLv2 API can be leveraged to streamline requirement verification by M&S through both simple and advanced simulation techniques. Specifically, with the help of the ePowertrain example, we show how a simulation workflow (consisting of a spreadsheet-based cell characteristic lookup table, battery sizing script analyses, and a system-level lumped-parameter performance simulation to estimate battery performance and the vehicle range) is connected to the SysMLv2 architecture via a model orchestrator that leverages the standardized API. Utilizing this workflow, a trade study is initiated from the SysMLv2 model that identifies the effect of cell choice on conflicting requirements such as the top-level range requirement and battery pack cost and mass. For the most viable system design candidate, a reparametrization of the relevant value attributes of the SysMLv2 model is conducted via the API.
Key takeaways will include:
- How SysMLv2's Definition and Usage concept enhances modularity and reusability in system modeling.
- Practical workflows for connecting SysMLv2 models with simulation tools via its robust API and a simulation orchestrator.
- Insights into verifying performance requirements of an ePowertrain battery system and the consequences for the system of interest in its context.
- Lessons learned and best practices for adopting SysMLv2 in the context of Model-Based Systems Engineering (MBSE).
This session offers systems engineers actionable insights and techniques to elevate their MBSE practices, empowering them to deliver innovative and reliable systems in today's electrified and connected world. Whether you are new to SysMLv2 or exploring its advanced capabilities, this talk provides a roadmap for integrating next-generation modeling standards with state-of-the-art simulation methodologies.

Presentation#252

Dynamic Reliability Analysis using Model Based Systems Engineering

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Presented on: Thursday, 14:00-14:25 EDT

Keywords. Reliability Analysis;Digital Thread;Model Based Systems Engineering;Model Based Definition;Failure Modes;Failure Rate;Failure Mode Distribution;Reliability Block Diagram;Safety Analysis;Functional Hazard Analysis;Failure Mode and Effect Analysis

Topics. 2. Aerospace; 3. Automotive; 4.3. Reliability, Availability, and/or Maintainability; 4.6. System Safety; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 6. Defense;

Abstract. In aerospace product development, most failures and safety issues can be prevented by ensuring there is a robust system design which factors in Maintenance and Reliability from the design phase. Reliability Block Diagram (RBD) is one of the most widely accepted approach to calculate how components and sub-system failures propagate to cause a system failure. RBD can be implemented in both the design and the operational phase to identify poor reliability and provide targeted improvements to lower the failure rates of the system. Traditionally in the industry, RBD is modeled post system design finalization based on the historical data of failure rates of the part, without any dependency on the system model. This lack of proper coupling between the system model and the reliability analysis could lead to the generation of erroneous failure rates which may not be reflective of the system configuration. Using Model Based Systems Engineering (MBSE) concepts applied to RBD analysis we have developed a mechanism that couples the RBD model with the system models to provide the probable failure rate values with improved accuracy. MBSE approach spans across the entire lifecycle of product design from Requirement Development to Design, Integration to Verification and Validation and After Sales Support.

Traditional RBD models do not account for dynamic changes to the system configuration due to the reduced dependencies on the system model which could result in imprecise failure rate calculations. Our proposed solution will include (1) A database containing the Failure Rate, Failure Modes and Failure Mode Distribution (FMD) of each part of the system under analysis; (2) System Architecture developed in SysML that captures the real-time failure mode data of the subsystem from the database; (3) Parametric computation that enables the architect to link the system architecture model with the reliability analysis to provide an accurate failure rate which accounts for the probability of subsystem Failure Modes.

This approach would establish a robust RBD model and enhances the FMEA table generation with accurate Risk Priority Numbers (RPN). The solution ensures (1) Interconnectivity between models providing more dynamic results. This means that changes to the system will be accurately reflected in the RBD analysis in real-time; (2) Ease of maintenance and configuration of models developed in SysML; (3) Scalable and portable solution with capabilities of reuse across all aerospace and automobile product lines; (4) Reduction in time for development and analysis of multiple safety models including FMEA and FHA.

This paper will provide details about our findings on (1) Traditional vs MBSE approach to RBD modeling; (2) Tool and Environment setup for using an MBSE approach to RBD modeling; (3) Example model to demonstrate the capabilities of the MBSE approach with improved result generation.

Presentation#256

Effective Requirements Management for Complex Systems using Model-Based Driven SysMLv2 Approach

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

Keywords. Model-Based Systems Engineering (MBSE);Systems Modelling Language (SysMLv2);Requirements Management

Topics. 2. Aerospace; 2.3. Needs and Requirements Definition; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; Other domain;

Abstract. The development of complex engineering systems is driven by extensive sets of requirements provided to the technical team by the key stakeholders of the project. These set of requirements are usually structured by specific project review organizations and are tracked during the entire project lifecycle. Space missions are typically very well known to follow strict procedures and requirement guidelines while developing spacecraft systems. A significant challenge for spacecraft teams is ensuring all requirements are satisfied within the scheduled timeline of the project. As spacecrafts are considered as payloads for the launch vehicles, delays in meeting all the mission requirements on time can result in missing out on the opportunity to be launched into space. The launch cost for a 1 kg payload to Low Earth Orbit is about $20,000; and a typical remote sensing and exploration satellite weighs about 100 kg. This equates to a loss of about $2 million.

Notable space missions such as James Web Space Telescope (JWST) and Hubble Space Telescope (HST) were also among the projects that faced delayed and cost overruns due to ineffective requirements management. Frequent revisions to the requirements of JWST caused multi-year delays; hence, resulting in the inflation of mission costs by up to 10 times. Similarly, the requirements of HST were inadequately verified based on inspections, quality assurance, and critical tests in order to meet the mission deadlines. Thus, an additional cost of about $ 1 billion was required to fix the calibration issues in orbit. For most engineering projects, the strategy used for managing requirements is still considered to be the traditional document-based. This approach is suitable for smaller and simpler projects. However, with the increase in system complexity, document-based approach is considered to be inefficient and error prone. Key drawbacks of using document-based approach for requirements management is the lack of effective traceability, poor visualization, scalability issues, verification and validation gaps, inefficient dependency management, and insufficient collaboration and communication across multi-disciplinary engineering teams.

To address these systems engineering challenges, the Systems Modelling Language (SysML) was introduced enabling a model-based systems engineering approach towards development of complex systems. In the model-based approach, the system is constructed and captured using various different models that include requirements model, structural model, architectural model, functional model, and verification model. These models can be interconnected to demonstrate traceability, functionality and dependency to give a clear visibility of the overall designed system. SysML offers nine different graphical represented diagrams that are utilized to create the above-mentioned system models. The first generation of SysML known as SysMLv1 was based on UML metamodel and was released in 2007. The semantics was implemented in a licensed tool known as MagicDraw. The tool allowed the user to create and connect different system models. Some of the limitations revealed for SysMLv1 are limited views, non-user-friendly interface, inefficient in tracking changes, manual creation of models, and weak integration with domain specific engineering tools. Thus, to address the limitations of SysMLv1, the next generation of SysML known as SysMLv2 was introduced in 2017 in the form of a pilot implementation. SysMLv2 was designed specifically to meet the needs of MBSE as it was based on a new KerML metamodel. SysMLv2 provided consistent terminologies, ability to integrate the models to different engineering tools, develop different configurations of the system models, version controlling, and offered flexible views for the system models. In SysMLv2, the user can construct system models using the new textual interface and auto-generate the graphical representations of these models.

This research focuses on utilizing the textual interface feature of SysMLv2 to develop an effective MBSE framework for designing complex engineering systems that are capable of capturing all the aspects of the system. One of the branches in our proposed MBSE framework is the requirements management stream that is the key focus of this study. A requirement usually contains a unique ID, title, text, rationale, allocation, verification, and status. In our developed requirements management strategy, all the characteristics of the requirements are stored in a requirements model that is based on the textual interface of SysMLv2. The aim is to have a single source of truth database where all the system models are stored in the form of SysMLv2 textual files. For effective version controlling and tracking, the SysMLv2 files are stored in a version-controlled environment such as GitHub or GitLab. Each requirement is linked to structural, architectural, or functional element in the system models and connected to test cases in the verification model. The requirements model developed using SysMLv2 textual file can be graphically represented using Jupyter notebook, Eclipse workspace or other recently released SysMLv2 tools that supports the textual interface.

For effectively tracking, tracing and extracting specific set of requirements, it is highly essential to actively query the set of system requirements. The current SysMLv2 infrastructure lacks robust querying capabilities for extracting specific requirements. Thus, an effective strategy is under-development as part of this study that connects the developed SysMLv2 textual-based requirements model stored in the version-controlled environment to an online database that facilitates the systems engineers to track, trace, and extract query-specific requirements. Changes made to the requirements stored in the online database will update the SysMLv2 textual-based requirements model stored in the version-controlled environment or vice versa. This framework enables real-time synchronization between the database and the version-controlled textual models. The developed requirements management approach is being tested and validated against a 500-requirement document provided by the project reviewers for a space project. Additionally, this study evaluates and provides insight to the emerging SysMLv2 tools and other MBSE platforms to test and compare different approaches to requirements management.

Presentation#111

Engineering Trusted AI Systems for Mission-Critical Operations

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Presented on: Tuesday, 15:30-15:55 EDT

Keywords. Trusted AI Systems;Human-AI Collaboration;Mission Engineering;Modular Open Systems Approach (MOSA);Digital Engineering;Cyber-Physical Systems Security;Mission-Critical Operations;Human Trust in AI

Topics. 14. Autonomous Systems; 2. Aerospace; 2.1. Business or Mission Analysis; 4.1. Human-Systems Integration; 5.11 Artificial Intelligence, Machine Learning; 6. Defense;

Abstract. The Trusted AI Systems Engineering challenge, sponsored by the Systems Engineering Research Center (SERC) and the Acquisition Innovation Research Center (AIRC), addresses the complexities of human-AI collaboration in mission-critical operations. The notional mission for this challenge involves a UAV, a UGV, and a human operator working as a team to clear a passage for a battalion by detecting and removing mines. This task presents several critical questions: Should the human operator assess imagery, even though AI can do so much faster? What specific role should the human play in this collaboration? How do we define

and measure trust in AI systems? And should system architecture or operations be explicitly designed to influence trust?

The challenge unfolds over three phases: Phase 1 took place in Summer 2024, Phase 2 concludes in December 2024, and Phase 3 is set for Spring 2025. Our team's solution for Phase 1 was ranked among the top two submissions across all participating teams. In this presentation, we will share our comprehensive solution, which will culminate at the end of the challenge.

Using a semi-formal systems engineering (SE) approach, we refined mission requirements, formalized the Concept of Operations (ConOps), and conducted trade studies to develop robust Operational Concepts (OpsCons) and mission architecture. Mission engineering was central to our process. By defining mission threads of increasing sophistication and incorporating diverse security scenarios, we explored and refined operational concepts tailored to specific mission architectures. Leveraging digital engineering tools, we efficiently developed SE artifacts, enabling a collaborative and iterative workflow.

A cornerstone of our solution was the adoption of a Modular Open Systems Approach (MOSA). This approach enabled us to establish multiple points of flexibility and reconfigurability across integration levels. The result was a system that could achieve high trustworthiness at the mission level, even when individual components exhibited reduced trustworthiness. MOSA provided the framework to balance adaptability and resilience in a wide range of operational scenarios. Specifically, flexibility in allocating decision authority between the UAV and the human operator allowed us to dynamically assign tasks to the actor with the strongest expected performance, creating robust strategies for surveying potential safe passages.

To address the challenge's multidisciplinary demands, our team brought together diverse expertise. The team included three graduate students and one undergraduate student, each offering unique technical skills. One graduate student focused on data analytics and operations research, optimizing decision-making within the mission. Another graduate student contributed expertise in cyber-physical systems security, ensuring AI trustworthiness in adversarial environments. A third graduate student integrated these contributions, producing cohesive SE artifacts that captured the broader system architecture and operational framework. The undergraduate student played a crucial role in generating digital engineering artifacts, streamlining workflows within a digital engineering environment.

Our presentation will provide the audience with actionable insights into engineering trusted AI systems. Attendees will gain a deeper understanding of how to define roles in human-AI teams, balance speed and accuracy, and design architectures that foster trust through modularity and adaptability. Additionally, we will demonstrate the application of digital engineering tools to streamline SE workflows and highlight the value of integrating expertise across disciplines to address complex challenges.

This presentation not only showcases our team's solution but also offers practical lessons for designing and implementing trusted AI systems in mission-critical environments. By addressing questions of trust, adaptability, and human-AI collaboration, our work contributes to advancing the systems engineering discipline and its applications to modern operational challenges.

Presentation#395

Enhancing the Future of Decision-Making - INCOSE DADM v1.0 Implementation

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

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; 2.4. System Architecture/Design Definition; 3.3. Decision Analysis and/or Decision Management; 5.3. MBSE; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. The INCOSE Decision Analysis Data Model (DADM) represents a significant advancement in decision-making frameworks within the field of systems engineering. Scheduled for release in February 2025, DADM v1.0 serves as a model-based approach that aligns with INCOSE Vision 2035, designed to empower practitioners with a robust, adaptable framework for navigating the complexities of modern decision-making. Our presentation will provide an overview of the DADM's development journey, its reception within the engineering community, and demonstrate an example implementation that illustrate its transformative potential.

Introduction to DADM v1.0
Developed by the INCOSE Decision Analysis Working Group (DAWG), the DADM v1.0 was designed to enhance consistency and clarity in the decision-making processes. This comprehensive framework captures both data models and detailed decision analysis process models and integrates theoretical foundations with practical applications, allowing users to navigate the complexity of decision analyses effectively. It consists of three layers—a conceptual layer, a logical layer, and a physical layer—facilitating a holistic understanding and straightforward usability.

Innovative Features and Future-Ready Approach
The DADM is characterized by its "Future-Ready Approach," which addresses emerging challenges in systems engineering, and leverages the latest model-based techniques to maximize interoperability and reuse. By moving beyond traditional document-based decision management methodologies that risk obsolescence, inconsistency, and duplicative effort, the DADM is constructed with a forward-looking perspective, considering the evolving landscape of systems engineering as outlined in INCOSE Vision 2035, and is now recognized as an INCOSE FuSE product. This adaptability ensures that the model remains relevant and serves as an actionable resource for practitioners aiming for data-driven, collaborative decision-making.

Anticipated Reception and Community Engagement
As we approach the release of the DADM v1.0, we expect a positive reception from the systems engineering community. Through engagement with practitioners and feedback loops, the DADM has been refined and enhanced based on user input and real-world needs. We will also discuss the initiatives taken to promote community adoption, including INCOSE chapter demonstrations and workshop sessions guiding users on how to implement the DADM effectively within their organizations.

Example Implementations
Our presentation will feature compelling case studies demonstrating the DADM in action. Our initial example implementation is being developed by the working group directly, while we crowd-source real-world test implementations from industry and academia. These examples will illustrate how organizations can utilize the DADM to enhance their decision-making processes, and provide a meaningful feedback mechanism for refining the DADM for version 2.0. These implementations will showcase the adaptability of the DADM framework, revealing how its structured approach can be tailored to meet the specific needs of diverse projects while still harnessing the power of data-driven decisions.

Conclusion
DADM v1.0 is more than just a theoretical model; it embodies a commitment to practical decision-making solutions that empower systems engineers to thrive in a rapidly changing environment. Our presentation at INCOSE International Symposium 2025 will articulate our vision for the DADM's role in advancing engineering practices and will invite attendees to engage with us on the future applications of this innovative framework. By fostering a community of practice around the DADM, we aim to build a more collaborative and informed decision-making landscape that resonates with the values of INCOSE Vision 2035. We look forward to sharing insights, gathering feedback, and collaborating with fellow practitioners as we collectively strive towards excellence in systems engineering decision-making.

Presentation#90

Ensuring Safety in AI/LLM Systems for Open-Source Intelligence: An STPA-Guided Approach

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Presented on: Wednesday, 13:30-13:55 EDT

Keywords. Large Language Models (LLMs);System Safety;Artificial Intelligence

Topics. 1.6. Systems Thinking; 11. Information Technology/Telecommunication; 14. Autonomous Systems; 4.6. System Safety; 5.11 Artificial Intelligence, Machine Learning; 6. Defense;

Abstract. Ensuring Safety in AI/LLM Systems for Open-Source Intelligence: An STPA-Guided Approach

Timothy Davison, Matthew M. Walsh and Shing-hon Lau

Introduction

Artificial intelligence (AI) systems, including large language models (LLMs), have immense potential to enhance operational capabilities across various sectors, particularly in mission-critical applications like Open-Source Intelligence (OSINT). However, deploying these systems in real-world settings demands rigorous safety measures to prevent unintended consequences. System Theoretic Process Analysis (STPA), a well-established method for safety assessment in complex systems, provides a systematic framework for identifying potential losses, hazards, and unsafe control actions (UCAs). By applying STPA to LLM systems, this work addresses unique operational risks, ensuring safer and more reliable AI deployment in contexts where precise intelligence is essential for decision-making.

Current LLM Evaluation Process

LLMs (Large Language Models) are traditionally evaluated based on performance metrics like accuracy, fluency, and robustness, with frameworks such as the Holistic Evaluation of Language Models (HELM) providing standardized benchmarks for model performance. However, while HELM and similar frameworks are effective for evaluating models, they are not designed to address the safety needs of applied systems within mission contexts. These frameworks do not comprehensively account for risks associated with operational use, such as the misclassification of critical information or the unintended synthesis of sensitive content. In contrast, System Theoretic Process Analysis (STPA) is explicitly designed to evaluate complex systems within a mission context, enabling a more comprehensive approach to identifying and mitigating operational risks.

As our work demonstrates, STPA provides a complementary approach by focusing on potential losses, hazards, and unsafe control actions (UCAs) that traditional evaluations overlook. By identifying specific safety risks within an LLM-based OSINT system, we address the critical safety requirements essential for high-stakes operational use. Poor or incorrect performance of the LLM, such as misclassifying intelligence or generating misleading content, can have severe ramifications for mission outcomes, including compromised decision-making or operational failure. By extending beyond performance metrics, this approach ensures that

the deployment of LLM systems aligns with mission-critical safety standards.

Framework for Safety-Centric Design

The System Theoretic Process Analysis (STPA) framework offers a structured approach to identifying and mitigating risks in LLM-enabled systems, which traditionally prioritize performance and accuracy over operational safety. STPA provides a systematic process for assessing safety in complex systems by identifying the following key elements:

Losses: These are unacceptable outcomes that the system must avoid, such as the misclassification of mission-critical information or inadvertent release of sensitive content. By defining potential losses early, we can focus on preventing scenarios that compromise operational objectives.

Hazards: Hazards are system-level behaviors or conditions that could result in a loss. For example, an LLM might generate ambiguous or misleading summaries under certain conditions, posing a risk to the accuracy of intelligence assessments.

Unsafe Control Actions (UCAs): UCAs are actions or inactions by system components that may lead to hazardous states. In an LLM-enabled OSINT system, an example of a UCA might be the classifier mislabeling a high-priority topic, resulting in delayed response to critical information.

Risk Scenarios: These are specific situations or sequences of events that may lead to UCAs and ultimately result in a loss. Loss scenarios help system designers anticipate and address conditions under which the system might fail, such as processing content in a language not covered by the LLM's training data.

By mapping the flow of information through each component of the LLM-based classification tool, STPA highlights areas where design modifications can mitigate these risks. This structured approach guides the development of safety fixes tailored to meet the unique requirements of mission-critical applications. Artifacts generated through STPA provide valuable resources for ongoing safety assessments and system refinement:

Metrics Development: UCAs identified during STPA analysis can inform the creation of targeted safety metrics. These metrics enable continuous monitoring and evaluation, ensuring that the system reliably avoids actions leading to hazardous outcomes.

Scenario-Based Safety Testing: Loss scenarios, derived from the STPA process, can be integrated into safety testing. By tracing specific scenarios to these potential losses, system developers can build test cases that validate the system's ability to handle high-risk situations effectively.

Informed Design Decisions: Safety fixes identified through STPA guide design choices that enhance system reliability. These decisions address specific UCAs and risk scenarios, ensuring that the OSINT tool’s architecture incorporates preventive measures, such as implementing synthetic data to improve classifier generalizability or adding preprocessing steps to handle noisy input.

Together, these STPA artifacts support a comprehensive safety strategy that extends beyond initial design to inform continuous safety validation throughout the system’s lifecycle.

In this presentation, we emphasize the iterative application of STPA in an LLM system. Using an LLM to classify and summarize high volumes of social media data, we outline the development and validation of safety fixes addressing issues such as classification accuracy, generation of training data, calibration for confidence, and handling of multilingual input. We propose six safety fixes to enhance system reliability and reduce risks in deployed LLM-based OSINT tools.

Key Metrics and Safety Fixes

Safety fixes for LLM systems require metrics beyond conventional accuracy, especially for applications where specific mission-critical information is at stake. The metrics used in our STPA application process guide targeted interventions, such as adding synthetic data to increase classifier generalizability, implementing a sparse keyword-based classifier to flag critical terms, and using preprocessing to manage noisy inputs. These measures align with the need for safe and effective intelligence classification and flagging in fast-evolving social media data streams.

Operational Example and Demonstration

In collaboration with a large organization, we tested the LLM OSINT system on a real-world dataset involving social media streams on topics including regional conflicts and public health. Through an STPA-driven safety process, the system incorporated design fixes to ensure reliability and robustness in handling varied input types, while avoiding unintended hazards such as information misclassification or unauthorized classification derivation. Results demonstrated the importance of iterative STPA application for identifying and mitigating risks throughout the development lifecycle.

Results and Conclusion

This work validates that STPA, when applied iteratively, can enhance the safety of LLM systems in defense applications by addressing both general system behavior and specific, potentially hazardous scenarios. Audience members will learn how to implement and evaluate safety fixes that extend the reliability of LLM tools across similar high-stakes domains.

Our findings indicate that while performance metrics like accuracy remain important, operational safety is equally vital for defense use cases. STPA artifacts are transferable across LLM systems, making this approach adaptable for a range of LLM-enabled applications beyond OSINT.

Presentation#74

Enterprise Model of the Dynamic Targeting Process Using the Unified Architecture Framework (UAF)

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Presented on: Tuesday, 11:30-12:10 EDT

Keywords. Mission Engineering;Mission Architecture;Mission Threads;Enterprise Modeling;System Threads Analysis;Unified Architecture Framework (UAF)

Topics. 2. Aerospace; 2.1. Business or Mission Analysis; 5.4. Modeling/Simulation/Analysis; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Use of a standardized Reference Model for the Dynamic Targeting process can play a key role in Mission Engineering and associated Capability Effectiveness Analyses where strategic and military intelligence information is used to drive the targeting activities within a military campaign. This presentation will show how standardized architecture views from the Unified Architecture Framework (UAF) were used to capture the essence of this process and of associated enterprise elements such as enterprise goals and objectives, strategic drivers and challenges, mission opportunities and capabilities, organizational roles and responsibilities, etc. This reference model of Dynamic Targeting was developed using the UAF Modeling Language (UAFML) such that it can be used as the foundation for building a particular enterprise model for your situation and then connect this model to related SysML models of the systems that are involved in Mission Threads.

The Dynamic Targeting process is defined in Joint Publication 3-60 in the context of an overarching Joint Targeting Cycle (JTC). Dynamic Targeting is sometimes referred to as a “kill chain” and is comprised of the following steps:
1) FIND (intelligence collection and target detection)
2) FIX (focus sensors, locate targets, identify targets, determine time available)
3) TRACK (prioritize intelligence, surveillance and reconnaissance, maintain track, update time available)
4) TARGET (determine resources, develop options, maintain track, weaponeer, deconflict, risk assessment, decide, etc.)
5) ENGAGE (order engagement, transmit order, monitor and manage, strike)
6) ASSESS (assess damage and target state, report results, reattack recommendations)

Dynamic Targeting occurs in the context of Phase 5 in the overarching Joint Targeting Cycle:
a) Phase 1. Commander’s objectives, targeting guidance, and intent
b) Phase 2. Target development and prioritization
c) Phase 3. Capabilities analysis
d) Phase 4. Commander’s decision and force assignment
e) Phase 5. Mission planning and force execution
f) Phase 6. Combat assessment

When planning and conducting a Mission Engineering (ME) study, it is important to have a complete, correct, and coherent model of the mission architecture. The Unified Architecture Framework (UAF) has been found to be effective for this purpose. The OUSD (R&E) Mission Integration office is exploring how to use the Unified Architecture Framework (UAF) for their ME architectures. This reference model of Dynamic Targeting was developed using the UAF Modeling Language (UAFML) such that this model can be used as a “starter kit” when building mission-specific models for use during an ME analysis effort.

The model contains the following seven UAF Viewpoints: Architecture Management, Strategic, Operational, Personnel, Resources, and Standards.

For the Strategic Viewpoint, the Strategic Motivation (St-Mv) view is based on the strategic elements defined

in JP 3-60 and other related documents. The Drivers, Enterprise Goals, Objectives, Challenges, and Opportunities are derived from these referenced documents. The Strategic Structure (St-Sr) view depicts the Joint Targeting Cycle (JTC) Capabilities, and the Capabilities are traced to Objectives in the Strategic Traceability (St-Tr) view. In addition, the targeting-related constraints are depicted in the Strategic Constraints (St-Ct) view. A set of notional, high-level Joint Targeting strategic requirements are captured in the Requirements Motivation (Rq-Mv) view, where these notional requirements can be replaced by mission-specific requirements when the JTC reference model is instantiated for an actual ME analysis effort. Measures of Success (MOSs) are defined related to the mission objectives of the particular campaign to be modeled.

From the Operational Viewpoint, the JTC Operational Performers are depicted in Operational Structure (Op-Sr) view and JTC Use Cases, i.e., Operational Activities, are depicted in Operational Processes (Op-Pr) view as Mission Threads (MTs) composed of Mission Tasks. Measures of Effectiveness (MOEs) are tied to the relevant Mission Tasks and underlying operational actions. The tracings from Operational Performers and Activities to JTC Capabilities and the tracing of Operational Performers to Activities (using “Is Capable to Perform” relation) are all depicted in Operational Traceability (Op-Tr) views.

JTC Resources defined in the JTC Mission Architecture Model are intentionally kept at a high level. The next level Objective Architecture and Contractors’ Solution Architecture can provide the implementation details that conform to the high-level Resources in the JTC Mission Architecture Model. In the Resource Viewpoint, the JTC Resources and Mission Operations Environmental Conditions are depicted in Resource Structure (Rs-Sr) views as the Mission Engineering Threads (METs). JTC Functions are depicted in the Resources Processes (Rs-Pr) view along with associated Measures of Performance (MOPs). The tracing from JTC resources to Operational Activities and Capabilities, respectively, and from JTC resources to functions are all depicted in Resource Traceability (Rs-Tr) views.

The Personnel views are not intended to model all aspects of the organizations involved in the mission but will instead only capture the JTC related Posts and their corresponding Competences in the Personnel Structure (Ps-Sr) views. Mapping of personnel Posts to JTC Capabilities is depicted in the Personnel Traceability (Ps-Tr) view. The Standards views captures the relevant standards for JTC phases and related DT steps. The overarching Architecture Management views captured JTC Mission Architecture principles in Architecture Management Motivation (Am-Mv) view and UAF Grid and Glossary in Architecture Management Information (Am-If) views. Referenced documents, their relations and UAF Workflow are captured as fit-for-purpose views.

The primary use of this Mission Architecture Model is to serve as the foundation for conducting a Mission Engineering study in accordance with the ME process defined in the ME Guide. This model has been used to validate an existing set of mission threads and to help enhance the mission model for a space-based sensing and targeting architecture development effort. This Dynamic Targeting Reference Architecture can be used in a general manner to help kickstart a mission engineering study that involves targeting activities within an overarching military campaign analysis.

Presentation#359

Exploration of MBSE Methodologies for Modeling Pre-Existing Systems

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Presented on: Wednesday, 06:00-06:25 EDT

Keywords. MBSE;Meet-in-the-Middle;as-is;to-be

Topics. 2. Aerospace; 5.3. MBSE; 5.5. Processes;

Abstract. As systems, and systems of systems, solve increasingly intricate and interdisciplinary problems, the document-based approach to systems engineering has regressed from an organized regulatory process to an incoherent labyrinth of document trails and long indexes that diminish the efficiency and productivity of engineering project team members. The model-based approach to systems engineering, MBSE, is an emerging discipline specializing in reforming the document-based approach by easing traceability and generating descriptive visuals in a single, methodical digital format. Currently, MBSE is uniquely implemented to generate systems top-down, with no physical representation of the final product; contrarily, experts in industry typically have a functional system which needs to be upgraded or altered. The purpose of this research project is to establish a method that can be used to adapt the MagicGrid framework for use in modeling preexisting systems.

As a result of lost productivity on preceding projects, many industries have already moved to requiring MBSE, especially as an early verification method. From the DoDI 5000.02 enclosure 3, section 9, “The Program Manager will integrate modeling and simulation activities into program planning and engineering efforts.” The Department of Defense has been one of the first industries to quickly adapt to the latest in systems engineering, holding the organization, flexibility, and robustness in high regard. Furthermore, MBSE is capable of handling intricate webs of systems integration. Industry Today shares it’s thoughts on using MBSE in the automotive industry, “Incorporating MBSE… can help manage the inherent complexity of building smart, autonomous vehicles” and “can facilitate multi-domain integration to enable disparate teams… to effectively collaborate.”

Our research resulted in the Modified Meet-in-the-Middle Methodology, M5. The M5 process facilitates the transition from an as-is product to a to-be evolution by creating a semi-formal, descriptive, verification model. The M5 framework consists of four steps. First, creating a conceptual model of the system by compiling its original needs and constraints while verifying the concept with the physical product. Second, pulling property data and documentation from the physical product to develop a technical architecture focused on the subsystems and components which will be replaced. Third, applying verification and trade techniques within the model to compose the to-be technical solution domain. Fourth, using the Magic Model to generate project deliverables.

The presentation will focus on guiding the audience through the process of developing a technical solution model. The first step is very similar to modern top-down modeling. The conceptual domain must always be completed first, as it organizes the structure of the system and team during the beginning stages of the process. The first step includes gathering the necessary documentation, digitalizing the preliminary data from the physical product (requirements, safety documentation, design concepts, etc.), developing system architecture, and coordinating team comprehension. Next, the physical product is used to populate the current conceptual architecture. The focus of the M5 technique is to efficiently develop an as-is solution that only considers the system architecture related to the components undergoing change. The conceptual domain makes this possible. By using the conceptual model as a framework, only the blocks, interfaces, exchange items, and activities which are directly related to the transient are modeled at the physical level. The third step introduces the technical solution domain, which is used for configuration and parametric analysis. All alternative components and related requirements are modeled in the technical solution packages. In these packages the current physical parts are replaced by their alternatives and the model is simulated to verify the new solution. When the best alternative is determined the to-be design is modeled and shipped in the to-be technical solution domain. Finally, the required early verification and validation documents are generated by the model.

By following M5 systems teams will foresee flaws more reliably, reducing the costs of failure further along the engineering V. The primary goal of our research was to provide a framework which gives systems engineering team’s direction when approaching the increasingly common situation of developing a preexisting model. The current method of teaching systems engineering top-down is too rigid, it fails to adequately prepare future systems engineers for the problems they will be facing during their careers. Our preliminary research found little to no research or methods that attempt to diagnose this issue.

Presentation#77

From Standards to Systems: Insights on Digital Transformation and MBSE Integration

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Presented on: Thursday, 13:00-13:25 EDT

Keywords. Standards;Digital standards;SySML;Model-based systems engineering;Digital transformation;MBSE;Digital integration;Ontology

Topics. 1.6. Systems Thinking; 2. Aerospace; 2.5. System Integration; 20. Industry 4.0 & Society 5.0; 5.5. Processes; 6. Defense;

Abstract. SAE International has heard from many customers that they want some standards in the form of MBSE models. But what does this really mean? SAE decided to find out by interviewing 20+ systems engineers from over 15 different organizations, ranging from industry to government to academic institutions. The findings from this research are presented in this session:
• If the model fits, you must…model; but if not, don't force it: Interestingly, many of the interviewees do not want a model of many industry standards. SysML may be overcomplicating the need for some standards. However, it depends on the standard. This session presents the types of standards that are the best fit for MBSE models and why.
• Models are purpose-built, but data is reusable: For many types of standards, systems engineers simply want access to the data. This may be in the form of a requirements list, or it may be access to data to support parametric functions, equations, or analyses, or it may be simply data tables. Ontology will be critical so that standards can be provided in a data schema that is accompanied by a "decoder ring" that defines how the data is defined. This session outlines how standards that are not a good fit for MBSE models can be converted into digital forms that can be leveraged by systems engineers.
• Apply software engineering concepts to standards: A fundamental rule in software engineering is DRY (don't repeat yourself). There are many subsections in standards that are repeated in several, sometimes hundreds, of standards. Thinking of standards as being built from a collection of reusable objects will enable those to be converted to reusable digital objects. Many standards could be converted to a wrapper that calls multiple digital objects, moving to a world where standards can be executable and not just "read."
• It's all about context, and it's got to be accurate: Using standards data without context is risky. Standards development organizations must ensure that that context is not lost in the creation of digital forms of standards, and that any digital content created from a standard is as accurate as the original standard. It is critical for digital versions of standards to be an authoritative source in the same way that standards are today when provided in PDF. This presentation provides guidance on how to ensure context and accuracy is maintained as standards are converted into digital forms.
SAE is committed to supporting our customers' digital transformation initiatives by offering standards in digital forms. These learnings are being shared so that other organizations can benefit from our research in this area as we all move to implement digital ecosystems that support more efficient business process.

Presentation#289

From Systems Engineering to Engineering Systems: The Power of Framing

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Presented on: Thursday, 09:00-09:40 EDT

Keywords. Systems engineering;Engineering systems;Context

Topics. 1.6. Systems Thinking; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. A decade ago, a great debate arose within the systems community. Is the practice "systems engineering" as it has been known for years or should it be termed "engineering systems"? What many dismiss as a somewhat pointless dialog focused on semantic nuances, in fact, highlights two different and important frames of reference. Systems engineering is the transdisciplinary and integrative contribution we make within the greater activity of engineering systems which delivers capabilities to address individual, organizational, or societal needs. Used properly, these frames provide important insights into our systems engineering methods, capability development, and transformation.

The frame of systems engineering bounds the principles, processes, methods, and tools that enable our practice. It defines approaches required to "enable the successful realization, use, and retirement of engineered systems, using systems principles and concepts, and scientific, technological, and management methods" (INCOSE definition of systems engineering). This frame enables the practitioner to acquire and apply the requisite knowledge, skills, and behaviors. However, as McChrystal states in Team of Teams, "one cannot understand a part of a system without at least a rudimentary understanding of the whole." Applying the frame of engineering systems establishes the greater context within which we practice systems engineering. Appreciating this context, inputs, outputs, and the collaboration surrounding systems engineering equips us to better understand and apply our practice as we seek to effectively transform needs into architecture delivering the desired business value.

The practice (and practitioners) of systems engineering is never static. As individuals, we grow throughout our careers applying our personal experience and new external insights to advance our work. As a discipline, we integrate insights from across the community as well as incorporate new approaches and technologies from beyond the discipline to advance the practice. In doing so, the frame of systems engineering once again provides a useful boundary allowing us to better focus inward on our concerns, methods, and techniques. Tools such as Helix and the INCOSE Systems Engineering Competency Framework empower workforce development. But systems engineering does not exist in a vacuum. Our organizations provide a greater capability, and the context for this capability is best viewed through the frame of engineering systems where we define the workflows and interactions by which systems engineering contributes to the greater mission. Those seeking to advance their systems engineering capabilities or engineer the enabling system must apply the frame of engineering systems to see the big picture.

As individuals and organizations, we grapple with the digital transformation using unprecedented computing power and storage to better deliver in today's world. From the frame of systems engineering, this transformation is realized through model-based systems engineering (MBSE) as we apply models to elicit, analyze, manage, and communicate the information necessary to transform needs into architecture. Though inward looking to the practice of systems engineering, MBSE done well in the greater context underpins the larger concepts of digital thread and digital engineering, both critical enablers in the digital transformation of engineering system.

Helix identified the paradoxical mindset and ability to simultaneously demonstrate big picture thinking and attention to detail as an important characteristic of effective systems engineers. Applying this to our discipline requires that we intentionally leverage the power of framing – systems engineering looking inward and engineering systems looking outwards. Looking inwards enables us to understand, apply, and advance the why, how, and what of our practice delivering the results demanded of us as systems engineers. Looking outward empowers us with the necessary context to make good decisions on the implementation and evolution of our practice. This presentation explores both frames and the insights they yield as we strive to better understand value, execute practices, and advance approaches in successfully delivering engineered systems.

Presentation#194

Generalizing the Systems Engineering Vee: Introducing Time as a Third Dimension and Refining the Role of Analysis Tools

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

Keywords. Systems Engineering;Vee Model;Analysis;Modeling;Simulation;Verification;Validation

Topics. 1. Academia (curricula, course life cycle, etc.); 1.5. Systems Science; 2.4. System Architecture/Design Definition; 2.6. Verification/Validation; 5.4. Modeling/Simulation/Analysis; 5.5. Processes; 9. Enterprise SE (organization, policies, knowledge, etc.); Other domain;

Abstract. In contemporary discussions at INCOSE and in industry, terms like “left and right side of the Systems Engineering (SE) Vee” and concepts like “shift left” are often used but frequently misinterpreted. These misunderstandings reduce the SE Vee to a simple timeline, ignoring the recursive and iterative character of system and product development and inaccurately categorizing Modeling & Simulation (M&S) tools solely as "design tools" confined to the left side of the Vee, traditionally associated with system design. Conversely, the right side is typically attributed to Integration and Verification & Validation (V&V).

This presentation emphasizes the SE Vee as a logical framework where time is an additional dimension. It demonstrates how specific development models, such as the waterfall (a misinterpreted Vee as time) and the spiral (iterations across multiple Vees), arise as distinct views of this framework. It also highlights that most M&S approaches and tools are primarily used for V&V on the Vee's right side, with only limited application as design tools on the left. Early-stage V&V analyses tend to be implicit and informal, transitioning to explicit, formal analyses or real-world tests in later stages.

The presentation is structured into two main sections:

First, the logical structure of the Vee is introduced with three generic levels—system context, system of interest, and system element—illustrating its recursive application across system hierarchies. A temporal view of the framework shows how multiple Vees over time and hierarchy levels represent system snapshots or baselines, such as at project milestones or integration stages. Key concepts like Mission Engineering, Systems-of-Systems, Operational Analysis, Agile practices, and M&S-based Digital Twins are contextualized within these logical and temporal views. Alternative models, such as Boeing's Dual-Vee, are briefly compared to the proposed interpretation.

Second, the roles of M&S tools are categorized across the Vee’s three levels. Most M&S tools are classified as predictive analysis tools for system or system element V&V, ranging from formal verification to informal analyses and trade studies. Exceptions, such as architecture modelers, CAD tools, and certain software design tools, are identified as prescriptive authoring/design tools. The distinction between V&V from both SE and M&S perspectives is clarified.

The presentation concludes by proposing a unified framework that reconciles these concepts, aligning with recent literature and industrial standards, and providing clearer guidance for practitioners.

Presentation#262

How Much MOSA Does Your System Need? Hitting the Sweet Spot Between MOSA Ambition and Lifecycle Costs

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Presented on: Tuesday, 16:30-16:55 EDT

Keywords. MOSA;lifecycle costs;modularity;economic tradeoffs

Topics. 2. Aerospace; 2.1. Business or Mission Analysis; 2.4. System Architecture/Design Definition; 4.2. Life-Cycle Costing and/or Economic Evaluation; 5.5. Processes; 6. Defense;

Abstract. Two years ago, we introduced a process for evaluating the extent to which an architecture adheres to Modular Open System Approach (MOSA), which is now a critical factor in the development of major defense system architectures. This process also generated artifacts that program offices can use to justify key architectural decisions and demonstrate compliance with MOSA principles. Focusing the evaluation on architecture requirements—rather than system designs or products—provided the additional advantage of characterizing MOSA implementation early during the requirements development phase. Hence, we evolved a systematic and traceable evaluation process based on defined evaluable criteria. The process leverages a digital engineering approach, enabling the establishment of traceability relationships within the authoritative source of truth (model), which can be queried and analyzed to validate whether an architecture and its resultant system incorporate modularity and openness.

However, the initial process did not fully address the economic tradeoffs inherent in MOSA implementation.

Hardware modularity can vary significantly in ambition. For example, creating an architecture that allows for truly “plug-and-play” hardware modules, sourced from the open market and installable in a live system, would require substantial investment. Conversely, an architecture designed for easier modification at a service depot with moderate effort would demand far less investment.

Similarly, software modularity exhibits varying degrees of ambition. At one extreme is the robust ecosystem exemplified by modern smartphone application stores, which allow countless companies to develop interoperable add-ons, installable on-the-fly. Developing such ecosystems entails significant investment. In contrast, initiatives like the “Carrier Grade Linux” consortium from the early 2000s demonstrate that more modest objectives—achieving “good enough portability” through agile methodologies—can be achieved with reduced costs and accelerated timelines.

This presentation will explore the economic tradeoffs across different levels of hardware and software modularity. An enhanced assessment framework will be introduced, integrating the economics of modularity, to help development teams align the level of MOSA ambition with the specific use cases and needs of system stakeholders.

Presentation#293

Insights from the Field: Applying the Capability & Maturity Assessment Framework

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Presented on: Thursday, 14:00-14:25 EDT

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;Digital Engineering Transformation;DE Transformation;Organizational Transformation

Topics. 22. Social/Sociotechnical and Economic Systems; 3.6. Measurement and Metrics; 5.3. MBSE; 5.5. Processes; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. The U.S. Department of Defense is driving the adoption of digital engineering (DE) through DoD Instruction 5000.97, issued on December 21, 2023. This directive represents a significant shift towards model-based approaches in system acquisition, development, and sustainment. However, many organizations face challenges in implementing this directive; the lack of a clear starting point, unclear direction, and incomplete maturity frameworks failing to comprehensively address strategy, processes, and tooling requirements. GTRI's DE Capability and Maturity Assessment Framework (C-MAF) synthesizes information from across existing guidance into a comprehensive evaluation tool that addresses all of these concerns.

GTRI presented the C-MAF to INCOSE last year and has since applied it to organizations at various levels of the US Armed Forces. While applying the framework, GTRI encountered challenges and collected lessons learned. This presentation describes how GTRI guided 3 different DoD organizations through using the C-MAF to evaluate their current digital engineering maturity and establish short- and long-term goals.
The organizations differ in size and type, as well as in their responsibilities in the systems engineering life cycle. This variety in organization size, type, and focus provided more feedback on the C-MAF than would have been otherwise possible. The presentation will characterize the organizations, describe similarities and differences in the application of the C-MAF, and present GTRI's lessons learned.
Organization A is large and has several suborganizations. It performs activities across the life cycle, including concept and capability requirement generation, acquisition or development, and all the way to sustainment and disposal. Org A manages multiple programs.

Organization B is relatively small; a single integrated product team focused on an acquisition effort.

Organization C is mid-sized, included multiple branches, and is responsible primarily for capability requirements and other work performed in the concept stage.
Overall, the descriptions of maturity levels were well-understood, with minimal overlap in criteria. The organizations found the normalized maturity levels valuable for maintaining focus and clarity. The framework effectively reduced concerns about blind spots by clearly scoping and planning necessary work for digital transformations.

Regardless of organizations' scope and size, each faced similar challenges when performing the evaluations. For example, it can be difficult to establish the boundaries for evaluation. Some organizations considered

suppliers as part of the organization when determining maturity levels. One organization was concerned that the C-MAF might evolve into yet another set of target metrics for which the organization would be held accountable. Key lessons from digital transformation efforts highlight the importance of trust throughout the organizational hierarchy for successful implementation. Establishing realistic short- and long-term maturity goals is essential to guide progress. The C-MAF is designed to avoid analysis paralysis and facilitate movement in the right direction, while also being mindful of Goodhart's Law. However, a significant challenge remains in integrating evaluation results with existing work-planning and tracking software. These insights underscore the need for a balanced approach that fosters progress while avoiding the pitfalls of rigid metric-driven management.

Examining how different organizations approached and applied the framework revealed nuanced insights. Most organizations implemented the framework with minimal customization, and many later reflected that a more tailored approach would have better served their unique organizational needs and challenges. When choosing digital engineering maturity goals, one organization selected mostly 3s (out of a range of zero to four) while another had a mix of mostly 3s and 4s. Although the maturity levels follow a similar pattern which make evaluations relatively simple to perform, GTRI observed that the level of effort required to increase from one level to another (from two to three, for instance) can vary quite a bit between the criteria. Understanding the level of effort associated with maturing various criteria is key to establishing goal maturity levels, especially when using the C-MAF tactically to plan the next increment of work. This raised the question of whether a consideration of level of effort should be built into the framework. GTRI also reminded organizations that it is OK to choose targets that turn out to be difficult to implement in a single increment and revise those targets during the next evaluation iteration.
GTRI approached several entities about adopting the C-MAF, but some declined based on their advanced stage in digital transformation. This experience highlighted that the utility of tools like C-MAF diminishes as organizations progress further in their digital transformation journey. GTRI compared this to revisiting an earlier lifecycle stage to complete a systems engineering artifact, even when it is unnecessary and the product development is already successful.

During its first year of use, the C-MAF was generally well-received and helped some organizations establish digital goals related to their needs. Feedback and lessons learned from its application will continue to shape the framework itself as well as guidance for its application.

Presentation#68

Integration of Agile and Systems Engineering to Deliver Safety-Critical Cyber-Physical Systems

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Presented on: Wednesday, 14:00-14:25 EDT

Keywords. Agile;Systems Engineering;MBSE;Digital Twin

Topics. 2. Aerospace; 20. Industry 4.0 & Society 5.0; 5.1. Agile Systems Engineering; 5.2. Lean Systems Engineering; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 6. Defense;

Abstract. The development of safety-critical cyber-physical systems (CPS), such as satellites, autonomous vehicles, and medical devices, presents unique challenges due to stringent safety, regulatory, and performance requirements. Traditional systems engineering methodologies, often rooted in Waterfall approaches, are evolving Agile concepts like iterative development, Minimum Viable Products (MVPs), and continuous integration to improve adaptability, accelerate delivery, and enhance system quality. This presentation explores the integration of Agile principles with systems engineering to address the complexities of developing large-scale, safety-critical CPS.
The presentation will focus on three key areas: the synergy between Agile and systems engineering, adaptations required for safety and compliance, and the measurable outcomes of this integration. Drawing on real-world examples, including satellite development programs, we will demonstrate how iterative development cycles, incremental verification, and continuous stakeholder engagement can be harmonized with rigorous safety analysis, traceability, and documentation practices.
The audience will gain:
1 A framework for applying Agile within systems engineering processes while adhering to safety-critical standards.
2 Insights into overcoming common challenges such as regulatory compliance, managing system complexity, and maintaining alignment across multidisciplinary teams.
3 Best practices and lessons learned from implementing Agile in industries such as aerospace, automotive, and healthcare.

This presentation is grounded in extensive experience in systems engineering, Agile practices, and safety-critical system development. Leveraging their backgrounds as Systems Integrators performing systems engineering, software development, and digital engineering, we provide actionable strategies to bridge the gap between flexibility and rigor.
Attendees will leave equipped with knowledge to initiate or enhance the integration of Agile and systems engineering in their organizations, delivering safety-critical systems faster, with higher reliability and adaptability.

Presentation#369

Integration of System Data Requirements in Stuttering-Aware Speech Recognition Systems

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

Keywords. System requirements;Artificial Intelligence;MBSE;System Engineering Models;Automatic Speech Recognition;Stuttering

Topics. 1. Academia (curricula, course life cycle, etc.); 14. Autonomous Systems; 18. Service Systems; 2.3. Needs and Requirements Definition; 2.4. System Architecture/Design Definition; 2.5. System Integration; 2.6. Verification/Validation; 22. Social/Sociotechnical and Economic Systems; 4. Biomed/Healthcare/Social Services; 4.1. Human-Systems Integration; 5.10. Diversity (cultural boundaries, diverse engineering teams, training underserved groups, etc.); 5.11 Artificial Intelligence, Machine Learning; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis;

Abstract. Purpose: This study investigates a formalized, but refined, Systems Engineering approach to data requirements for the automatic recognition of stuttered speech in AI-enabled systems (SE4AI).
Focus: Stuttering is speech that is characterized by the repetition or prolongation of sounds, syllables, words, and hesitation or pauses that disrupt the rhythmic flow of speech. People who stutter (PWS) want to use artificially intelligent automatic speech recognition (AI-ASR) systems but are frequently misunderstood and cutoff because AI-ASR models are optimized on data from people who do not stutter. A primary reason for the deficiency in current AI-ASR models is the lack of large, diverse, and specified data on stuttered speech. To remedy this problem, this study proposes a refined Systems Engineering (SE) approach to data specification and modeling of stuttered speech for AI-ASR. While traditional SE lifecycle and principles have been successful in building heretofore complex systems,
current AI-enabled systems have introduced new paradigms that do not fit SE traditions. Using an ad-hoc approach, AI-ASR systems are capable of sophisticated behavior that allow them to learn and evolve during operations, making their prior specification difficult or impossible. Despite the difficulty, this study advocates a refined SE approach in establishing design integrity, artifacts, and configuration
baselines for such systems.
Methods: This study proposes to assemble the largest dataset of diverse stuttering speech data to date. The dataset assembly and specification will be done in a predetermined way, using a systemic approach to planning, analysis, design, implementation, verification, validation, deployment, and maintenance.
Firstly, data requirements (data type, size, nature, quality, distribution, complexity, annotation, classification) will be elicited from all relevant stakeholders (people who stutter, researchers, foundations, data banks, etc.). The elicited data will be analyzed and prioritized according to an agreed-upon scheme. Next, a Data Baseline Architecture composed of a Requirements Traceability Matrix,
Verification and Validation Cross-Reference Matrices, and Systems Engineering Data models (conceptual data model, logical data model, physical data models) will be created as configuration baselines within an MBSE environment to manage and maintain the data. Complementing the collection and labeling of the dataset, this study proposes the use of Systems Engineering modeling approaches to create models
for the specific classes of stuttering, including repetition, prolongation, hesitation, and pauses. It concludes with examples of verified and validated AI-enabled ASR systems that correctly recognize and transcribe stuttered speech because of this approach.
Results: The benefits include well-formulated, complete, and stable data requirements for the automatic identification and classification of stuttered speech using AI-ASR models and devices; a centrally managed and maintained data repository that provides an enduring, authoritative source of truth so that stakeholders have current, authoritative, and consistent information for use over the lifecycle; open and better collaboration in the research community.
Implications/Conclusion: The systematic specification of data requirements and systems engineering models for stuttered speech when deployed in AI-enabled ASR systems is poised to improve the recognition and transcription of stuttered speech and help reclassify low-confidence “normal speech” ASR outputs into high-confidence “stuttering” classifications.

Presentation#191

MBSE Collaboration with SysML 2.0: A Pre Release Investigation from A&D PLM Action Group

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Presented on: Thursday, 10:45-11:15 EDT

Keywords. PLM;MBSE;SysML;SysML v2;KerML;Interoperability

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

Abstract. In 2024 the Aerospace and Defence (A&D) PLM Action Group’s MBSE Working Group conducted a comprehensive investigation to explore the potential of Systems Modeling Language (SysML) 2.0 as a potential mechanism to promote greater MBSE collaboration across the Aerospace and Defence (A&D) industry. This investigation aimed to assess how significantly SysML 2.0 advances the capability for greater and more efficient collaboration of models produced in industry today - crucially determining whether these advancements are likely to foster mass industry adoption of SysML 2.0.

The A&D Product Lifecycle Management (PLM) Action Group’s Model-Based Systems Engineering (MBSE) Working Group, comprising leading aerospace and defence companies, spearheaded this investigation. Dedicated to advancing MBSE practices across the industry, the group conducts annual collaborative investigations into key topics affecting model based systems engineering deployment and use.

The Phase 5 investigation involved thorough analyses of the SysML 2.0 specification, pilot implementations and theoretical collaborative experimentations. SysML 2.0 has been promoted as a step change towards improved collaboration - compared with SysML 1.x. Our priority was in validating how far the needle has moved - and crucially if it is enough to foresee widespread adoption - towards enabling greater and more efficient collaboration of systems architecture models across industry.

This year at INCOSE IS 2025 we will delve into the key findings from our Phase 5 report. We will discuss the implications of SysML 2.0 adoption for the A&D industry, emphasizing both opportunities and challenges. We invite symposium attendees and the broader systems engineering community to provide direct feedback on our Phase 5 investigation. Your insights and experiences are invaluable in shaping our future work and ensuring that our efforts align with the industry’s needs and priorities. Additionally, we will introduce the topic of our Phase 6 investigation that launched in early 2025.

Presentation#349

Methodology for Evaluating a Digital Architecture in Terms of Systems Engineering Lifecycle Using Variables in the Context of Digital Twin

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Presented on: Wednesday, 14:30-14:55 EDT

Keywords. Digital Architecture (DA);Model Based Systems Engineering;Digital Twin (DT);Pearson Correlation Coefficient (r);Linear programming;Innovative methodology;Quantitative assessment;Heat Map

Topics. 3.6. Measurement and Metrics; 5.3. MBSE; 5.7. Software-Intensive Systems;

Abstract. Contracts in the aerospace and defense industries are becoming increasingly demanding, placing significant pressure on organizations to operate more efficiently and effectively in order to secure them. These contracts often come with rigorous requirements for innovation, reliability, and cost-effectiveness, pushing organizations to adopt advanced strategies to stay competitive. Among the concepts currently in use are Digital Architecture (DA) to support the lifecycle of the system using approaches such as Model Based Systems Engineering (MBSE), and Digital Twin (DT) which collectively aim to streamline processes, improve design accuracy, and enhance product quality. These approaches enable organizations to deliver products that not only meet customer requirements but also increase competitiveness. However, evaluation to justify the investment and use of these methodologies to ensure customer satisfactions and gain market share are required.
Concepts like Digital Architecture (DA) and Digital Twin (DT), when combined with MBSE methods, have been regarded by organizations as approaches to gain competitiveness and efficiency in delivering services and products.

DA provides a blueprint for structuring and managing applications that support the development and management of the system, while DT creates virtual replicas of physical systems to simulate, predict, and optimize performance so an infrastructure needs to be developed. MBSE complements these by providing a systematic approach to managing system requirements, design, and analysis. Together, these methodologies form a powerful ecosystem of applications and methodologies to support the complexities of modern systems engineering and create competitive advantages. Despite their use and potential there is a minimal quantitative evaluation based on performance to support the lifecycle of the system and the context of variables that have direct input in the structure and behavior of the ecosystem.
This presentation introduces an innovative methodology designed to evaluate a digital architecture in the context of the system lifecycle. By focusing on variables related to Digital Twin, quality assurance, and technology assessment, this approach provides a structured framework for assessing how well a digital architecture supports the various phases of a system’s lifecycle. The system lifecycle encompasses needs analysis, concept exploration, concept definition, advance development, engineering design, and integration and evaluation. Understanding how a digital architecture contributes to these phases is crucial for maximizing its potential benefits.
The methodology utilizes linear programming, a mathematical optimization technique, to quantitatively assess the contributions of digital architecture. Linear programming is particularly well-suited for this purpose as it can handle complex relationships among multiple variables, providing a clear pathway to optimization. This quantitative assessment is further enhanced through the use of a correlation matrix and the Pearson Correlation Coefficient (r). These tools help to identify and measure the strength of relationships between key variables, offering deeper insights into how they interact and influence overall system performance.
To make the findings accessible and actionable, the methodology incorporates a heat map, which provides a visually intuitive interpretation of the data. The heat map enables stakeholders to quickly identify areas of strength and weakness within the digital architecture, facilitating informed decision-making and prioritization. By combining linear programming, statistical analysis, and visual tools, this approach offers a comprehensive solution for evaluating digital architectures in a way that is both rigorous and user-friendly. This methodology not only supports ongoing research and evaluation but also provides a practical framework for organizations striving to enhance productivity and efficiency in an increasingly competitive landscape.

Presentation#299

Model Based Test and Evaluation Master Plan: Applying Digital Transformation to T&E Strategy for Major Acquisition Programs

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Presented on: Tuesday, 14:00-14:25 EDT

Keywords. Model Based Systems Engineering;MBSE;Model Based Test Engineering;MBTE;Test and Evaluation;T&E;Test and Evaluation Master Plan;TEMP;Digital Transformation;IDSK

Topics. 2. Aerospace; 2.6. Verification/Validation; 3.7. Project Planning, Project Assessment, and/or Project Control; 5.3. MBSE; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. The US Department of Defense is undergoing a digital transformation in the way it accomplishes major acquisition programs. This involves, in part, an adoption Model Based Systems Engineering (MBSE) in lieu of programmatic, technical, and requirements documents and developing a “digital thread” to link those models cohesively together. Within the traditional framework, a Test and Evaluation Master Plan (TEMP) was a high-level programmatic document which outlined the overall strategy for testing of the new acquisition. Although it had specified points to be updated throughout a program’s execution, it remained a static artifact and was not generally informed or up to date with program test execution data or results. Presented here is a modeling approach based on MBSE principles that captures the essential data contained in a TEMP, creates new interconnections and relationships linking the TEMP data together internally, utilizes digital artifacts produced from other functional areas within the acquisition program, incorporates the Integrated Decision Support Key (IDSK) framework, and is dynamically informed by detailed test plan models. As a result, the Model Based TEMP greatly increases the value and insights available to stakeholders within the acquisition and Test and Evaluation enterprises and allows for data mining and dashboarding of relevant data for executive level leadership. Application and lessons learned are provided from applying this modeling approach on a major acquisition program for the Department of the Air Force.

Presentation#34

Observations in Establishing AI Practices in Highly Regulated Environments

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Presented on: Monday, 13:30-14:10 EDT

Keywords. Artificial Intelligence;DevSecOps;Agile;Machine Learning

Topics. 2.3. Needs and Requirements Definition; 5.11 Artificial Intelligence, Machine Learning; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Observations in Establishing AI Practices in Highly Regulated Environments
Dr. Jose Andre Morales, Douglas J. Reynolds, Matthew Walsh, Joseph Yankel, Hasan Yasar
For the last several years, the domain of highly regulated environments [1] (HREs) has advanced in the development, deployment, and real-world usage of AI in their suite of capabilities. In this presentation, we detail observations we made of obstacles that hamper these activities and their impacts to efforts for including AI in HREs. We also provide descriptions of observed implemented practices and recommendations for potential solutions for avoiding obstacles to future AI-establishment efforts. Our observations come from a long-term engagement with a large and well-funded AI incubator housed in an HRE and tasked with establishing organization-wide AI practices. Our observations impact the following categories of work:

• Model development
• Model deployment
• Post-deployment model sustainment
• AI-relevant security requirements

The above categories, and the associated observations we present, impact every major phase of the AI lifecycle from initial development to post-real-world deployment. The observations are as follows:

• There is no standard process and environment for AI model development. All observed project teams employed their own method of development with their own toolsets and development environment. This disconnect between teams, in some cases, resulted from an HRE requirement for isolation of technical boundaries between projects for a diverse set of reasons. In other cases, the absence of a defined approach led to teams selecting tools, creating environments, and implementing development practices based on their efforts to recognize community best practices and tailoring them to what was best for the project team at that time.

• Teams are hindered when acquiring desired data sets. Teams acquired and easily used the desired data sets only in a few observed projects. Most of the projects, on the other hand, often experienced difficulties in one or more of the following:

o lack of motivation to share by data owners
o HRE-imposed distribution restrictions and requirements
o extensive paperwork and approvals as pre-requisites on behalf of an HRE

Another post-data acquisition obstacle we often observed involved how teams dealt with the format and labeling of acquired data. In almost all cases, data was either not labeled or it contained labels that were not relevant to the project. This resulted in extra time and effort to employ personnel to interpret and correctly label desired elements across several individual pieces of data. In some

cases, useful, labeled data was excluded from sharing due to HRE restrictions.

• Model testing was narrowly focused. Project teams exceled in creating appropriate test sets to validate correct functionality of a trained model. The testing almost always confirmed the presence of desired elements in each article of data. The test sets were populated with true positive samples, leaving out false positives and true and false negatives.

• HRE security guidelines lacked focus on AI-relevant requirements. The security requirements put forth for adherence covered categories typically seen in HREs including source code flaws, vulnerabilities, malware, and allowed files. Satisfaction is typically shown with a body of evidence including a malware scan, static code analysis, vulnerability scan, and list of all files present in a software bill of evidence (SBOM) container. The guidelines don't address the following two AI-centric components: (1) the data used for model training and testing, and (2) the performance of the trained model once deployed into the real world. This absence facilitates compromise of the data and prevents evaluating for data poisoning and purposeful training deficiencies resulting in model drift far sooner than anticipated.

• Trained model packaging lacked a standard. Each project packaged a trained model for real world deployment in their own subjective way. In most cases, the deployable artifact that housed the model was a container. The container's configuration, operating system, and container-external interface were different and tailored to the real-world environment in which this model would be in use.

• There is no evidence of implementing the tracking of a post-real-world deployed model's performance. Every project we observed focused on training a model to fulfill a particular need. Then, the model was packaged and deployed into its target, real-world environment to commence execution with real-world data. In the process, we did not observe efforts to include metrics gathered within the container to measure model performance. Further, a process to observe the mode's performance was not implemented. This lack makes it difficult to detect drift on a timely basis.

• There is no plan to retrain or update deployed models. Once deployed into the real world, models were left running with no process to collect the real-world data analyzed by the model for retraining or other purposes. Further, there was no system in place to replace the currently active model or to retrain the existing model. If a determination was made to modify or replace the currently active model, the mechanics to do so were not defined.

These observations affect each phase of the AI lifecycle and have obvious negative impacts on model creation and long-term usage. In this presentation, we detail several recommendations, and describe tailored implementation for each AI use case, to assist in alleviating and avoiding the aforementioned deficiencies. The recommendations include establishing the following:

• development, testing, and deployment environment configurations should be standardized across the enterprise, use automated DevSecOps deployments and processes, and used by all projects
• requirements gathering to attempt automated collection and processing of desired labeled data
• guidelines on what to include in model packaging to sustain both long-term monitoring and effective model retraining, updates, and replacements.

In conclusion, this presentation describes observations of hindrances to AI development, deployment and sustainment observed within an HRE. We outline each observation with potential impacts to the AI lifecycle and offer guidance on how to avoid or mitigate them. The observations we highlight reveal gap areas for others in the community to address by proposing implementable solutions.

[1] https://dl.acm.org/doi/10.1145/3234152.3234188

Presentation#365

Optimizing System Design: Integrating DfT and DfM through Model-Based Engineering Strategies

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Keywords. DfM;DfT;Co-Simulation;System Design;SysML;Modelica

Topics. 2. Aerospace; 2.2. Manufacturing Systems and Operational Aspects; 2.4. System Architecture/Design Definition; 3. Automotive; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 6. Defense; Other domain;

Abstract. Design for X (DfX) methodologies, including Design for Testability (DfT) and Design for Manufacturing (DfM), aim to optimize system performance by incorporating specific objectives—such as testability and manufacturability—into the early design phases. Leveraging a Model-Based Engineering (MBE) approaches, this integrated methodology enables the consideration of multiple aspects of system development by incorporating these objectives into system models. By utilizing SysML for system representation and Modelica for physics-based modeling, the approach allows engineers to assess testability, manufacturability, and other key system attributes early in the design process.

In the context of DfT, the proposed methodology enhances a system's design by embedding testability features and requirements, ensuring that testing, operations, maintenance, and support functions are efficiently captured in the system model. While testability in software has undergone extensive study, often driven by error occurrences (induced error), complex safety-critical systems primarily comprised of highly coupled hardware call for a different approach. The methodology includes failure mode and effect analysis (FMEA) artifacts that allow addressing the current constraints in the identification of multiple failures, and the roll-up of these failures to other elements at the same level or a higher level.

Similarly, DfM integrates manufacturing constraints into the design process at the system level, ensuring that considerations for manufacturability, time, and cost are addressed before detailed designs are created. This model-based approach allows engineers to evaluate different design alternatives, such as varying part geometries, against manufacturing requirements, enabling informed decision-making, and fostering more efficient designs.

These digital engineering frameworks are exemplified through the design of lubrication system scavenge module components and parts, where system-level modeling and co-simulation techniques are applied to evaluate and optimize key design parameters. By integrating testability, manufacturability, and system performance considerations directly into the early design phase, these comprehensive frameworks enable a robust, multidisciplinary approach that identifies potential issues and performance bottlenecks prior to physical prototyping. This approach facilitates more informed decision-making, enhances system integration, and ultimately drives more efficient and cost-effective system development across the entire lifecycle.

Presentation#392

Qualifications, certifications, what’s the point? How and why to formalize competency in your organization

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Presented on: Tuesday, 11:30-12:10 EDT

Keywords. formalizing competency;qualifications;certification;implementing competency

Topics. 20. Industry 4.0 & Society 5.0; 3.5. Technical Leadership; 4.5. Competency/Resource Management; 5.9. Teaching and Training; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Speaker will discuss formalizing SE competency in organizations.
The presentation will follow a systems engineering approach while addressing themes as follows.

Understanding your requirements: Begin by getting clarity on the intent and goals of a formal program; what is the problem you are seeking to solve? Does your organization need to build a new strengths or capabilities? Are you addressing current or future skills gaps? Have failures occurred which obviated a need to have more confidence in employee's skills? Additional questions will typically follow. How much of your workforce needs the qualifications? How quickly do you want to have qualified employees? Are multiple levels of qualifications needed? Will the qualification program be voluntary or mandatory? Get concurrence on these requirements with relevant leadership (enterprise level or as relevant to the impacted portion of the organization.)

Architecting your program. Consider whether you will seek to qualify current employees, or start only as new employees onboard. Will the qualification program entail demonstrating knowledge only or also experience? Based upon these answers, can you leverage external qualification programs, (for example INCOSE's SEP certification), or do your needs dictate that you create your own, or develop a tailored or blended approach? An example will be offered which leverages the INCOSE Competency Framework and Assessment Guide, tailored for a specific industry application.

Interfaces: How tightly will your qualification program interface with your Human Resource functions? Will certain positions have requirements for this qualification? Who will track and manage the recordkeeping? If the program will have internally developed or controlled elements, who will be responsible for this? In other words, which current employees will have new responsibilities as part of this program? How much administrative support will be required? (The more customized and more extensive the program, the more support is typically needed).

Integration: When and how will the program be launched? Take considerable time to curate the messaging about why this qualification program is being implemented. If current employees will be impacted, ensure they understand the goals of the program and how they will be asked (or required) to participate. Be prepared for some friction and have a strategy for managing it, typically with additional intentional messaging.

Testing: Ensure that all processes and procedures for executing the program are well documented. Plan for a pilot period to test the process and procedures. Identify a suitable set of pilot participants and any relevant internal personnel who will help execute the program (for example mentors, approval or signature authorities, panel members). Develop and deploy feedback surveys for all pilot participants. Review the results of the pilot and feedback surveys with the same leadership that approved the program requirements. Make adjustments as needed.

Operations and Maintenance: Fully implement the program, continue with surveys. Consider a formal in process review at a relevant timeframe (6 months or 1 year). Capture best practices that emerge.

The presentation will conclude with a discussion of the benefits of formalizing competency. These include having a common knowledge, language and perspective, as well as consistency of behavior. This additionally enables organizational flexibility (shifting employees across projects knowing they are similarly capable). Other benefits include better clarity on the "health" of your organization's workforce, both current and for future planning. Culturally the program may improve aspects of mentoring, collaboration, and a sense of community.

Presentation#362

Robust Testing and Simulation Frameworks for Artificial Intelligence Systems in Spacecraft Operations

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Presented on: Wednesday, 16:30-16:55 EDT

Keywords. Artificial Intelligence;Space Systems;Verification;Testing;Simulation;Human Factors

Topics. 14. Autonomous Systems; 2. Aerospace; 2.6. Verification/Validation; 5.11 Artificial Intelligence, Machine Learning; 5.12 Automation; 6. Defense;

Abstract. The growing reliance on artificial intelligence (AI) for spacecraft operations demands robust testing and simulation methodologies to ensure system reliability and mission success. This paper presents a comprehensive framework for testing and simulating an AI system used in spacecraft, focusing on robustness, adaptability, and fault tolerance. Key aspects include creation of a high-fidelity simulator environment to accurately replicate the dynamic conditions of space, the integration of stress-testing protocols for anomalous conditions and scenarios, and the implementation of tools to validate AI decision-making. Emphasis will be placed on the iterative testing cycles which will leverage synthetic data generation and real-world telemetry to define and expand performance metrics, as well as human factors implications. Performance metrics will be proposed in order to evaluate AI resilience against environmental changes and unforeseen circumstances, and to define what safe-guards and overrides should be available real-time. By addressing challenges such as a hard-ware/software co-design, computational constraints, and real-time processing demands, this paper provides a roadmap for ensuring that spacecraft AI systems are not only accurate but also capable of learning and improving while functioning under the extreme and unpredictable conditions of outer space.

Presentation#374

SE, S and T: A Sociotechnical Systems Analysis of United States Scientific and Technical Policymaking

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Presented on: Wednesday, 11:30-12:10 EDT

Keywords. engineering policy and diplomacy;governmental systems analysis;decision making in government;science and technology policymaking;systems engineering integration

Topics. 1.6. Systems Thinking; 17. Sustainment (legacy systems, re-engineering, etc.); 2.1. Business or Mission Analysis; 22. Social/Sociotechnical and Economic Systems; 3.3. Decision Analysis and/or Decision Management; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Systems Engineering (SE) has the capacity to bring new insights to areas traditionally considered

outside of the SE scope of work, by providing a holistic perspective, elucidating relationships, and clarifying process flows, among other contributions. While government, in its various forms, is widely acknowledged as a type of system, it is less commonly evaluated through a systems lens, especially in disciplines outside of engineering.

This work presents a comparative analysis of state-level legislative systems and processes within the United States, with specific focus on the various methods for incorporating scientific and technical (S&T) information into policymaking. S&T is integral to many modern challenges facing global communities and societies; examples include water accessibility and potability, transportation of people and goods, and energy availability and efficiency. As such, many policies considered or created by lawmakers may benefit from consultation of the most relevant S&T information. However, S&T is not commonly incorporated into United States state-level policymaking processes. There is an opportunity for a systems review of these processes to demonstrate gaps where S&T consideration may be integrated into policymaking, as well as to suggest ways to redesign sociotechnical political structures to allow for such integration.

This analysis demonstrates the differences in state governmental systems procedures for S&T policies, models information flow in policymakers' decision-making processes, and reveals where resource and methodological gaps in S&T policymaking may exist. A sociotechnical SE lens enables effective review of the interaction between the technological, organizational, and social systems considered. The goal is to determine the most efficacious approaches for integration of S&T information into the policymaking process to benefit stakeholders including lawmakers and the public. The work could be scaled to consider governmental systems from local to international contexts, where similar analyses could demonstrate efficacy of programming and/or reveal areas for improvement to reach specific goals in other endeavors.

The audience will receive an engaging summary of a systems approach to analyzing governmental structures, employing methods including MBSE, process analysis, life cycle analysis, human factors, and technical cross-cultural communication. Attendees will be invited to discuss the benefits that engineering design frameworks may bring to law and policymaking, and how systems analysis in other enterprises could lead to new insights and novel solutions for societies.

As a master's student in systems engineering with a Bachelor of Science in anthropology, the presenter is prepared to deliver a summation of integrated research elements from the fields of social science and engineering and speak about the various contexts and applications in which overlapping these disciplines can balance and enhance results. Additionally, as a co-investigator of the Arizona Science and Technology Policy Fellowship project, the presenter is versed in science and engineering policy within the United States and interested to engage the audience in discussion of engineering diplomacy in an international context.

Presentation#358

Secure Cyber Resilient Engineering: Methods and Tools

Peter Beling (Virginia Tech) - beling@vt.edu
Tom McDermott (Stevens Institute of Technology) - tmcdermo@stevens.edu

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

Keywords. Cybersecurity;Resilience;Requirements;Trade-offs

Topics. 2.3. Needs and Requirements Definition; 4.4. Resilience; 4.7. System Security (cyber-attack, anti-tamper, etc.);

Abstract. The Department of Defense (DoD) mandates that new acquisition programs address cyber survivability attributes (CSAs) in their requirements. CSAs 7-10 specifically focus on cyber resilience, emphasizing the functions of detection, mitigation, and recovery from cyberattacks. Secure Cyber-Resilient

Engineering (SCRE) provides a robust framework for deriving associated resilience requirements, enabling systems engineers to integrate survivability into the foundational architecture of cyber-physical systems (CPS).

This presentation establishes the core principles of SCRE, which integrates system-theoretic modeling, predictive analytics, and adaptive control to ensure operational continuity. Foundational methodologies such as Systems-Theoretic Process Analysis for Security (STPA-Sec) and the Cyber Resilience Requirements Methodology (CRRM) equip engineers to identify mission-critical loss scenarios, design resilience mechanisms, and validate their effectiveness through model-based systems engineering (MBSE).

The Adversity Chain provides an innovative framework for resilience by focusing on operational recovery and adaptation rather than solely on prevention. It models a sequence of adverse system transitions starting from the "loss scenario," defined as the system state associated with the culmination of adversarial actions. Importantly, a loss scenario does not necessarily coincide with a catastrophic loss of mission or system functionality; subsequent evolution of the system from this state can be mitigated by operator actions, environmental factors, or the activation of resilience mechanisms engineered for the purpose.

This framework complements traditional prevention-focused methodologies, such as the Cyber Kill Chain, by reasoning from the loss scenario forward. Through STPA-Sec and CRRM, engineers can map causal pathways, simulate adverse transitions, and design resilience mechanisms to disrupt or limit cascading failures. Sentinel-based mechanisms, for instance, detect and isolate faults, enabling dynamic reconfiguration and reducing the likelihood of mission-critical losses. The Adversity Chain's emphasis on adaptive recovery aligns with DoD-mandated CSAs 7-10, making it instrumental in deriving actionable resilience requirements. It reframes resilience as the capacity to limit the progression of adverse transitions, ensuring mission continuity even under compromised conditions.

The talk will feature discussion of a novel simulation approach that provides a quantitative foundation for balancing resilience trade-offs among performance, cost, and complexity. Simulations quantify mission/system resilience by measuring the effectiveness of sentinel scenarios and associated mechanisms in mitigating loss scenarios. By varying parameters such as detection time and response execution, engineers can optimize system performance while meeting CSA requirements. This process directly supports DoD acquisition programs, offering a structured approach to navigating the resilience trade space.

SCRE principles have been applied to diverse CPS domains such as the Future Long-Range Assault Aircraft (FLRAA) program, unmanned vehicle systems, and networked munitions. Those case studies demonstrate SCRE's ability to support mission-critical functions and guide MBSE-based design for adaptive, resilient systems. The talk will feature a case study of current research in which SCRE is being applied to offshore wind energy farms. This project includes a comparison of SCRE methods with other approaches to continuous monitoring and lifecycle risk management developed in the energy sector.

Attendees will gain: (1) A detailed understanding of SCRE's foundational methods and their relevance to DoD-mandated CSAs; (2) insights into the Adversity Chain framework and its role in deriving actionable resilience requirements; (3) practical knowledge of simulation-driven trade-offs for optimizing resilience mechanisms; and (4) examples of SCRE's application across diverse domains, illustrating its effectiveness and adaptability.
This presentation aligns with INCOSE's focus on systems resilience and security, offering actionable strategies for embedding cyber survivability into CPS design. By addressing both foundational principles and advanced methodologies, it provides a comprehensive perspective on resilience engineering.

Presenter Qualifications:
Dr. Peter Beling is the director of the Intelligent Systems Division at the Virginia Tech National Security Institute and is a professor in the Grado Department of Industrial and Systems Engineering. His research interests lie at the intersections of systems engineering and AI and include digital and mission engineering, AI adoption, reinforcement learning, and transfer learning. His research has found application in a variety of domains, including cyber resilience of cyber-physical systems, prognostics and health management, and smart manufacturing. He serves on the Research Council of the Systems Engineering Research Center (SERC).

Mr. Tom McDermott is a leader, educator, and innovator in multiple technology fields. He currently serves as Chief Technology Officer (CTO) of the SERC at Stevens, as well as a consultant specializing in strategic planning for uncertain environments. He studies systems engineering, systems thinking, organizational dynamics, and the nature of complex human socio-technical systems. He teaches system architecture concepts, systems thinking and decision making, and the composite skills required at the intersection of leadership and engineering. He has over 30 years of background and experience in technical and management disciplines, including over 15 years at the Georgia Institute of Technology and 18 years with

Lockheed Martin.

Presentation#72

Should I Use MBSE On This Project?

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Presented on: Tuesday, 15:30-15:55 EDT

Keywords. MBSE;Quantitative;Fundamentals;Assessment

Topics. 2. Aerospace; 3.3. Decision Analysis and/or Decision Management; 3.7. Project Planning, Project Assessment, and/or Project Control; 5.3. MBSE;

Abstract. In the context of MBSE, while most often discussed in terms of large multi-year programs and connecting big datasets and tools, there exists a need for solid model-based systems engineering for small-to-midsize projects, one-off design/build efforts and prototyping. But is it worth the effort standing up and executing MBSE for these kinds of projects? Organizations familiar with document-based SE processes and tools, of which they have built-in efficiencies from repetition and familiarity, may rightly ask the question if the cost in time and talent is worth it for these smaller or limited projects. For organizations where MBSE is a mainstay or an emerging practice, similar questions can be raised. Therefore, is there a way for an organization or project team to objectively determine, quickly and in a quantitative way, if using MBSE is worth it for a specific project? There are well-known qualitative aspects and attributes for using a MBSE approach, but using these qualities alone to determine a project's technical path may lead to a large degree of subjectivity in the answer, which also may in turn directly lead to greater project risk.
In this session, participants will learn a method to quantitatively assess the utility for using the MBSE approach on a specific project-by-project basis. This is most often performed prior-to or at inception but can also be used upon entering a project at any stage of the lifecycle. Quantitative scoring is performed first to determine the magnitude of utility for MBSE across a spectrum from "MBSE is highly recommended" to "MBSE is not recommended". We identified the most relevant (six) quantitatively scorable factors, which once totaled, results in a sum score that is displayed as a graphical result or "heat map". This makes the answer easy to assess using visual inspection by project and budget stakeholders. If the scoring results are less definitive (i.e. closer to the middle of the range), we then can apply selected qualitative criterion to assist the systems engineer in judging whether the score should be adjusted towards one end of the spectrum or the other.

Presentation#29

Shu Ha Ri for SE (For the Journey to Expertise in SE, Enhance the Path with Shu Ha Ri)

Fred Robinson (The MITRE Corporation) - frobinson@mitre.org

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

Keywords. mastery;generalists;specialists;wicked problems;shu ha ri

Topics. 1.6. Systems Thinking; 3.5. Technical Leadership; 5.9. Teaching and Training;

Abstract. This work offers considerations & enhancements to current programs systems engineering professional development, incorporating characteristics of expertise & mastery throughout. Shu Ha Ri represents an approach for 3 phases of mastery development, established in ancient practices like martial arts & mimicked in current approaches. Ericsson’s research on expertise depicts 3 levels of progression, naïve practice > purposeful practice > deliberate practice. Yet, Ericsson’s model is limited to domains where expertise can be characterized, is well understood, & is measurable or objectively evaluable by existing domain experts. For a given population of experts in SE, there is a shared set of highly diverse experiential assessment characteristics which diverge from some other assessment levels. Epstein suggests the power of generalists comes to play more when experts address wicked problems (those lacking a pre-ordained approach for solving) than when specialists address kind problems (the opposite). Solving wicked problems without exemplar solutions often requires the generalist’s leveraging of analogic thinking, and the recognition and possible synthesis of matchable patterns learned from diverse experience sampling of other domains, not merely relying on T-shaped or Pi-shaped knowledge. Using the Shu Ha Ri framing presents an opportunity to consider enhancements to earlier SE practitioner development stages towards excelling beyond emergence & effectiveness.
This presentation has been presented in smaller technical society venues, but is new to IS, and is based upon a paper in INCOSE's SE practitioner journal.

Presentation#284

Software Defined Vehicle: behind the “Smartphone on wheels” claim, a multidimensional system challenge!

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Presented on: Tuesday, 14:00-14:25 EDT

Keywords. Systems Engineering;Automotive;Software;System and Software interface;Services;Service Oriented Architecture;Micro-Services;SOA;Software-Defined Vehicle;Software-Defined;SDV

Topics. 3. Automotive; 5.7. Software-Intensive Systems;

Abstract. Software has long been an essential driver of automotive products and services, but its continuing exponential growth has now triggered several threshold effects. The unmanageable number of networked Electronic Control Units (ECUs) in a flat network has led to structuring resources by domain, but this is not sufficient. The volume of code and the profusion of complex external interfaces continues unabated. These effects have pushed the industry towards several ongoing disruptions, often grouped under the term Software-Defined Vehicle (SDV), including Service-Oriented Architecture (SOA). But is this just a new soup of shiny buzzwords and acronyms, or does SDV represent a real breakthrough? a necessary condition for future mobility?
Looking beyond the oft cited "smartphone on wheels” analogy, it is evident that this subject is heavily coupled, in several ways, with Systems Engineering (SE). To explore this, the INCOSE Automotive Working Group (AWG) launched two new, related workstreams that view those disruptions through a systems lens. One addresses the broad SDV ecosystem, the other focuses on the closely related transition to SOA, a key enabler for SDV. This presentation of AWG’s work to date will give attendees a better understanding of the SDV concept, its many couplings with SE, and the associated challenges. The next steps for AWG workstreams will also be considered.Numerous publications on SDV were reviewed, exploring the multiple dimensions found in a variety of descriptions from industry leaders and technical publications. We identified definitions and SE content, and contrasted them with recent “SDx” experiences in other domains, such as Software-Defined Radio, highlighting similar characteristics and differences. A few SDV publications that highlight the importance of using the right systems approach were identified, but these have limited depth. This confirms the relevance of the project. Three main themes emerged from this review, each bringing a different need for a systems approach and SE:- Software and hardware (electronics) technology,- Value for customers,- Business model.
The first refers to an SDV’s technical characteristics (centralized electronics, SOA, networking). The associated need for SE is relatively straightforward to understand in traditional SE terms (combining interrelated technologies, managing technical complexity) and generally maps well to skillsets already present in SDV activities (electric-electronic architecture, software architecture, software engineering, networking). Nonetheless, tailored processes and tools will be essential to support this transition to SDV.The second consideration starts from justly recalling the heavy value enrichment for customers and other stakeholders. SDV will allow a wider range of new vehicle features to be developed and distributed more easily, quickly and cheaply. Over-the-Air updates also increase resale values. Ultimately, SDV addresses a broader service ecosystem spanning customers, social networks and the businesses they interact with. This explosion of value will be only possible if a proper systems approach is applied considering the full scope of an SDV implementation, including relevant physical on- & off-board components, like sensors, actuators, charging stations, and app stores. It is not sufficient to only account for the “software + ECUs” aspects. Likewise, all lifecycle phases must be considered, as must the full spectrum of use cases involving the many stakeholders. In contrast, the catchy “smartphone on wheels” analogy brings with it a risk of underestimating this “wider scope of interest”, in terms of risks, safety, processes, tooling, and skills. This applies to the development of a single vehicle, but is even more important for the overall product line management

encompassing the whole vehicle range.The third consideration, ‘business model’, addresses the several “new deals” brought by SDV. Some of the many related issues that remain open include:- Selling over-equipped vehicles, possibly with ECUs, sensors & actuators that are not immediately necessary, justified by upgradability throughout the vehicle’s life through "Feature as a Service",- Challenges to the traditional “OEM-Tier 1” business model for the ECU and software supply chain,- Key importance of the mid-layer software and the automotive applications ecosystem:-- Should OEMs move development in house, co-develop, or buy off the shelf?-- How can value be maximized through standardization?-- What should be the role of open-source software in safety critical automotive applications?- Scope of the SDV “Product+Service” platforms delivered in B2B relationships

This new situation is extraordinarily complex, considering the variety, number and size of competing companies involved. These include traditional and newcomer OEMs, Tier1 to TierN suppliers, the semiconductor Industry, the big-tech GAFAM giants, not to mention a host of startups. Moreover, this is happening in parallel with the other fundamental breakthroughs in Autonomy, Connectivity, Electrification and Shared mobility (ACES) . Systems thinking applied to this big picture will not deliver any “magic optimal way”, but it can help to orient decisions towards long-term thinking. It also helps ensure that the needs of all relevant stakeholders are considered across the three main themes identified.

Armed with this clearer understanding of concepts and analysis of “system needs”, the presentation will look to the other ongoing activities in the workstreams and the planned next steps. These include a survey launched to gain a better understanding of the status of services and micro-services in the automotive domain. AWG has also initiated several contacts with international organizations and research projects that are addressing future of SDV, typically concentrating on the software content. AWG’s perspective complements this well, encompassing People-Process-Methods-Tools concerns and the overall system scope. The extensive challenges include refining “HW-SW decoupling” for a mechatronic sub-system; tailoring processes; harmonizing concepts and reference data structures for digital continuity; supporting synthetic views on the future industrial ecosystem; and more.

In conclusion, SDV and SOA are very challenging trends in the automotive industry. From a business point of view, risks are unavoidable, but success will depend on many factors, and a systems approach is one of them. Without properly tailored SE, it is unlikely that industry players will be able to ensure the proper integration of software inside and outside the vehicle. More generally, systems thinking will be a key element in the rapid evolution of business models and the value they bring to customers and the industry.

Presentation#384

Solving the Selfish Octopus Problem with the Reusable Asset Specification (RAS) 3.0

Matthew Hause (SSI) - matthew.hause@hotmail.com

Presented on: Wednesday, 15:30-15:55 EDT

Keywords. Reuse;MBSE;Models;Acquisition

Topics. 17. Sustainment (legacy systems, re-engineering, etc.); 2.4. System Architecture/Design Definition; 5.3. MBSE; 5.6. Product Line Engineering; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. In the animal kingdom, knowledge is passed from parent to offspring via conditioning, reward/punishment, observation, and via instinct/DNA. The passing on of this “tribal knowledge” helps to ensure the survival of the species. The octopus is a highly intelligent, curious creature with the ability to solve problems, use tools, and adapt to its environment. However, it is a solitary creature, so any knowledge gained by one octopus is not passed on to the next generation. The knowledge gained and lessons learned are repeated by each succeeding generation. Projects are like the octopus. The knowledge and experience gained during the execution of large projects remains mostly in the heads of the engineers, but often is not

successfully distributed more widely. In Model-Based Systems Engineering (MBSE) projects, this knowledge is made explicit in an easier to reuse form. Models can include problem solving techniques, algorithms, libraries of types, patterns, interfaces, components, etc., that when properly curated become highly effective means of passing on large amounts of that knowledge.

One of the ways to preserve this knowledge is by creating libraries of these reusable assets. For example, the newest version of Unified Architecture Framework (UAF) included a library developed by Mitre of 1200 different security controls defined in National Institute of Standards and Technology (NIST) standard 800-53r5. Other libraries include standard model libraries developed for SysML, RAAML and other modeling languages. In fact, the emerging SysML v2 standard emphasizes the use and reuse of libraries over modeling extensions and stereotypes. While the compilation of these libraries is useful, they need to be shared widely to be of any practical use. For a library to be of use, people need to know where it is, be able to access it, reference the elements that they need, and suggest items to be added or updated. Regarding model reuse, most organizations have asset repositories, but few people know about which assets are reusable or how to access them. With no metadata catalog or useful search capability, organizations are not treating these repositories as libraries, Projects can't safely reference or add to any asset content. We need a solution for curated model libraries as well as the supporting infrastructure, such as metadata catalogs.

Donna Rhodes from MIT has done heroic research on model curation. She sums up the current situation as follows: "Rouse (2015) stresses that the wealth of existing models is often not used because of a lack of knowledge of these resources and the difficulty in accessing them (Rouse, 2015). Lack of access to models, mistrust of models, and perception of legitimacy of models are all barriers in model reuse and longevity. According to Reymondet et al. (2016), model expertise is largely resident in individuals, and the ability to select and compose sets of models is typically limited to the original use. Modeling efforts are often duplicated across programs, and the individual programs may lack model experts preventing benefit from the collected wisdom of the enterprise (Rhodes & Ross, 2015). A question arises as to whether a model curation function at the enterprise level could lead to more effective use of models and digital assets at all levels." (Rhodes, 2019) Wu et al (2021) describes a maturity assessment of Systems Engineering reusable assets to facilitate MBSE adoption, basically a Capability Maturity Model (CMM) for model and asset reuse. Finally, Hause (2014), defines how the OMG Reusable Asset Specification (RAS) was used to build an asset library to harvest, curate, and share SysML model assets to promote and enable model asset reuse. The OMG RAS 2.0 was published in 2005 and provides a means of categorizing assets for reuse. An effort is underway at the OMG to update the standard to address asset discovery. Asset metadata "meta-card" catalogs, libraries, associated APIs, and other applicable standards will support the OMG Model Based Acquisition (MBAcq) initiative, product line engineering, and a host of other project and industry needs. This presentation discusses the problem of asset sharing and the work going on to develop RAS 3.0.

Presentation#73

Space Domain Enterprise Architecture Reference Model

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

Keywords. Architecture;Reference Model;Space Domain;Enterprise;UAF;SEA;Space Enterprise Architecture;MBSE;Model Based Systems Engineering;Unified Architecture Framework

Topics. 2. Aerospace; 5.3. MBSE; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. As Model Based Systems Engineering (MBSE) becomes more widely accepted across disciplines and specifically within the space domain a common approach towards modeling enterprise architectures in that domain is critical. Having a common approach ensures consistency in what is delivered and what is shared across groups to promote inter-organizational collaboration. Enforcing a standardized modeling structure that facilities resolution of commonly occurring system acquisition problems can help assure mission success in a timely manner. This presentation is on the Space Enterprise Architecture (SEA) references models. The SEA reference model comprises nine separate model libraries built using the Unified Architecture Framework (UAF). When these model libraries are used together, they can capture space system characteristics such as physical location, operational status, operators, networks etc. It also helps enterprise modelers to document space enterprises in a consistent fashion. The SEA models provide a baseline set of features for space systems and how they interface with one another as well as a model pattern for how to address what-if mission threads and kill chain analyses for the space domain. Additionally, the SEA models include example patterns that can be referenced to enable a consistent approach for enterprise modeling such that multiple organizations can have the standardized understandings of the characteristics of systems. Enterprise modelers can leverage the SEA models to begin enterprise modeling to capture and address acquisition problems the space domain is tackling using the typical systems and interfaces, found in the SEA library models, which helps reduce the amount of time needed to create the foundations typically needed for modeling.

The SEA’s focus on space enterprise modeling for the completion of mission engineering studies is a case study in capturing the needs and lingo of a customer and translating it into a methodology powered by a generic modeling language that was not designed explicitly for the customer’s lingo. A systems engineer needs to be able to translate the abstract needs of a stakeholder into more concrete actions to be executed upon. How to go about said translation for a model-centric enterprise modeling paradigm has not been thoroughly explored or documented. Moreover, proper mission engineering studies identify the configuration of systems, policies, and personnel that will be the likeliest to maximize the fulfillment of a commander’s needs and goals throughout the conduct of a mission. Mission Engineering studies need robust understandings of the architectural elements at play for a given time epoch. Without an architectural modeling framework and library geared for the study’s domain area, the study’s understanding of the architectural elements will likely be of poor quality.

Defense and non-defense government organizations and their contractors who do work on mission architecting modeling would find interest in the approach taken to develop a methodology to standardize the creation of the customer’s desired mission architecture views. For enterprise architectural modelers, guidance is provided on for how to organize the collection of modeled enterprise elements to enable model reuse as well as model sharing across customer lines of efforts. Lastly, space systems architects can find value in identifying the specifics of how SEA divides the functionality of space systems into broad categories as a way for to organize their own thinking about the functionalities of the system systems they oversee.

Presentation#56

SysML v1 to SysML v2 Model Conversion Approach

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Presented on: Thursday, 09:35-10:05 EDT

Keywords. SysML v2;SysML Model Conversion;SysML Model Transformation;SysML v2 Transition;MBSE

Topics. 2. Aerospace; 2.3. Needs and Requirements Definition; 2.4. System Architecture/Design Definition; 2.6. Verification/Validation; 3.5. Technical Leadership; 3.7. Project Planning, Project Assessment, and/or Project Control; 5.3. MBSE; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.); Other domain;

Abstract. The Systems Modeling Language (SysML) v1 was adopted by the Object Management Group (OMG) in 2007. SysML v2 is the next generation systems modeling language. The SysML v2 beta specification was approved by the OMG in June 2023, and the updated specification is expected to be submitted for final adoption in 2025. There is a critical need for organizations to maintain their investment in SysML v1 models as they transition to modeling with SysML v2.

The SysML v2 specification includes a transformation specification that defines how a conformant SysML v1 model can be automatically transformed to a SysML v2 model. However, additional steps may need to be taken to convert a SysML v1 model to a SysML v2 model and fully benefit from the features of SysML v2. A proposed SysML v1 to SysML v2 conversion approach is summarized in this presentation.

The conversion approach was defined as part of a project hosted by the DoD Department of Digital Engineering, Modeling and Simulation. Some tool vendors are also using this approach to guide their own model transformation implementations and guidance. This approach will continue to evolve as implementations are applied to projects.

The project is developing guidance for organizations, projects, and practitioners to support their efforts to transition from modeling with SysML v1 to modeling with SysML v2. This project will enable the department of defense to properly plan for and understand the implications of converting a SysMLv1 model to a SysML v2 model.

Presentation#292

Taking CI-CD DevOps to Digital Engineering -- Unit Testing, Model Assessments and Build Automation

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Presented on: Thursday, 13:30-13:55 EDT

Keywords. Digital Engineering;DevOps;MBSE;Model Assessment;Unit Test;CI/CD;Build Automation;Integration Testing;QA

Topics. 1. Academia (curricula, course life cycle, etc.); 11. Information Technology/Telecommunication; 2.6. Verification/Validation; 3.8. Quality Management Process; 5.4. Modeling/Simulation/Analysis; 6. Defense;

Abstract. A cornerstone for modern software development, continuous integration and continuous delivery (CI/CD) practices have streamlined developer workflows by enabling faster feedback through automated testing and deployment. We propose that adopting similar DevOps practices could revolutionize model-based systems engineering (MBSE) workflows. Current MBSE practices generally rely on quality controls that involve manual checks on the latest change, leaving the modeler unable to validate all prior changes.

This presentation addresses this critical gap by introducing integration testing of MBSE models using a free CI/CD server (Jenkins). This testing incorporates essential tasks such as quality checks and Rules of Construction conformance scans. Following this process can decrease testing time and standardize running the tests to improve agility. It can be used to develop the model against some rules of construction or develop rules of construction against a model. Having standard and automatic testing will help improve the release cycle time to improve collaboration both internally and externally.

Between us, we have over 40 years of software development experience in the full range of embedded to web, research to production, small to large, and most significantly from design, development to integration and release. We have experience implementing automated CI/CD processes successfully for product releases in SW. This presentation is about bringing a similar process to MBSE while showing the unique benefits and limitations.

Presentation#174

Taming the beast: Best Practices of Extending SysML V2

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Presented on: Thursday, 10:10-10:40 EDT

Keywords. SysML V2;MBSE;Language Extensions;Best Practices

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

Abstract. While developing Systems Modeling Language (SysML) version 2 libraries for Unified Architecture Framework (UAF) version 2, we pushed the boundaries of the SysML V2 extension mechanism. This journey involved extensive collaboration with SysML V2 leadership and making tough decisions to move forward. It was a pioneering experience, filled with insights that we're eager to share with anyone looking to extend SysML V2 in their own environment. From libraries to metadata, text to graphics, and tool enhancements, we'll cover everything you need to tame the beast.

Presentation#79

Transforming an Acquisition Process with SysML v2

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

Keywords. Model-Based Acquisition;Digital Engineering;Model-Based Systems Engineering;SysML v2

Topics. 2.3. Needs and Requirements Definition; 3.1. Acquisition and/or Supply; 5.3. MBSE; 6. Defense;

Abstract. Overview

Many organizations across the U.S. Department of Defense (DoD) have adopted Systems Modeling Language (SysML) v1 as a tool supporting their model-based systems engineering (MBSE) capability. These same organizations need to understand how the release of SysML v2 may impact their business processes as well as the costs and timeline associated with the migration of their existing SysML v1 models. To this end, the Office of Systems Engineering and Architecture (SE&A) has released recommendations to help guide transition planning.

Critically, SysML v1 and v2 will coexist for some time. Organizations need to understand how their processes and model-based activities may be impacted when they have legacy SysML v1 models. Specifically, what are the advantages and constraints if the organization needs to decide if they should use their legacy SysML v1 models simultaneously with newer models crafted in SysML v2 versus redoing their legacy models and transitioning wholesale to SysML v2? What are the trades between the capability gains associated with SysML v2 and the effort required to pursue any of these options?

This research uses SysML v2 to work through an example acquisition activity for the Skyzer Mission Model, a SysML v1 model developed by the Systems Engineering Research Center. The goal is to scope the transformation so that it is practical, affordable, and scalable.

Problem

There is existing work from SE&A that details how to completely transform a set of SysML v1 models to v2 using the example of the Skyzer Mission Model. There is also a transformation specification that SysML v2 tools use to automatically migrate models from v1 to v2. Regardless, the conversion process must include validation of the results. This research demonstrates a specific example portion of a DoD acquisition process that is transformed by using SysML v2 to work through the activity. This effort provides an example that demonstrates how existing workflows may be altered with the introduction of SysML v2. It also introduces a validation approach that traces the models to the information they provide to the process.

Approach and Methods

This research introduces new requirements to the Skyzer Mission Model to illustrate a notional acquisition process for a system block upgrade. In particular, the focus is the generation of a Requirements Verification Traceability Matrix (RVTM) used to support the entrance and exit criteria of a System Requirements Review (SRR). This focus provides information requirements and artifact structure to guide the modeling efforts in SysML v1 and v2. The modeling effort includes developing and implementing patterns to capture the existing requirements in SysML v1 and new requirements in SysML v2 in the form required to generate the desired RVTM structure. Both patterns must produce the same structure so the existing and new requirements can be combined into a single RVTM.

The work breakdown leads to a cost estimation procedure: architecture, modeling, and transformation may be allocated to appropriate personnel like model architect, junior modeler, and software engineer in order to roughly estimate the cost of generating the artifact from SysML v1 and v2. This estimate could be compared to the cost of other alternatives like completely converting the existing SysML v1 models to v2. Moreover, the work may be allocated to tools like Cameo Systems Modeler, SysON, SysIDE, and JupyterLab to begin to envision the digital engineering environment that facilitates the integration of SysML v1 and v2.

Results

It is crucial to conduct pilot studies using SysML v2 to support the DoD acquisition process in order to understand what systems engineering will look like in practice with the new version of SysML. This research focuses on the RVTM to scope the migration from SysML v1 to v2 and develop a process to estimate the cost of migration. This leads to a general approach to generate other artifacts of the acquisition process (or other processes) and a roadmap to migrate the models that support the process to SysML v2.

The incremental approach allows the organization to continue to extract value from their existing SysML v1 models while they balance the migration to SysML v2 with other priorities. Indeed, SysML v1 modeling patterns normalize the model to reduce future costs of migration and provide traceability to organizational processes to identify the elements of the model that need to be migrated.

Overall, this research envisions what work may look like as MBSE for the acquisition process transitions to SysML v2, demonstrating a team of diverse skill sets collaborating to generate an RVTM in support of the SRR activity. The notional workflow realizes the SysML v2 promises of interoperability and usability, providing an example for organizations to consider as they develop their SysML v2 transition plans.

Presentation#399

Transforming Decision-Making with AI and the DADM Framework

Jared Smith (Deloitte Consulting) - jarsmith@deloitte.com
John DeHart (Avian INC) - jdehart@avian.com

Presented on: Tuesday, 11:30-12:10 EDT

Keywords. mbse;ai;LLM;agent;decision analysis working group;digital transformation;decision;decision analysis;decision management;sysml;architecture;management;project management;risk;configuration management;patterns;reuse

Topics. 1. Academia (curricula, course life cycle, etc.); 3.3. Decision Analysis and/or Decision Management; 5.11 Artificial Intelligence, Machine Learning; 5.3. MBSE; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. In today's fast-paced technology landscape, organizations must navigate increasingly complex decision-making challenges. This presentation invites you to a live, hands-on demonstration of our innovative agent-based AI decision prototype. The tool aims to enhance decision-making processes by integrating advanced large language model (LLM) technologies with a structured decision framework, offering a potential solution to contemporary challenges faced by organizations across various sectors.

The Decision Analysis Data Model (DADM), an INCOSE FuSE product, standardizes decision-making processes, providing a framework for consistent documentation and efficient referencing of past decisions. This model serves as the backbone for our tool, which leverages LLMs to facilitate more effective and informed decision-making. By streamlining decision workflows, the tool ensures that organizations can respond swiftly and accurately to the demands of an increasingly dynamic environment.

Technical Integration:
Our prototype employs cutting-edge AI technologies, including Retrieval-Augmented Generation (RAG) with vector databases powered by Qdrant, alongside custom fine-tuned models. A Streamlit web-application framework serves as a user-friendly interface, ensuring seamless interaction with AI-generated insights. This integration not only simplifies access to complex data but also enhances user engagement by making sophisticated analytical tools accessible to non-technical stakeholders.

We’ve worked with decision management subject matter experts (SMEs) from the INCOSE Decision Analysis Working Group (DAWG) to train tailored AI agents to support the decision analysis process. This setup integrates expertise into the tool, providing strategic guidance for decision-makers or decision analysts. Through regular feedback and updates, these SMEs ensure that the AI agents remain aligned with the latest industry standards and best practices, continuously enhancing their effectiveness and relevance.

For this initial prototype, these AI agents will focus on three priority processes: Decision Framing, Structuring Objectives and Measures, and Generating Alternatives. But this framework can quickly expand to the other key processes in a decision analysis as outlined in the DADM. The flexible nature of the design allows for rapid scaling and adaptation to meet evolving organizational needs, making it a versatile tool that grows with the user.

Future iterations of this tool could support the following advanced use cases:

* Automated Report Generation: Produces reports from decision data, reducing the time and effort required for manual compilation and allowing stakeholders to focus on strategic oversight.

* Enhanced Decision Context: Offers real-time contextual insights by integrating data from diverse sources, providing a comprehensive view of the decision landscape.

* Stakeholder Communication: Simplifies complex data into narratives that are easy to understand, facilitating transparency and ensuring all stakeholders are informed and aligned.

* Feedback Loop Analysis: Refines processes iteratively by capturing and utilizing outcome data, promoting continuous learning and improvement.

* Interactive Training: Engages users with simulated scenarios, offering a hands-on approach to learning and reinforcing decision-making skills in a safe environment.

By functioning as an intelligent facilitator, assisting with context gathering, problem framing, structuring objectives, and generating alternatives, our AI solution aims to improve efficiency, consistency, and thoroughness of decision analyses, providing decision-makers and decision analysts a simplified method for aligning with the best practices for decision management and empowering them with insights and support to make data-driven decisions.

Expected Outcomes and Impact:
Participants will explore AI's role in enhancing decision-making frameworks and its strategic potential. By fostering continuous improvement and collaboration, the tool addresses modern decision-making challenges. This engagement offers a unique opportunity to witness how AI integration can transform traditional decision-making processes into agile, data-driven operations that are better equipped to handle future uncertainties.

Our agent-based AI tool represents progress in decision analysis. Aligning AI with structured frameworks, we propose solutions to enhance efficiency, reliability, and transparency. Join us to explore these innovations and shape the future of decision analysis in an AI-driven world. We invite you to be part of this transformative journey, co-creating the next generation of decision-making tools to meet the demands of tomorrow.

Presentation#268

Transforming Engineering: Implementation of Cross Domain Configuration Management (CDCM) at Bosch

Christoph Bergner (GfSE) - c.bergner@mid.de

Thomas Schwarzkopff (Robert Bosch GmbH) - thomas.schwartzkopff@de.bosch.com

Presented on: Tuesday, 15:30-15:55 EDT

Keywords. Cross Domain Configuration Management;Global Configuration Management;Configuration Management;Cross Domain Traceability Management;OSLC;OSLC Config management

Topics. 3.2. Configuration Management; 5.6. Product Line Engineering; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.);

Abstract. Modern product line engineering requires a comprehensive strategy to make local configurations of various engineering domains transparent and support their management in cross-domain configurations. A cross-domain configuration can be seen as an “engineering BOM” for a product. IBM has promoted this idea with the IBM ELM platform and its “Global Configuration Management” application. However, this approach is limited to ELM tools, focusing on global configuration as the foundation for traceability management and analysis. Today, most organizations use simple tools like Excel to manage configuration item lists.
In reality, large organizations designing complex systems need a broader approach for their transformation to

a fully digital product design process. This approach includes all authoring tools and repositories across all domains, including MBSE related tools, document management, source code, PLM, and many more.
The presentation will highlight the conceptual and implementation challenges of building an Enterprise-wide Cross Domain Configuration Management (CDCM) platform with and for Bosch, targeting:
1. Enforcing the re-use of engineering assets
2. Increasing transparency on the maturity of work products across the engineering lifecycle
3. Increasing efficiency in managing Cross Domain Baselines
The CDCM platform is now available in V2 and is being rolled out at Bosch. A brief demo will show how conceptual challenges have been addressed.
Looking ahead, Cross Domain Configurations will serve more scenarios, such as:
1. Cross Domain Traceability Management: This can only be done based on Cross Domain Configurations. Every authoring tool showing links to other tools needs to set a global context in the form of a Cross Domain Configuration. Hence, CDCM is crucial for compliance with ASPICE, ISO-26262, DO-178C, and other standards.
2. Cross Domain Analysis and Reporting: These need a Cross Domain Configuration as a context when more than one domain contributes to the analysis or report. Cross Domain Configurations are used to generate data marts.
3. Cross Domain Configuration Templates: These will increase process speed in the early phases of a project.
4. Holistic Variant Management: This will use Cross Domain Configurations as a template for generating multi-domain 100% models.
5. Digital Twin: The comprehensive product definition contained in a Cross Domain Configuration will significantly contribute to the digital twin.
The implementation of scenarios 1 to 4 of these advanced applications of CDCM will be demonstrated. The solution is based on the OASIS standards “OSLC Lifecycle Integration Core,” “OSLC Configuration Management,” “OSLC Tracked Resource Set,” and “OSLC Linked Data Management."

Biography

Christoph Bergner (GfSE) - c.bergner@mid.de
Serial Entrepreneur
Owner of MID GmbH Nuremberg, 200 Employees
Product-Line Leader for Tool Interoperability and Tool Integrations
Masters Degree in Mechanical Engineering at Technical University Darmstadt

Thomas Schwarzkopff (Robert Bosch GmbH) - thomas.schwartzkopff@de.bosch.com
Over 20 years working as Engineer at Bosch Mobility in various positions (central functions & engineering)
Since 7 years Chief Expert for Model-Based Engineering. Responsible for Method Framework, MBSE Trainings, Digital Thread and Engineering Ontologies in the Mobility CTO office.
PhD in Numerical Methods for Aeroacoustics Simulation, Stuttgart University
Master Degree in Aeronautical Engineering, Stuttgart University

Presentation#36

Using SysML v2 to Define a Digital Engineering Methodology

Bernard Dion (ANSYS, Inc.) - bernard.dion@ansys.com
J Simmons (Digital Engineering Consultant) - j.simmons-ext@ansys.com

Presented on: Thursday, 09:00-09:30 EDT

Keywords. Digital Engineering;Methodology;Model-Based System Engineering;Digital Threads

Topics. 14. Autonomous Systems; 2. Aerospace; 3. Automotive; 5.1. Agile Systems Engineering; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 5.5. Processes;

Abstract. A Methodology is a comprehensive set of technical guidance providing model patterns and work instructions to engineer a system throughout its life cycle in an efficient and consistent manner.
Digital Engineering is “an integrated digital approach that uses authoritative sources of system data and models as a continuum across disciplines to support lifecycle activities from concept through disposal” (US DoD, https://man.fas.org/eprint/digeng-2018.pdf).
A Digital Engineering (DE) methodology is expected to provide a comprehensive, data driven approach to system development, utilizing digital models and simulation across the entire lifecycle. Methodology objectives are to enable faster, more informed decision-making, to improve collaboration, to reduce risks, and to obtain higher quality end-products.
Model-based Systems Engineering (MBSE) is a discipline within digital engineering that relies on creating digital models to manage the entire system lifecycle. It is commonly accepted that MBSE execution requires three things to be effective: a descriptive modeling language, a compatible modeling tool, and a methodology.
By formalizing the use of an architecture model with complete and unambiguous technical guidance to perform Systems Engineering activities, an enterprise can realize tangible improvements in its digital engineering practices. These improvements include ensuring architecture models have sufficient detail without giving into the temptation to “over-model”, developing self-consistent, reusable architecture models with teams ranging in size from 5 to 500, and providing a shared basis of model-based communication between systems engineers, subject-matter experts (SME’s), and system stakeholders.
This presentation will describe the architecture of a well-defined Digital Engineering methodology modeled in SysML v2. The methodology relies on the definition of processes and the creation of libraries to support the application of these processes. Processes are defined by model patterns, which are sets of elements and relationships for representing an aspect of a system, and modeling approaches specifying how to use the model patterns. To support the application of these processes, libraries have been created to provide methodology users with templates, which are sets of elements that are pre-assembled to easily implement model patterns, and work instructions to use these templates to perform Systems Engineering activities.
This model-based approach encompasses the full spectrum of Digital Engineering activities. These activities are performed within a purpose-built Digital Environment that establishes links between system development and system analyses to enable informed decision making about the system architecture.
The Digital Environment provides the capability for hosting and integrating configuration managed Authoritative Sources of Truth (ASoTs), Views, View Producers, View Consumers, and Digital Threads. View Consumers are actors (human or software) within a Digital Environment requiring access to content within an ASoT presented in a manner fit for their use. Similarly, View Producers are actors (human or software) within a Digital Environment that render Views for View Consumers. And Digital Threads are Views of a specific set of linked content, from one or more ASoTs, connected by well-defined relationships used to efficiently leverage enterprise knowledge in support of a Systems Engineering activity. The analyses that are enabled within the Digital Environment include performance analyses through simulation, compliance analyses (incl. safety and cybersecurity), and system software analyses, thus giving engineers an interoperable, scalable and collaborative ecosystem to continuously verify if designs meet requirements, thereby accelerating design cycles, eliminating rework, and reducing the need for physical testing.
The model-based approach also provides processes to support the above activities, including technical planning based on an Agile system development, and automated generation of documents and presentation of formatted artifacts, including a Methodology Handbook for use by methodology stakeholders. Moreover,

the Digital Engineering methodology itself has been developed while using the methodology. Unlike a car or a plane which are cyber-physical systems, a methodology is an abstract system, but it is a system whose components include processes and libraries. Based on this approach, the methodology can be used as is, but it can also be customized to specific usages by Methodology Engineers, be it for a specific domain (e.g., automotive, aeronautics, or medical), or for applying enterprise practices. The process of customizing the methodology is an integral part of the methodology.

During this presentation, which will be illustrated by examples, enterprise leaders will learn why adopting a well-defined DE methodology is an essential part for digitally transforming an enterprise and how to recognize when a DE methodology is well-defined. Systems Engineering leaders will learn how they can plan and lead a model-based approach for developing a well-defined DE methodology in SysML v2, and Systems Engineering practitioners will learn how they can leverage such a methodology to perform familiar Systems Engineering tasks.

Dr. Bernard Dion is an Ansys Fellow with more than 35 years of experience in Systems and Software Engineering. He holds a Ph.D. in Computer Sciences from the University of Wisconsin. He has been a Professor in Systems and Software Engineering for 10 years. He then co-founded the Esterel Technologies company to develop model-based languages, tools and methodologies for achieving efficient software certification in aeronautics, and he has deployed these tools and methodologies on a worldwide basis. More recently, while at Ansys, he has been co-developing the Digital Engineering methodology presented here, and its customization to develop safe AI-enhanced embedded software in aircraft. For the past 25 years, he has largely been involved in working groups building certification standards in aeronautics, including RTCA DO-178C for embedded software, and now the future SAE ARP6983 for embedded AI/ML in aviation.

Dr. J. Simmons is a Digital Engineering Consultant with nearly 20 years of experience in Digital and Systems Engineering. He holds a Ph.D. in Space Systems Engineering from the Air Force Institute of Technology. Dr. Simmons specializes in the development and execution of MBSE process, with an emphasis on model integration and the use of digital threads to support analytically driven decision making. His industry experience covers all corners of US Aerospace and Defense including US government, its contractors, and national labs. Before working as an independent consultant, Dr. Simmons served as a Digital Engineering manager and an internal MBSE consultant at Northrop Grumman. He is presently co-leading the development of the MBSE methodology described in this presentation.

Presentation#234

Value Methodology as an Enabler for Architectural Definition: A Case Study in Product Development

Fabien Cochet (Baker Hughes) - fabien.cochet@bakerhughes.com
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Presented on: Tuesday, 06:30-06:55 EDT

Keywords. value methodology;architecture definition process;model based systems engineering

Topics. 1.6. Systems Thinking; 15. Oil and Gas; 2.4. System Architecture/Design Definition; 3.3. Decision Analysis and/or Decision Management; 8. Energy (renewable, nuclear, etc.);

Abstract. The architectural definition process in systems engineering often struggles to generate innovative design alternatives and incorporate emerging technologies effectively, especially in established industrial contexts.

This presentation explores the potential of value methodology to complement systems engineering practice to enhance architectural conceptualization and decision-making in product development. Through a comprehensive case study based on our experience as Baker Hughes Industrial & Energy Technology (IET), we demonstrate how value methodology can serve as a structured mechanism for identifying and evaluating alternative architectural candidates, thereby expanding the design solution space and promoting innovation.

The presentation introduces value methodology principles and illustrates their application within a product development context. By sharing examples of how value methodology can be leveraged to generate and assess architectural alternatives, the study provides systems engineering practitioners and researchers with a practical framework for injecting innovative thinking into early design stages.

Furthermore, the presentation offers forward-looking insights into potential model-based systems engineering (MBSE) integration strategies.

It is aiming to highlight value methodology's transformative potential in architectural definition, offering both theoretical perspectives and practical implementation strategies for systems engineering professionals.

Presentation#57

Value of Using Large Language Models in Building Software for Systems

Mark Sherman (CMU SEI) - mssherman@sei.cmu.edu

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

Keywords. Large Language Models;Software Development;AI;Generative AI

Topics. 11. Information Technology/Telecommunication; 5.11 Artificial Intelligence, Machine Learning; 5.7. Software-Intensive Systems;

Abstract. Software has an increasing role in new systems. Improving the construction of software can be key for delivering systems on time and spec. One technique being promoted to generate software with system constraints is AI assisting developers, specifically LLMs. To determine the safety and security of the tactic, we systematically tested various LLMs to evaluate their effectiveness, and how the technology has improved over time. We have used the results of our manual evaluation of millions of line code to systematically evaluate how well these models can recognize problems in "in-the-wild" source code and provide fixes. We share the results of our investigations of using large language models for evaluation of program source code. The results are mixed but give insight as to the trustworthiness of these kinds of systems in various scenarios and applications.

(I uploaded a version of this presentation given elsewhere to provide more details on the discussion, though it would be tailored to the INCOSE audience.)

Presentation#135

When Assurance Cases are needed for Security

Mark Winstead (MITRE) - mwinstead@mitre.org

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

Keywords. Security;Cybersecurity;Assurance;Assurance Cases;Risk Management Framework;Overarching Properties;Trustworthiness

Topics. 1.1. Complexity; 2.6. Verification/Validation; 4.7. System Security (cyber-attack, anti-tamper, etc.);

Abstract. Security including cybersecurity is too commonly an exercise in prescriptive compliance but many sources in the literature indicate the needed for goal-oriented assurance cases. The scenarios for goal-oriented assurance cases include complex-adaptive systems using more cutting-edge technology as well as systems with higher consequences to security and safety incidents.
Moreover, what should these goals be? “Being secure” is too high level and vague – overarching properties of intent, correctness, innocuity, and evolvability are hypothesized as providing a framework for assurance case goals (or claims) for security.
This session will discuss at high levels assurance cases, the challenges of and place for prescriptive compliance such as the United States Risk Management Framework (RMF) and the opportunity for alternatives to create better assurance for complex systems of high consequences to safety and security, such as the use of NIST SP 800-160 Volume 1 Revision 1 which the presenter co-authored. It will conclude with a look at overarching properties to shape the goals of assurance cases for security. Participants should expect to understand the need for assurance cases and a high-level approach to shaping goals for the cases.

Key Reserve Papers

Key Reserve Paper#361

A Transformative Process for Model-Based Design Reviews

Saulius Pavalkis (Dassault Systemes) - saulius.pavalkis@3ds.com
Peter Drozdzewicz (Dassault Systemes) - Peter.Drozdzewicz@3ds.com

Keywords. Design Reviews;CDR;MBSE;PDR;SRR;SysML

Topics. 2. Aerospace; 2.5. System Integration; 3.4. Information Management Process; 3.7. Project Planning, Project Assessment, and/or Project Control; 5.3. MBSE; 5.5. Processes; 6. Defense;

Abstract. The integral role of Systems Engineering Reviews within the design ecosystem cannot be overstated. These evaluations serve as a cornerstone, instilling growing assurance among key stakeholders regarding the system's development. Although many processes now employ the context of MBSE (Model-Based Systems Engineering), the majority of systems reviews are still conducted and presented with static documents at in-person events. This paper will provide a transformative method to engineering reviews so that they can be performed in a completely digital space, by providing traceability throughout the entire review workflow process, eliminating both the need for physical in-person events, as well as the countless errors and gaps that come with static documents. The addition of MBSE-driven reviews will provide a more streamlined and sophisticated incorporation to one's MBSE ecosystem.

Key Reserve Paper#164

Enterprise Transformation Planning with UAF

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Keywords. Model-Based Enterprise Architecture;UAF;Enterprise Transformation;Business Transformation;Digital Transformation;planning;enterprise as a system

Topics. 5. City Planning (smart cities, urban planning, etc.); 5.3. MBSE; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Enterprise Transformation, Business Transformation, Digital Transformation are widely used terms in today's literature. To achieve a successful transformation proper planning is a key. Documents are widely used for this purpose today. They provide limited analytical support to the decision maker and lead to delays and failures of Enterprise Transformation. Model-based Enterprise Architecture can effectively support transformation planning by considering available resources such as systems, personnel, and technologies as well as identifying the new resources to either acquire or develop. This paper studies a city bus transportation transformation from hybrid to fully electrical using Unified Architecture Framework (UAF). It tests the feasibility of UAF and proposes a new model-based approach to efficiently apply UAF to enterprise transformation planning.

Key Reserve Paper#108

Integration of MBSE and Agile Development by Seamlessly Creating Test Plans from Model Simulations in SDV Development

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Keywords. SDV;BEV;MBSE;SysML;Agile;Verification;Test Case

Topics. 3. Automotive; 5.1. Agile Systems Engineering; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis;

Abstract. With the advent of software-defined vehicles (SDVs) such as self-driving cars and battery electric vehicles (BEVs), the automotive industry faces the most drastic change in one hundred (100) years. SDV is expected to enhance its functionality by the over-the-air (OTA) update at high frequency. The connected car concept creates new value by communicating with external systems. On the other hands, the complexity of these systems is significantly increasing due to the required software amount and the connected car concept. To ensure the quality and enhance the agility of the SDV development, many automotive manufacturers tries to introduce Model-Based Systems Engineering (MBSE) and Agile development approach concurrently. However, they are facing the difficulties to balance MBSE and Agile development because of the gap and cultural difference of these two approaches. This paper shows the methodology and practices to combine MBSE and Agile development by connecting a model and simulation to a verification planning seamlessly. The requirements, logical architecture and test cases are modeled and analyzed with Systems Modeling Language (SysML). And the System Architecture model captures the engineering information that reflects to a verification planning and actual verification. Since the requirements and needed verifications are evolved continuously in Agile development, the proposed approach can ensure the requirements, design and test cases are updated alongside each iteration without sacrificing Agility and allows high level of reuse of model and simulation to contribute in verification planning for both quality and agility.

Key Reserve Paper#128

Model-Based Systems Engineering for Industrial Systems

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Paper not presented

Keywords. MBSE;system of systems;supply chain;Industrial system;manufacturing;logistic;system analysis

Topics. 2. Aerospace; 2.2. Manufacturing Systems and Operational Aspects; 3.3. Decision Analysis and/or Decision Management; 5.3. MBSE;

Abstract. Model-Based Systems Engineering (MBSE) in a modeling and simulation approach has emerged as a critical approach for designing and managing complex systems. While traditionally applied to product development, its application to Industrial systems (e.g. Manufacturing, Supply chain) is even more important from complexity and lifecycle costs consideration. This paper explains the challenges and the benefits of MBSE for Industrial system. It develops the key systems / methodological concepts to develop Industrial Systems, in a context of a co-engineering with end-product systems. It will be illustrated on a commercial aircraft manufacturing system use case from industrial network system up to a production line system.

Panels

Panel#295

AI in systems engineering, education and skills development

Shamsnaz Bhada (Worcester Polytechnic Institute) - ssvirani@wpi.edu
Ali Raz (George Mason University) - araz@gmu.edu
Ananda Swarup (Alcon) - Annda.Das@alcon.com
Jyotirmay Gadewadikar (MITRE) - jgadewadikar@mitre.org

Presented on: Thursday, 13:00-14:25 EDT

Keywords. AI;Systems Engineering Education;INCOSE Certification;Digital Engineering

Abstract. Systems Engineering Education has traditionally followed the INCOSE handbook as a guideline for curriculum development. SE skills most commonly taught in Masters Programs originate from INCOSE Handbook and are listed below. This list was developed as part of INCOSE academic council's project on systems education for all engineers. With increasing integrations of AI within all aspects of systems engineering lifecycle we would like to re-examine this list and with experts from Industry and Academia. The questions to the panelists will be
1.What new skills are needed for the current systems engineering workforce?
2.What is the impact of AI on systems engineers and systems engineering?
3.Does this list still represent the necessary skills for an MS in systems engineering?
4.How can Industry and Academia Collaborate on filling the skill gap?

Systems Science and Fundamentals
a. Understanding Complexity
b. Systems Theory
c. Emergence
d. System Patterns
e. System Taxonomies
Systems Thinking
a. Multi-disciplines Interdependencies
b. Problem Analysis
c. Total Life-cycle View
d. Multiple and holistic perspectives
e. System definition, purpose, scoping
f. Users / stakeholders
g. Context and environment
Design and Analysis
a. Systems Architecture and Analysis
b. System Modeling
c. Requirements Analysis
d. Trade off and decision analysis
e. Dealing with complexity
f. Systems Integration
g. Verification &Validation
h. Concept of Operations (CONOPS)
i. Design reviews
j. -ilities (inc. reliability, availability,

supportability, producibility, security,
safety, usability, affordability, sustainability)
Technical and Project Management
a. Dealing with Uncertainties and Change
b. Risk/opportunities
c. Life-cycle models
d. Project Planning and Performance
e. Configuration management and control
f. Requirements Management
g. Milestone Reviews (program & technical)

Biography

Shamsnaz Bhada (Worcester Polytechnic Institute) - ssvirani@wpi.edu

Shamsnaz Virani Bhada is an Assistant Professor in Systems Engineering Program at Worcester Polytechnic Institute (WPI). Dr. Bhada's research interests include Model Based Systems Engineering (MBSE), Systems Engineering Education and Engineering and Public Policy. Her research as received funding from National Science foundation, Veterans Affairs, MITRE and Department of Defense.

Position Paper

INCOSE is at the forefront of the AI integration within its technical processes, management and education. As a systems engineering educator, I have used AI and ML in my research and collaborated with INCOSE fellows to integrated them within our courses. While students and generative AI are getting sophisticated in building Systems Engineering Management Plans(SEMP) and other systems engineering artifacts, it is difficult to police them and or evaluate them. I struggle with my role(educator/ trainer) within the classroom. Do I teach students prompt engineering to help generate the best possible SEMP or critical evaluation skills or both. How will this impact my course design and will I still satisfy my learning objectives for the course. Another challenge is the AI technology keep evolving, and they are not always reliable and therefore need new prompts and evaluations. While there is promise of AI in accelerating Systems Engineering by automatic generation of its artifacts, I will discuss the need of critical skills such as critical thinking, pattern and anti pattern detection, public policy and governance required for Systems Engineering professionals to master the constantly evolving AI technology and its adoption in Systems Engineering.

Ali Raz (George Mason University) - araz@gmu.edu

Ali K. Raz is a professor in the Department of Systems Engineering and Operations Research at George Mason University's College of Engineering and Computing. His research focuses on understanding the collaborative nature of autonomy and developing systems engineering methodologies for integrating autonomous systems. Raz's research brings a systems engineering perspective, particularly inspired by complex adaptive systems, to information fusion and artificial intelligence/machine learning technologies that form the foundations of collaborative and integrated autonomous systems.

Position Paper

Will be discussing the development of a graduate course in AI and Systems Engineering at George Mason University

Ananda Swarup (Alcon) - Annda.Das@alcon.com

Ananda is an AI Senior Manager in Data and Digital Transformation at Alcon, a medical equipment manufacturer based in Geneva, Switzerland, working from Bangalore. With over 10 years of experience in technology, consulting, and systems engineering, Ananda focuses on in solving complex problems and driving digital transformation. Ananda has tackled cold-start challenges and contributed to developing a pioneering conversational agent for a mobility company using systems engineering methods. At Alcon, Ananda focuses on the pharmaceutical sector, creating algorithms to uncover unmet patient needs from unstructured data and designing systems to enhance field-force engagement with healthcare professionals. Ananda's expertise continues to advance data and digital transformation efforts at Alcon.

Jyotirmay Gadewadikar (MITRE) - jgadewadikar@mitre.org

Jyotirmay Gadewadikar is the Chief Scientist for AI Integration and Systems Engineering at MITRE. MITRE works with the Government's national security sector, public sector, and industry to identify innovative and practical AI-enabled solutions and protective measures. In MITRE, Jyotirmay provides leadership to advance the Integration between the Systems and AI in Enterprise Applications by bringing significant resources - people, technology innovation, and knowledge-sharing processes - to scale MITRE's impact.

Position Paper

The evolving landscape of systems engineering necessitates a workforce proficient in AI, machine learning, and data science, with a strong grasp of digital engineering concepts, digital twins and model-based systems engineering (MBSE). Engineers must be agile and adaptable to keep pace with rapid technological changes, while maintaining a keen awareness of security and mitigating inadvertent results to protect AI systems and data. AI's impact on systems engineering is profound, enhancing efficiency by automating routine tasks and supporting complex decision-making, while fostering interdisciplinary collaboration with data scientists and software engineers. However, challenges such as AI inaccuracies and security vulnerabilities must be addressed. For education in systems engineering, integrating AI tools into existing courses and introducing new AI-focused courses are crucial, alongside reinforcing programming and analytics skills. Collaboration between industry and academia is vital, involving joint curriculum development, internships, research collaborations, and professional development programs to bridge skill gaps and standardize AI integration practices.

Panel#224

Bridging the Divide: Linking Architectural Specification and Verification by System Simulation

Alexander Busch (NAFEMS INCOSE SMSWG / Ansys) - alexander.busch@incose.net
Phyllis Marbach (INCOSE SMSWG) - prmarbach@gmail.com
Mike Nicolai (Siemens Digital Industry Software) - mike.nicolai@siemens.com
Saulius Pavalkis (Dassault Systemes) - saulius.pavalkis@3ds.com
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Presented on: Wednesday, 13:30-14:55 EDT

Keywords. Systems Engineering;MBSE;System-level Simulations;System Simulation;Verification;Digital Engineering

Abstract. As a follow-up to the first SMSWG panel at IS24, this panel explores the opportunities and challenges associated with integrating architectural models, e.g., developed in SysML or Capella, with system simulations represented in proprietary tools and/or standards (Modelica, FMI, SSP, SysPhs). As industries increasingly demand robust systems that perform predictably under complex conditions, the push to bridge architectural and simulation models is stronger than ever. However, despite advancements such as in standards like SysPhs, FMI, or vendor-specific point-to-point solutions, a cohesive and general link between architectural modeling and system simulation remains a challenge. Key challenges include tool implementation, methodology, model fidelity levels, parameter consistency, validation workflows, interdisciplinary communication, propagation of model elements such as state machines, and collaboration/model exchange across organizational boundaries. This panel aims to engage experts from tool vendors and the NAFEMS INCOSE SMSWG as well as attendees in a critical discussion on how to best achieve a seamless transition from architectural specifications to verification of the system by simulations, addressing both the technological and organizational obstacles along the way.
Attendees should expect to learn where to start when transitioning from architectural system models to

system simulation.

Biography

Alexander Busch (NAFEMS INCOSE SMSWG / Ansys) - alexander.busch@incose.net

Alexander Busch, Ph.D., CSEP, is a Systems Engineer for fluid-thermal systems and an expert in modeling and simulation. After holding several positions in industry, he currently works as a Senior Application Engineer at Ansys, where he is involved in model-based engineering such as Systems Engineering/MBSE and systems simulation. He is a member of both INCOSE and the INCOSE-NAFEMS Systems Modeling and Simulations Working Group where he leads the Focus Team “Refine the understanding of Systems Modeling and Simulation”. He has contributed to the German translation of the INCOSE SE Handbook v5.

Alexander received his MSc in Mechanical Engineering from the University of Applied Sciences HTW Berlin and his PhD in Energy and Process Engineering from the Norwegian University of Sciences and Technology (NTNU), Trondheim, Norway.

Position Paper

We need to advance the connectivity of the two fields by bringing people from either field together, in standardization work, in projects, in tool development, and in forums like this one. In addition to solving many technological challenges, we also have to create a foundational methodology to build a more solid bridge between MBSE and Simulation., specifically when looking at SysML and Modelica or similar language combinations. The key to connectivity between MBSE architecture modeling and system simulation is leveraging open standards and addressing practitioner challenges such as tool and standard incompatibilities, incompatible level of details, lack of methodologies, data exchange issues that come with collaboration across organizations.

Talk “Empowering Systems Engineers: Bridging MBSE and Simulation for Enhanced Analysis”

- Role of Systems Engineers in Analysis & the current gap between MBSE and Simulation

- Industry challenges: Tool & Standard incompatibilities, Incompatible level of details and Lack of methodologies, collaboration across organizations

- Technological Enablers for Bridging MBSE and Simulation

Phyllis Marbach (INCOSE SMSWG) - 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.

Position Paper

Neutral

Mike Nicolai (Siemens Digital Industry Software) - mike.nicolai@siemens.com

Dr. Mike Nicolai leads the Simcenter MBSE product portfolio, focusing on innovative tools that bridge system architecture and simulation. Under his leadership, Simcenter Studio and Simcenter System Architect empower engineers to explore novel system architectures through Generative Engineering and MBSE. The approaches are deeply driven by simulation, leveraging the capabilities of Simcenter and Artificial Intelligence to seamlessly integrate architectural design with performance analysis. Mike holds a PhD in Computational

Engineering Science from RWTH Aachen University and a master degree in Electrical Engineering from Technical University Braunschweig. His current main interests are engineering design, systems engineering, artificial intelligence, simulation, optimization and high-performance computing. Before starting at Siemens Digital Industries Software, he worked for both academia and industry, with assignments in various engineering domains - reaching from oilfield sector over medical devices up to automated driving and others.

Position Paper

The integration of system architecture, typically represented in SysML or similar modeling frameworks, with system simulation tools presents significant challenges due to the diversity and heterogeneity of the tools used for simulation, as well as the differing levels of abstraction between the architectural and simulation models. System simulation tools, whether proprietary (e.g., Simcenter Amesim) or standards-based (e.g., Modelica, FMU, SSP), are designed with specialized focuses, methodologies, and data representations, leading to potential interoperability issues.Moreover, architectural models often operate at a high level of abstraction, capturing the system's structural and functional elements, while simulation models delve into detailed dynamic behavior and physical fidelity. This disparity in abstraction levels creates difficulties in mapping elements between the two domains, aligning their assumptions, and ensuring consistency. These challenges are further compounded when attempting to maintain traceability and coherence between the architecture and the simulations throughout the system development lifecycle. Addressing these issues requires a collaborative effort to establish standards, develop translation mechanisms, and adopt tools that can bridge these gaps effectively.

Talk: Overcoming the Challenges in System Architecture and Simulation Tool Interoperability

A promising development in addressing these challenges is the introduction of the SysML v2 library concept, which offers a flexible framework for managing abstraction levels tailored to specific program, project, or organizational needs. By enabling the definition of reusable, customized libraries, SysML v2 allows teams to create models that can seamlessly align architectural elements with corresponding simulation parameters at the appropriate level of detail. This capability helps bridge the gap between the high-level perspectives of system architects and the detailed fidelity required by simulation engineers. The library concept fosters standardization where needed while supporting adaptability, enabling more effective communication, integration, and collaboration across disciplines and tools.

Saulius Pavalkis (Dassault Systemes) - saulius.pavalkis@3ds.com

Saulius Pavalkis, PhD, ESEP

- Global MBSE EcoSystem Director at Dassault Systemes, MBSE R&D Cyber Portfolio Manager – NAM.

- 20 years of MBSE adoption experience in MBSE ecosystem, digital engineering, system architecture and simulation as Cameo co-creator and consultant.

- CSE Board of Advisors the University of Texas at Arlington.

- INCOSE ESEP, OMG OCSMP, No Magic lifetime modeling and simulation excellence award.

- PhD in Software engineering in models queries.

- Owner and main contributor to largest MBSE Execution youtube community with 5300 members. Also public MBSE community owner at Dassault Systemes - go.3ds.com/cyber-systems

- Contributed to MBSE SysML based method and framework MagicGrid book and recent "Agile MBSE Coocbook" book by Bruce Douglas. Guide.

- Current contractor for NGC, former affiliate for JPL NASA for MBSE consulting, contractor for Boeing MBSE transformation.

Position Paper

We need to provide system architecture part as input for analysis and get results back. There are differences in system descriptive and analytical models but they are complimentary. We can leverage standards for connectivity e.g. FMI, SSP, or API's to connect. Ones connected the best approach could be using parametric and structure interchange similar how IoT like MQTT protocol works. We need contact connectivity and co-simulation for rapid prototyping.

Talk: Enabling Digital Engineering with Co-Simulation Across the Full Engineering Cycle, Leveraging Open Standards"

- Can we automate the engineering process through co-simulation across the entire engineering lifecycle—from user needs analysis to optimal system architecture in SysML, multiphysics analysis, manufacturing simulation, verification and validation (V&V), and the operational feedback loop using Internet of Things (IoT) technologies?

- How to get the power of open standards in building solution of the future: SysML v2, IoT (MQTT), FMU, Modelica, AI - LLM?

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. In her current role, she works closely with Development and leading customers in new product areas. Prior to joining MathWorks, Becky worked for a US government contractor doing system-level simulation for stability and controllability analysis of launch vehicles for US government satellite launches. She received a B.S. in physics and an M.S. in mechanical engineering from Michigan Technological University.

Position Paper

Simulation is hard. Building the tools and models necessary to do useful simulation at varying levels of fidelity is an involved task that requires both domain expertise and tool knowledge. But the benefit of bringing these models together at the system level and coupling them to system architectures is too great to ignore. The task at hand is to establish standards, methods, and capabilities to ease the integration of disparate domain models that may use different languages, simulation technologies, and tool chains. Lowering the barrier to full system simulation is critical to make it cost-effective for systems engineers to achieve the benefits of early trade-off studies and system verification that system simulation can provide. In addition to evolving standards that specifically aim to bring simulation to MBSE - e.g., SysML v2, SSP, and FMI/FMU - emerging AI technology can help make these models more accessible and appropriate for the system level through reduced order modeling (ROM) or model construction assisted by Large Language Models (LLMs). Validation of constructed models against the original domain models can be automated to further reduce the barrier to entry for systems engineers. We've arrived at an interesting inflection point for systems engineering, and bringing the advanced modeling and analysis techniques from the design domain into MBSE is an obvious, and challenging, next step.

Talk "Simulation without Tears: Making domain models useful in MBSE"

Panel#247

Cost Impacts of Generative AI in Systems Engineering Processes

Raymond Madachy (Naval Postgraduate School) - rjmadach@nps.edu
Barclay Brown (Collins Aerospace) - barclay.brown@collins.com
Ricardo Valerdi (University of Arizona) - rvalerdi@arizona.edu
Gan Wang (Dassault Systèmes) - gan.wang@3ds.com
Marilee Wheaton (The Aerospace Corporation) - marilee.j.wheaton@aero.org

Presented on: Wednesday, 15:30-16:55 EDT

Keywords. generative AI;system cost modeling;systems engineering processes;COSYSMO;large language models;cost estimation;economics

Abstract. The panel will discuss the cost impacts of using generative AI in systems engineering processes. A disruptive transformation is occurring on how systems engineering teams develop, deliver, and sustain systems due to AI assistance. There are corresponding new challenges in cost modeling to account for the new source of cost variance.

The goal is to better understand and quantify the cost impacts of AI. Significant effort reductions are possible with generative AI using large language models (LLMs). AI-based tools can assist in virtually all lifecycle phases and activities excepting hardware production. New parametric cost models should cover the full spectrum to estimate total lifecycle cost.

Participants will learn about a modeling and measurement framework that codifies the practices of generative AI. It is used to quantify the degree of AI assistance and cost impacts on projects, serving as a harmonized process maturity and cost model for organizations to assess financial impacts of AI adoption.

Topics to be discussed include:
- What are key best practices to leverage generative AI on projects?
- How can processes using generative AI be codified and measured for cost?
- What are the investment costs for leveraging AI in an organization?
- What are the potential cost savings and increases due to generative AI, and how do they vary by phase and activity?
- What are the effects of team size overhead on project cost reductions from AI?
- How can the SE community support empirical data collection?

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; modeling and simulation of systems and software engineering processes; affordability and tradespace analysis; integrating systems engineering and software engineering disciplines; and systems engineering tool environments.

His current research for cost modeling of generative AI in systems engineering is funded by the Naval Research Program. Previous research has been funded by diverse agencies across the DoD, National Security Agency, NASA, and several companies.

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. His upcoming book What Every Engineer Should Know about Python is currently in-press, and he is writing Systems Engineering Principles for Software Engineers. He served on the INCOSE San Diego Board of Directors from 2014 - 2018.

Position Paper

Goals of a systems engineering project include delivering the required functionality within cost and schedule budgets. Cost models are used to estimate the cost and schedule for project planning, perform tradeoff analysis, and can support many other project and organizational decisions. However, existing cost models have been broken by the advent of generative AI, introducing a new source of cost variance that appears to outweigh other factors in terms of cost impact.

AI-based tools can assist in virtually all lifecycle phases and activities, with the exception of hardware production. New cost models should cover the full spectrum to estimate total lifecycle cost. A research goal is to better understand and codify the advantages and pitfalls of integrating AI into systems engineering processes. This includes evaluating the cost benefits, challenges, and potential inefficiencies associated with over-reliance on AI. Costs encompass both organizational investments and project costs.

A modeling and measurement framework that codifies the practices of generative AI can be used to quantify the degree of AI assistance and its cost impacts on projects. The existing Constructive Systems Engineering Cost Model (COSYSMO) is a parametric model that is open and extensible to add new cost factors. A new cost factor for generative AI usage has been identified for data collection and model calibration.

We have observed that drastic reductions in effort are possible using AI assistant tools that leverage large language models (LLMs). However, the effective integration of generative AI into systems engineering is not a one-step process. Organizations need a structured approach to assess their readiness, plan their adoption, and track progress.

A new harmonized AI process maturity and cost model provides a comprehensive view of the technological, organizational, and financial aspects of AI adoption. The maturity model offers a roadmap for integrating generative AI, covering key practices such as investments in hardware and infrastructure, knowledge integration and data management, LLM customization, fine-tuning and training, and personnel training. The cost model quantifies the associated project cost impacts at the different maturity levels.

Empirical data is necessary to calibrate the updated cost model. Initial data indicates that the use of generative AI appears to cause far more cost variation than other factors. This variation can be expressed as a productivity range, suggesting that AI provides the most leverage to influence costs compared to any other project factor. Expert judgment can also be used in conjunction with project data, and the panel will provide their assessments of cost impact.

Many research questions still need to be explored: Under what conditions is AI assistance cost-effective? What is the desired form of an updated cost model? What skills and training are desirable for personnel? What are the different impacts of generative AI across the 15288 lifecycle standard activities? How is product quality affected with AI? How do productivity gains scale from individual work tasks to large, integrated product development teams?

Barclay Brown (Collins Aerospace) - barclay.brown@collins.com

Dr. Barclay R. Brown is Senior Fellow for AI Research at Collins Aerospace, a division of RTX. Before joining Collins, he was an engineering fellow in Raytheon Missiles and Defense, focusing on MBSE, and prior to that he was the Global Solution Executive for the Aerospace and Defense Industry at IBM. Dr. Brown holds a bachelor’s degree in electrical engineering, two master’s degrees in psychology and business and a PhD in industrial and systems engineering.

He is author of Engineering Intelligent Systems, published by Wiley, and is a certified Expert Systems

Engineering Professional (ESEP), certified Systems Engineering Quality Manager, and former CIO of INCOSE. He has also served as Chair of the INCOSE AI Systems Working Group.

Position Paper

The applicability of generative AI to systems engineering tasks is hard to understate. As more and more systems engineers understand its capabilities and how to best use it, it will provide more and more value. In their early days, spreadsheets running on personal computers were thought to be mainly for financial analysis—a simpler form of larger mainframe computer-based accounting and financial software systems. Today, it would be difficult or impossible to list all of the use cases for spreadsheets, even if limited only to engineering uses. It would be similarly impossible to list all use cases for a chat application like Teams or Slack by trying to identify all the possible conversations people might have. Generative AI systems are mainly language models, though language now includes not only text, but sound, speech, images, and video. These are all the communication "languages" we know of. Systems engineering is largely about communication, so we reason that it should have broad applicability. For example, anytime a body of information (say a set of requirements) must be compared to another body of information (say an industry or company standard) and the result produced in a needed form (say a report) generative AI can be applied. It is actually difficult to imagine a systems engineering task involving the rearranging, summarizing, correlating, tracing, or even deriving, where generative AI could not be of great assistance, or even automate the task entirely. When systems engineers are asked to make system-level decisions, such as selecting among design alternatives, choosing primary system architectures, or defining primary technological foundations, it is possible that generative AI may still be of assistance, but the primary agent would be the human systems engineer.

Ricardo Valerdi (University of Arizona) - rvalerdi@arizona.edu

Dr. Ricardo Valerdi is a Distinguished Outreach Professor and Head of the Department of Systems & Industrial Engineering at the University of Arizona. He is the developer of the COSYSMO model and has been involved with various collaborators (many on this panel) on improvements to the model.

He studied under Prof. Barry Boehm, developer of the COCOMO II model which was the inspiration for COSYSMO. Valerdi’s research has been funded by the Office of Naval Research, Air Force Office for Scientific Research, National Science Foundation, and Major League Baseball. He obtained a PhD from the University of Southern California and is a Fellow of INCOSE.

Valerdi is also the Founder of Science of Sport, a non-profit dedicated to inspiring STEM among K-12 students through sports examples. He has developed the Science of Baseball (used by the Dodgers, Cubs, Diamondbacks, and others), Science of Football (used by the Broncos, Cowboys, and Eagles), Science of Soccer (used by the Dynamo, Sounders, and LAFC), and Science of Basketball (used by the Knicks, Grizzlies, Spurs, and Mavericks).

Position Paper

COSYSMO has benefitted from multiple iterations of evolution since its initial version in 2005. All of COSYSMO’s improvements have been driven by users who have discovered limitations of the model or who have anticipated changes in related areas like Model-Based Systems Engineering, agile development, evolutionary acquisition, and capability maturity models. Improvements have also been motivated by the application of COSYSMO in domains outside of the U.S. aerospace and defense industry, the model’s origin.

Today we are faced with tremendous challenges and opportunities driven by the availability of AI at our fingertips. Leveraging AI in cost estimation can be done in multiple ways. The first potential benefit is speed. AI can analyze vast amounts of historical data to identify patterns and trends that humans might overlook. By learning from past projects, AI can provide more accurate cost estimates based on similar conditions, materials, and labor requirements. The second potential benefit is enhanced predictive capabilities. AI can analyze market trends, economic conditions, and historical data to predict future costs, such as fluctuations in material prices, labor rates, or regulatory changes. This allows businesses to better prepare for cost changes that may arise during the lifecycle of a project. The third potential benefit is integration with other tools. AI can integrate with other project management, financial, and enterprise resource planning (ERP) systems to provide a holistic view of the project’s cost dynamics. This ensures that cost estimations are aligned with other project data, such as schedules and resource allocation.

Realizing these benefits requires us to rethink how we work with cost models and how to “prompt engineering" which is the practice of carefully crafting instructions, or "prompts," to guide artificial intelligence models, especially large language models (LLMs), to generate specific and desired outputs by providing them with the right context and formatting to accurately interpret the user's intent.

Gan Wang (Dassault Systèmes) - gan.wang@3ds.com

Gan Wang is the Vice President for Systems Engineering Ecosystem at Dassault Systèmes, where he leads the company's systems engineering integration strategy and fosters collaboration with systems engineering communities across the industry, including industry associations and standardization bodies. His expertise spans systems engineering processes, architecture, design reuse methodology, cost estimating and analysis, and decision support techniques. Gan has been a major contributor to the COSYSMO research. Gan holds a Ph.D. from the University of Virginia and an MBA in Finance from the University of Maryland. He is an ESEP, a Fellow of INCOSE, and serves on the board of directors for the Object Management Group.

Position Paper

Generative AI has emerged as a game-changing technology with the potential to transform how we live and work. One area where it can have a profound impact is in cost estimating and analysis. Parametric cost estimating, in particular, relies on analyzing historical data and identifying patterns to predict future costs. However, collecting and analyzing large volumes of data from various projects is often tedious, time-consuming, labor-intensive, and can be woefully unattractive for those involved. As a result, there is a tendency to oversimplify and limit the scope of the data considered. As systems grow more complex and development becomes increasingly evolutionary and incremental, these challenges only intensify.

Generative AI, with its ability to process vast datasets, detect patterns, and generate predictive models, offers a powerful solution that could revolutionize cost estimating as a practice. AI can scale up data analysis, incorporate more variables, and autonomously identify the key cost drivers, thereby improving the accuracy and precision of cost models. Moreover, AI can adapt to the dynamic nature of project factors, changing stakeholder requirements and mission needs, thereby providing continuous, real-time cost estimates as projects develop. Most importantly, generative AI boosts efficiency, saves time, and frees systems engineers from tedious and repetitive tasks, enabling them to focus on more valuable and productive work. By integrating AI into parametric cost estimating, organizations not only improve decision-making but also gain a competitive advantage in today's fast-moving, data-driven world.

Marilee Wheaton (The Aerospace Corporation) - marilee.j.wheaton@aero.org

Marilee J. Wheaton is currently a Systems Engineering Fellow at The Aerospace Corporation. In this role, she is responsible for providing technical leadership and building capability across the Corporation to include enterprise systems engineering, systems architecting, digital engineering and model-based systems engineering. In previous assignments she served as a subject matter expert in cost estimating, cost model development and cost research. A long time affiliate of the USC Center for Software and Systems Engineering (CSSE), she is currently the President of the Boehm CSSE which was established to carry on the Barry Boehm legacy of research in the areas of system and software development practices and the evolution of these practices as well as the estimation of cost/schedule for all things related to software, systems, and system of systems (SoS) engineering and development.

Wheaton holds a B.A. in mathematics from California Lutheran University, an M.S. in systems engineering from the University of Southern California (USC) and is a graduate of the UCLA Executive Program in Management. Wheaton has served as adjunct faculty in the Systems Architecting and Engineering Program at USC Viterbi.

Wheaton is a Fellow of AIAA and is an active member of the Systems Engineering Technical Committee, and past Chair and longtime member of the Economics TC. Wheaton is also a Fellow and Life Member of the Society of Women Engineers (SWE) and a Fellow of the International Council on Systems Engineering (INCOSE). She served as the INCOSE President in 2022-2023.

Position Paper

With recent AI resurgence paced by generative AI and machine learning advances, several engineering disciplines including systems engineering turn to AI to improve system model accuracy, process flexibility, content exploration and search, and team productivity. All of these aspects need to be diligently considered and captured in the current cost models in use for estimating. A key aspect when we think about the impact of AI when estimating system costs is to go beyond technology and think holistically about artificial intelligence for systems engineering throughout the system life cycle. Dr. Azad Madni in his paper in the INSIGHT Special Issue, Systems Engineering and AI [Madni, 2020], focuses on how AI has become a means to augment rather than replace human capability. This perspective alters AI’s role from autonomous intelligence to what Dr. Madni defines as augmented intelligence (AugI). Madni defines AugI as teaming human and AI to capitalize on their strengths while circumventing and/or compensating for their respective limitations. Inherent in this view, he states that AI and human together can perform certain tasks better than either could alone. AI-augmented systems engineering encompasses the system, the infrastructure support facilities, and processes, and is all about human-AI collaboration.

Panel#201

Navigating Organizational Change: Transforming for a Digital Engineering Future

Frank Salvatore (SAIC) - FRANK.SALVATORE@SAIC.COM
John Forsythe (Government & Public Services (GPS))
Sanford Friedenthal (independent consultant)
Marco Ferrogalini (Airbus Group)
Thomas McDermott (Stevens Institute of Technology)

Presented on: Monday, 13:30-14:55 EDT

Keywords. Culture Change;Organizational Change;Digital Engineering;Change Management

Abstract. In the era of digital transformation, the integration of advanced technologies and methodologies into engineering practices is not just a choice but a necessity for organizations striving to remain competitive and innovative. This panel discussion, titled "Navigating Organizational Change: Transforming for a Digital Engineering Future," aims to delve into the intricate landscape of organizational change required to successfully implement a digital engineering transformation initiative.

The panel will bring together industry experts, thought leaders, and practitioners who have navigated the challenges and triumphs of driving digital engineering initiatives within their organizations. Topics to be explored include the cultural shifts necessary for embracing digital methodologies, the redefinition of roles and responsibilities, the integration of cutting-edge technologies, and the establishment of collaborative frameworks to foster cross-functional communication.

Through real-world case studies and insights, the panelists will share their experiences in overcoming resistance to change, fostering a culture of continuous learning, and aligning the workforce with the goals of a digital engineering transformation. Attendees can expect to gain actionable strategies, best practices, and valuable lessons learned to guide their organizations through the dynamic landscape of digital engineering, ensuring a seamless and successful transition into the future of engineering excellence. Join us for an engaging and enlightening discussion on charting the course for organizational change in the pursuit of a digital engineering future.

Biography

John Forsythe (Government & Public Services (GPS))

John Forsythe is a Managing Director in the Government & Public Services (GPS) Organizational

Transformation Practice of Deloitte Consulting. He specializes in helping executive clients lead change across organizational boundaries. He is the Senior Sponsor of Deloitte's GPS Culture Transformation Offering, and the Accelerating Being Digital Signature Issue. He has over thirty years of business experience, including twenty-four years in Public Services Consulting. During his career, he has led many consulting assignments, developing expertise in culture, leadership development, strategic change, organizational assessment, communications, leadership alignment and executive coaching. John also leads Deloitte's research and eminence in GPS Human Capital Trends, the single most-downloaded annual research that the Deloitte Global firm produces. He has provided strategic advice and counsel to clients from across the Government and Commercial Sectors, and his clients include the following Public Sector organizations: UNICEF, American Cancer Society, U.S. Air Force, U.S. Navy, U.S. Army, U.S. Marine Corps, Office of the Secretary of Defense, U.S. Transportation Command, Special Operations Command, U.S. Department of Commerce, U.S. Patent and Trademark Office, U.S. Department of Agriculture, U.S. Forest Service, U.S. Department of Veterans Affairs, U.S. Department of Housing and Urban Development.

Position Paper

In our work across a variety of industries, Deloitte leaders are fond of saying -the 'hard' stuff is easy, the 'soft' stuff is hard. Time and again, we see organizations struggle with digital transformation & services, not because of their technical limitations, but because of their inability to effectively build and manage their desired culture. Specifically in technology fields, we are used to systems that behave as directed and along programmed rules & guidelines. But our people are not bots – they have different beliefs, values, and behaviors driven by a collection of factors that influence organization culture. Our beliefs are individual and subconscious and often difficult to change, but collectively we can develop values that create common 'beliefs' across an organization and provide north stars the teams can galvanize around. Behaviors are the most important to drive because they are the outward manifestation of your beliefs & values. Just as beliefs & values influence your behaviors, our behaviors (much like habits) can subtly change your beliefs & values as well. To be successful, organizations to evaluate how they organize, operate, and behavior across several levers to create the environment to inculcate the desired culture. This requires leaders who can communicate effectively & model the behaviors they wish to see, talent that is rewarded & recognized for instantiating the wanted conduct, systems / procedures / policies that support the organizational goals, and a peer influence network that creates a positive feedback loop into the system. Only when we fully cultivate the right mindset can we set the conditions for the right culture to flourish and ascend from merely doing digital things to truly being a digital organization.

Sanford Friedenthal (independent consultant)

Sanford Friedenthal is an industry leader and independent consultant in model-based systems engineering (MBSE). He was formerly a Technical Fellow at Lockheed Martin, where he led the effort to enable Model-Based Systems Development (MBSD) and other advanced practices across the company. His experience includes the application of systems engineering throughout the system lifecycle from conceptual design, through development and production on a broad range of systems in aerospace and defense. Mr. Friedenthal has been a leader of the industry standards effort through the Object Management Group (OMG) and INCOSE to develop the Systems Modeling Language (OMG SysML ®) that was adopted by the OMG in 2006. He is now co-leading the effort to develop the next generation of SysML (v2). He is co-author of 'A Practical Guide to SysML' and 'Architecting Spacecraft with SysML'. He also led the effort to develop the Systems Engineering Vision 2035 for INCOSE.

Position Paper

System integrators have embarked on many improvement initiatives over the last several years to reduce development cost, schedule and risk including zero defects, total quality management (TQM), lean engineering, concurrent engineering, integrated product and process development (IPPD), capability maturity model, simulation-based design (SBD), model-based systems engineering (MBSE), and more recently digital engineering (DE). These initiatives are often difficult to sustain. A successful improvement initiative often start at a grass roots level that demonstrates success and gains credibility with leadership. Changing organizational behavior requires a champion, investment, and a focus on addressing systemic issues. A key enabler is the establishment of an improvement team represented by the stakeholders impacted by the improvement that build on existing initiatives to develop and execute continuous improvement strategies and plans.

Marco Ferrogalini (Airbus Group)

Marco Ferrogalini works for the Airbus Group leading digital transformation on the Modelling and Simulation stream within the Digital Design Manufacturing and Services (DDMS) program across all Airbus divisions (commercial aircrafts, defense and space systems and helicopters). He has been involved in complex vehicles system engineering activities, especially on the systems development and integration on sports cars, on rolling stocks and more recently on aerospace systems. He develops processes/methods/tools approaches driving towards continuous improvement. He also manages large engineering teams.

He has experience on modelling and simulation approaches (FEM, vehicle dynamics, CFD, Acoustic) with a strong focus on Model Based System Engineering (MBSE) for system operational analysis and functional/logical architectures. In the last decade he has been pioneering and leading the introduction of this approach in the railway industrial sector for two major worldwide OEMs developing end to end all processes, methods, tools, training/coaching and change management.

Marco is active in the System Engineering social networking and contributes to the INCOSE MBSE Working Group, and givs lectures on System Engineering and Model Based System Engineering in many Engineering schools. Since January 2013 he’s certified as INCOSE CSEP.

Position Paper

MBSE has been introduced a bit more than a decade ago and its adoption has been quite slow for many years, especially in not space or defense related industrial sectors. But in the last few years, there has been quite an exponential acceleration because of several factors, mega-trends on digital transformations certainly one of the most important. Here, at Airbus, we have set MBSE at the heart of the new way of working. MBSE will indeed enable us to tackle the much increased complexity of our future sustainable products but also permit us to reach our overall business target in terms of optimization of product together with its industrial system and the support in service.

Thomas McDermott (Stevens Institute of Technology)

Dr. Thomas McDermott is the Chief Technology Officer of the Systems Engineering Research Center (SERC) at Stevens Institute of Technology in Hoboken, NJ. With the SERC he develops new research strategies and is leading research on digital transformation, education, security, and artificial intelligence applications. Mr. McDermott also teaches system architecture concepts, systems thinking and decision making, and engineering leadership. He provides executive level consulting as a systems engineering and organizational strategy expert, applying systems approaches to enterprise planning. He currently serves on the Board of Directors of the International Council on Systems Engineering (INCOSE).

Position Paper

System level modeling has been in practice since there was systems engineering. The purpose of a systems level model is synthesis: the behavior and performance of the whole. Conversely, much of the up-front SE process is focused on analysis: necessary decomposition of system structure/function and work breakdowns so a system can be created by development teams. Good SE organizations maintain and use models describing a holistic view of system behavior and performance for the team in support of all the other disciplines that do the detailed design work of their functions and performance.

With SysML and MBSE tools, we now have a structured digital language and toolset to describe and visualize that system model in a form that can be digitally connected to the decomposed analysis models. A good holistic system model provides insight to the development team that cannot be gained from lower-level analysis models, and the digital infrastructure creates connectivity of the systems level behavior and performance down lower-level components and disciplines. There is nothing in the SysML language or the MBSE tools that cause these, only how they are used. Thus, no amount of investment in tools and training will drive adoption unless the workforce sees value being created from this in their daily work. The value of a digitally-connected system model has two components: it provides insight on the end product performance that improves my decision-making, and it creates digital connectivity to data and analysis models that improves my efficiency. Cultural change is essentially people showing other people better ways to accomplish their work. Really talented systems modelers are needed to create models that help others on the team make faster and better decisions, and really good software/information technology people are needed who transparently improve the team’s efficiency through the digital connectivity. The workforce needs to see these people and these benefits before they will embrace adoption of the tools and methods.

The SERC has been analyzing through survey, interviews and literature review the detailed pain points and lessons learned that are related to DE/MBSE adoption. SERC research codified 12 categories of adoption factors that must be addressed in an organizational culture to enable adoption and is building a set of detailed lessons learned around each. The bolded factors are the core value drivers, the rest are enablers or barriers. These will be discussed in the panel with the emphasis on how digitally connected system models improve decision-making and efficiency.

Panel#204

No Organization Builds Just One: The Feature-Based Path to Product Line Success

Marco Forlingieri (PTC) - marco.forlingieri@gmail.com
Prof. Dr.Danilo Beuche (PTC) - dbeuche@ptc.com
Dr. Charles Krueger (BigLever Software) - ckrueger@biglever.com
Hugo Guillermo Chale (Airbus) - hgchaleg@gmail.com
Tim Weilkiens (oose) - tim.weilkiens@oose.de

Presented on: Monday, 15:30-16:55 EDT

Keywords. Product Line Engineering;System Family Engineering;Commonality and Variability;Systematic Reuse;Feature-based;Model-based

Abstract. An organization that builds only one product is unlikely to remain competitive for long. In contrast, organizations developing multiple products often build on the legacy of past efforts. But how can they fully maximize this advantage?

Rather than relying on "accidental or opportunistic reuse," what if organizations deliberately plan for a systematic approach to sharing engineering assets — guided by features that balance commonality and variability? However, conventional systems engineering practice focuses on a single system of interest rather than holistically on the system family. This mismatch introduces significant engineering risks. Resolving this mismatch requires us to elevate the system family to be the system of interest!

The present moment offers unprecedented opportunities to master the art of product lines. Advances such as large and small language models, SysML v2, the new configuration management standard, and other emerging innovations are finally enabling product lines to become a standard approach in modern enterprises. Learn from the pioneers of product lines—across North America, Europe, and Asia, they are reshaping industries through this approach.

For the first time, the leading experts in the field will come together on a single stage. The session, moderated by the chair of the PLE Working Group, features four distinguished panellists who have shaped the history of product line engineering.

These experts have been instrumental in developing the language, tools, and methods of PLE, while pioneering its application in the aerospace, automotive, and transportation industries.

This session offers clarity and guidance to all those that would like to explore feature-based product line engineering, driving innovation and efficiency in the development of complex, sustainable and software-intensive systems.

Biography

Marco Forlingieri (PTC) - marco.forlingieri@gmail.com

He is currently serving as the Technical Representative of IBM Engineering in Southeast Asia, has gathered over 10 years of experience 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 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 and PLE, pioneering the two disciplines sin the city state.

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.

Position Paper

His perspective as an expert reflects his deep engagement with advancing Product Line Engineering (PLE) and Model-Based Systems Engineering (MBSE), supported by extensive industrial experience. Beyond his roles as an author and educator, Marco has accumulated deep practical knowledge from years in industry, consulting, and tool development, particularly in sectors such as aerospace, automotive, and defense. This hands-on background ensures that his contributions are grounded in real-world applications, making them highly relevant to engineers tackling complex challenges.

He has contribute to the literature in this field through works such as "The Four Dimensions of Variability at Airbus," "Variability on System Architecture Using Airbus MBPLE for MOFLT Framework," and "Two Variants Modeling Approaches for MBPLE at Airbus." The latter was recognized with the "Best Paper" award at the INCOSE IS 2022 in Detroit. These contributions, combined with his professional expertise, highlight Marco’s commitment to shaping the future of MBSE and PLE by integrating them into what he terms MBPLE.

From Marco’s perspective, MBPLE represents the synergy of feature-based PLE and MBSE, with architecture models serving as a pivotal but not exclusive foundation for implementing product lines and their variants. He emphasizes that feature-based PLE provides a single, independent source of variability across engineering assets, while MBSE ensures digital continuity and consistency. This combination is especially crucial for designing product lines of complex systems. As Marco succinctly puts it, “MBPLE secures a comprehensive approach to variability management and system architecture, making it indispensable for advancing engineering practices.”

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Marco is also the lead author of the first book dedicated to MBPLE, set to be published by Wiley in March 2025. This book consolidates his extensive industrial experience and theoretical expertise, offering a hands-on, simplified approach to complex concepts.

At IS2024 in Dublin, Marco's tutorial with Tim Weilkiens attracted over 50 participants, making it the most attended session of the event. Additionally, Marco organized and moderated two impactful webinar series in May 2024: "Road to IS2024 with the PLE WG" and "Road to IW2025 with the PLE WG." These series, comprising seven episodes each, showcased expert insights from various industries, fostering significant community growth. Under his leadership, the PLE Working Group expanded its membership from 420 to over 600 within 2024.

Prof. Dr.Danilo Beuche (PTC) - dbeuche@ptc.com

He works as VP of Strategy and Go-to-Market at PTC. He is the former CEO and co-founder of pure-systems, a software company that created pure::variants, a software developed for the implementation of product line technologies in embedded software systems. Danilo began his career in the field of embedded operating systems and software families in the mid-90s. His research on tool development for feature-based software development at the University of Magdeburg ultimately led to the establishment of pure-systems in 2001. Additionally, since 2016, he is serving as an honorary professor at the Institute for Information Systems (IWI) at the University of Leipzig.

Position Paper

After dedicating three decades to product lines—first as a developer grappling with the lack of tools and methods to manage the complexity of highly configurable software systems, and later as a pioneer in feature-based Product Line Engineering (FBPLE)—Danilo has witnessed its transformation into one of the most effective, if not the definitive, best practice for managing complex systems and software product lines. But now that FBPLE is established, the question arises: what remains to be done?

As a community, we must tackle the challenge of integrating the more physical aspects of engineering—mechanical and electrical disciplines, for instance—into the PLE paradigm. Only by bridging these domains can we achieve a truly holistic approach to PLE. One significant challenge lies in the differing speeds at which changes are executed across these disciplines, often leading to misalignment in product evolution.

Another critical challenge is the co-evolution of product line superset assets and derived product instance assets. Should co-evolution be avoided as an inefficiency, or embraced as a necessary and valuable process within every product line? From Danilo's perspective, co-evolution, when managed well and supported by the right tools, is not only inevitable but also a key success factor for PLE in many organizations. Tools that effectively facilitate and streamline this process can significantly enhance the benefits of PLE.

Finally, there is an ongoing debate about the relationship between MBSE and PLE, particularly the also model-based PLE approach. Are these two methodologies orthogonal, or must they be so tightly coupled that they become inseparable? He firmly stands with the view that while PLE and systems engineering are undeniably interconnected, PLE's effectiveness has been proven independently of MBSE. While MBSE offers invaluable benefits, PLE can and does succeed on its own. That said, the choice to integrate MBSE into a PLE strategy depends on the organization's needs and the complexity of the systems at hand.

Dr. Charles Krueger (BigLever Software) - ckrueger@biglever.com

He is founder and CEO of BigLever Software, which for over 20 years has helped organizations adopt and benefit from Feature-based Product Line Engineering (PLE). With more than 30 years of experience in systems and software engineering practice, he is an acknowledged thought leader in the PLE arena. Dr Krueger brings innovative PLE concepts, state-of-the-art methodologies, and success stories to the forefront of the systems engineering community. He is the lead editor for the ISO/IEC 26580 & 26581 standards on Feature-based PLE and past co-chair for the INCOSE PLE International Working Group and is a current member of the Forbes Business Council. Krueger received his PhD in computer science from Carnegie Mellon University, where he helped to pioneer the field of systems and software product lines.

Position Paper

The introduction of the Feature-base Product Line Engineering (PLE) standard, ISO/IEC 26580, finally provided a definitive answer to the question, "what is PLE?" It also presents the systems and digital engineering community with an awkward question. If virtually all complex systems engineering organizations build and deliver a product line – a family of similar systems with variations in features and functions - then why do our tools and methods teach and enable us to build the individual point solutions within a family rather than how to engineer a system family as a whole?

No matter how elegantly and precisely we weave the digital engineering fabric for individual point solutions in a family, trying to patchwork them together into a unified system family using conventional methods such as clone-and-own will always lead to non-digital engineering, with reliance on tribal knowledge to hold it all together. The result is tears, bulges, stains, wrinkles, holes, gaps and other unpleasantries in the digital fabric for the system family.

Engineering a product line, or system family, holistically is much more effective, efficient, elegant, and precise than engineering each of the systems individually. This requires us to engineer the product line as the single System of Interest, with variations formally defined to support the individual system instances within the family.

Feature-based Product Line Engineering (PLE), as defined by the new ISO/IEC 26580 standard, is the modern digital engineering approach to PLE. It now plays an essential and critical role in the new digital engineering age, while continuing to offer the engineering economies in effort, cost, time, scale and quality needed to deliver the most challenging product lines and system families.

Hugo Guillermo Chale (Airbus) - hgchaleg@gmail.com

He is Head of Product Lines and Multidisciplinary Analysis and Optimization (MDAO) at Airbus. He has over twenty-five years of experience in Systems Engineering and Product Line Engineering in the Energy, Infrastructure, Automotive, Railway and Aerospace & Defence sectors, where he has worked on the tailoring and application of SE, MBSE and PLE to the development of systems and products. Over the years, he has been particularly interested in safety-critical systems, formal methods, architecture description languages, autonomous systems, baseball and The Beatles. Guillermo holds a PhD on Energy & Thermal Systems, a Master on Energy Conversion and Internal Combustion Engines, and an Engineering Degree on Mechanical-Electrical Engineering. He is founder and former chair of the PLE International WG, former founder and chair of the Automotive WG and member of the Transportation WG and the MBSE Initiative of INCOSE.

Position Paper

Many organizations struggle to propose attractive and innovative product and service offers, while facing growing pressures to decrease costs and times to market. As product-services become smarter and highly interconnected through new technologies, their complexity continues to grow. Adding to this complexity is the inherent complexity of the business contexts, competitors and industrial landscapes of today’s world market. Statements:

1) In this context, typical clone-and-own (a.k.a. branching) have reached their limits. Organizations everywhere look for more efficient means to architect, design and produce their product-services. But even today, virtually no technological system is created from scratch, every organization performs a more or less formalized form of reuse.

2) Applying PLE in an efficient way to meet strategic business objectives through the definition of the appropriate product line, while ensuring that all product instances will satisfy the needs of specific markets and customers, is no small affair. No organization can succeed in this endeavour without a structured approach. Feature-based PLE looks like the best way to achieve this.

3) A successful implementation of PLE is far from being a technical problem. This is a systems problem that requires forethought and upfront investment, plus the alignment of all functions in the organization. If these conditions are not satisfied, AI and other advanced techniques will not help.

Tim Weilkiens (oose) - tim.weilkiens@oose.de

He is a member of the executive board of the German consulting company oose, an MBSE consultant and trainer, and an active member of the OMG and INCOSE communities. He is a co-author of the SysML v1 specification, was co-chair of the task forces responsible for the last SysML v1 versions, and is active in the ongoing work on SysML v2. He was co-chair of the task force that worked on the final submission of SysML v2. Tim is involved in many

MBSE activities, and you can meet him at several conferences about MBSE and related topics.

As a consultant, he has advised many companies in different domains. His insights into their challenges are one source of his experience that he shares in books and presentations.

Tim has written many books about modeling, including “Model-Based System Architecture”, “AI Assisted MBSE with SysML”, and Variant Modeling with SysML”. Tim is also co-author of the book Model-Based Product Line Engineering, which will be published by Wiley in March 2025.

Position Paper

As an MBSE expert in many projects and different domains for over twenty years, Tim has been repeatedly confronted with the topic of variant modeling. Strictly speaking, fewer and fewer projects describe just a single system but a system with different variations at different levels.

The INCOSE Vision 2025 predicts that MBSE will become the norm for systems engineering. This also means that common systems engineering methods must be migrated to a model-based approach. According to the newest INCOSE Vision 2035, model-based PLE will effectively leverage enterprise investments.

Tim demonstrated early on that the SysML modeling language can be used in a standard-compliant manner and independently of special tools to model system variants. He developed the language profile VAMOS, which stands for “Variant Modeling with SysML,”and published it in a book in 2016. The VAMOS profile is tool-independent. However, tool support is useful for practical use in larger projects.

He co-authored the paper “Two Variants Modeling Approaches for MBPLE at Airbus,

which was recognized with the Best Paper award at the INCOSE IS 2022 in Detroit, and which includes a practical application of VAMOS.

The tutorial on MBPLE, which Tim held together with Marco at IS2024 in Dublin, is based on a logical further development of the methods and has already included the use of SysML v2. The next-generation systems modeling language SysML v2, which also explicitly supports variant modeling, provides a solid foundation for future MBSE challenges and opportunities.

Even if SysML v2 does not explicitly support the modeling of features, this is still possible with the help of a language extension. Together with the SysML v2 API, this offers great potential for making the variability definitions of the feature model accessible to all relevant engineering tools.

Panel#385

Think Like an Ecosystem: Re-envisioning the Future of Systems on Earth

Rae Lewark (Studio SE Ltd) - rae.lewark@studiose.design
Matthew Hause (SSI) - mhause@systemxi.com
Allison Lyle (Studio SE) - allison.lyle@studioSE.design
Casey Medina (CVM Design, Inc.) - caseymedina@yahoo.com

Presented on: Tuesday, 13:30-14:55 EDT

Keywords. Ecological design;Sustainability;Nature-inspired Innovation;Interdisciplinary Collaboration

Abstract. As we progress into the 21st century, the consequences of the industrial paradigm we've followed for the past several centuries are becoming increasingly apparent. Now is the time to reimagine how we design systems—what we prioritize, how we collaborate, and the paths we choose as organizations, governments, and nations. If we continue down the current trajectory of "business as usual," we risk deepening ecological degradation, amplifying atmospheric instability, and triggering socio-economic collapse. The question we face is: how do we rethink, re-envision, and redesign our future as a species on this planet?

The solution lies in embracing nature's wisdom. By thinking like ecosystems, we can design with nature as our guide. The 3.8 billion years of evolutionary knowledge embedded in natural systems offer profound insights into how complex systems adapt, evolve, and thrive. Nature demonstrates how resources can be optimized for long-term sustainability, how outputs can be reintegrated into the system without harmful externalities, and how resilience can be built by respecting complexity and fostering emergent properties. By observing and learning from nature's designs, we can uncover new approaches to the engineering challenges we face.

Though the task ahead may seem monumental, we are uniquely positioned to drive systemic change. Systems engineering professionals, with their expertise in complex system design, are ideally suited to address the challenges of transforming industries, sectors, and even global systems. With cutting-edge technology, interconnected global knowledge networks, and an unprecedented ability to collaborate, we have the tools and capacity to accelerate the shift toward more sustainable and resilient systems.

This panel brings together a diverse group of ecological and engineering professionals to explore how principles from biological and ecological systems can inform and enhance systems design across industries and borders. Together, we will discuss strategies for integrating ecological insights into engineering practices, fostering collaboration across sectors, and accelerating the transition to a more sustainable future.

Biography

Rae Lewark (Studio SE Ltd) - rae.lewark@studiose.design

Rae Lewark is an ecologist focused on the integration of human and ecological systems. Having performed research on both the arachnid biodiversity of Ecuador and the anthropomorphic influence of ecologies in film and literature, Rae explores the intersection of environments and human behavior. An educator of natural sciences and their connection with the arts, Rae’s work is founded on the intersection of research and creativity. A free dive athlete and trainer, she believes strongly that the integration of humans and the environment begins with reconnecting to nature. If she isn’t writing about ecology, or hunting down new spider species, you can find her enjoying the planet's many underwater ecosystems.

Position Paper

Rae Lewark, as an ecologist with extensive experience collaborating within the engineering field, I am deeply passionate about the integration of human and ecological systems through the lens of inter-industry innovation. I firmly believe that the future of engineering lies in a symbiotic relationship with the natural world, where ecological principles are not just considered but are central to the design process. As a staunch advocate for the environment with the ability to speak the language of engineering, I serve as a liaison in the systems engineering design process, helping to bridge the gap between ecological knowledge and engineering practices. By incorporating ecological information into engineering systems, I believe we can foster resilience, efficiency, and longevity as emergent properties of the solutions we create. Far from being a limitation, nature offers profound insights into how we can design systems that work in harmony with the environment, minimizing waste and optimizing resource use. Circularity and biomimicry are powerful tools for engineers to adopt, and I am dedicated to helping those in the engineering field integrate these principles into their work. On this panel, I will bring an ecological perspective that emphasizes the urgent need to reconnect humans with the natural world and to design systems that operate within the ecological limits of our planet. Sustainable system design is not just a consideration—it's a necessity for the future of our world.

The systems we design today will shape the future of life on Earth, and it is critical that we build them with a deep respect for ecological health and sustainability. As an ecologist, my primary goal is to ensure that sustainability is at the core of the engineering process. I am here to be a resource for engineers who are ready to embrace this shift toward ecological integration, helping them to design systems that are not only technically effective but also aligned with the health of the planet. Together, we can build solutions that are truly sustainable, fostering a future where both people and the planet thrive in harmony.

Matthew Hause (SSI) - mhause@systemxi.com

Matthew Hause is a Principal Engineer at SSI, this thought leader in MBSE serves as chair of the UAF group, co-chair of the OMG Reusable Asset Specification team, and a member of the OMG SysML specification team. With over 45 years of experience as a systems and software engineer, he has contributed to complex, multinational systems across industries, including power systems, command and control, SCADA, distributed control, and military applications. He has authored over 100 technical papers and is recognized for his expertise in consulting, mentoring, standards development, conference presentations, and training course development. A proud recipient of the INCOSE MBSE Propeller Hat Award, his work continues to shape the future of model-based systems engineering.

Position Paper

Matthew Hause, one of the abiding memories of my teenage years was watching Sesame Street with my younger siblings. It was initially launched in 1969 and the values and worldview presented there represented those of the era. In one segment, Sesame Street showed the garbage collection and disposal process of New York City. The garbage trucks collected refuse from around the city, loaded it onto barges, which then dumped it into the ocean. At the time, we thought nothing of it. With hindsight, this was of course a short-sighted view of the Earth and its ecosystems. The Earth's resources were treated as infinite, and no real thought was given to the long term consequences of our actions. This situation was parodied in comedy Futurama, where the trash dumped in space was threatening the Earth. Eventually, the practice of dumping trash into the ocean was stopped, and trash was disposed of in landfills, some of which have been turned into parks. Recycling has also helped to reduce the amount of refuse to be dumped into landfills.The treatment of the Earth as a literal garbage dump extended to many other areas of industry, urban development, farming, industrial waste, etc. and continued for many years. The ecology or green movement of the 60's, 70's and continuing up to today has influenced attitudes in the government, the general public, and in systems engineering. We have come to realize that the number of stakeholders involved in any system needs to include the environmental aspects or Mother Earth and nature. We also need to truly get the "Big Picture" for our engineered systems. Process control theory teaches that all the inputs and outputs in a system need to be balanced for a system to be successful. Systems engineers model the inputs and outputs of their systems and well as any interacting systems. Enterprise architects perform the same balancing act for the drivers and outcomes in their architecture descriptions, as well as the inputs and outputs in their constituent systems of systems. As in all systems there must be balance. We need to ensure that the effort is universal as we only have one atmosphere and one oceanic water system of systems. And we need to ensure that the economic stakeholders are also respected. One recent example where the economics were ignored in favor of the ecology was Sri Lanka, which nearly bankrupted itself by converting their agriculture and economy to green too quickly and ignored the societal effects. Those who suffered the most were those at the lower end of the economic scale.What is needed is a gradual approach where we move towards these green technologies while weighing the effects on society, the economy, as well as the ecology. A short-term attitude or over-emphasis on any of the factors in a system is never a good idea. We need to ensure viable and sustainable systems, or we will fail to achieve our goals. We also need to support multiple technologies rather than single sourcing technological solutions. We must for example, explore both electrical and hydrogen powered transportation systems. By pursuing multiple solutions, we have alternatives should one prove unworkable. In other words, we need to engineer the future as systems engineers with our eyes wide open, evaluating and re-evaluating our choices, humbly admitting when we are wrong, and provide the guidance and wisdom that industry and government need to forge a future for all humans and for the rest of the planet

Allison Lyle (Studio SE) - allison.lyle@studioSE.design

Allison Lyle is a trainer and engineering consultant specializing in systems thinking for interconnected physical, ecological, and social systems. She leverages Model-Based Systems Engineering (MBSE) to design resilient systems, with expertise spanning medical devices and sustainability. Allison has led projects through the full product lifecycle, including design, regulatory approval, and commercialization. Now focused on upstream systems, she explores how technical and biological resources support health, happiness, and economies. With degrees in Mechanical Engineering (B.S., M.S.) from the University of Colorado and a B.A. in

Communications from the University of Iowa, her work bridges people, systems, and their environments.

Position Paper

Allison Lyle, as an engineer and systems thinker, I am deeply committed to designing resilient, sustainable solutions that address the complex, interconnected challenges of our time—spanning the physical, ecological, and social domains. With extensive experience in Model-Based Systems Engineering (MBSE), I have gained a comprehensive understanding of the product lifecycle, from regulatory approval to commercialization. This broad expertise has shaped my approach to solving systems engineering challenges and given me a diverse perspective on how to integrate sustainability into every stage of the engineering process. I firmly believe that integrating ecological considerations into engineering practices should not just be a priority—it must be a top priority for the industry. As we face escalating environmental pressures, including climate change, resource depletion, and biodiversity loss, engineers have a critical responsibility to adopt a holistic, systems-based approach. This means accounting for the long-term health of ecosystems as an integral part of our work, alongside the economic and social systems that depend on them. In my work, I have developed a keen awareness of the ecological risks our future faces, and I advocate for sustainability to be central to all engineering endeavors. I see sustainability as both an ethical obligation and a technical necessity. Engineers are uniquely positioned to drive positive change, shaping systems that not only solve technical problems but also contribute to ecological resilience, economic sustainability, and human well-being. The solutions we design today will determine the health of our planet—and the quality of life for future generations. In this panel, I will emphasize the critical role engineering and technical solutions can play in bridging the gap between ecological resilience, economic sustainability, and human well-being. Drawing on systems thinking principles, I will advocate for a balanced, integrated approach—one that recognizes the intricate dependencies between environmental, economic, and societal factors. Engineers have a unique opportunity—and responsibility—to design systems that are not only effective and efficient but also sustainable and resilient. The future depends on our ability to create solutions that work in harmony with nature, ensuring a sustainable and thriving world for all.

Casey Medina (CVM Design, Inc.) - caseymedina@yahoo.com

Casey, owner of Studio SE, is a seasoned instructor and dynamic speaker specializing in Systems Engineering, MBSE, and product development. His company provides pragmatic training programs that transform individuals into effective practitioners across industries, equipping teams with the skills needed for today’s digital engineering challenges. With expertise in requirements engineering, MBSE methods, system architecture, risk management, human factors, and verification, Casey has trained countless professionals in best practices. He holds multiple patents in medical device development, with several more pending. Frequently invited to speak at professional societies and universities, Casey is recognized as a leader in his field.

Position Paper

Casey Medina, with experience across a broad range of systems engineering sectors, I have developed a deep understanding of the complex challenges engineers face when integrating new operational goals into existing systems. Whether adapting to evolving technologies or responding to changing market demands, systems engineers must continuously navigate the complexities of balancing stakeholder needs, technical constraints, and operational objectives. In today’s environment, however, there is an added layer of complexity: the increasing degradation of our planet's ecosystems due to industrial activity. This challenge underscores the urgent need to incorporate sustainability into the systems engineering process, ensuring that the systems we design are not only effective but also environmentally responsible and resilient. As the moderator for this panel, I will leverage my broad understanding of systems engineering principles alongside my strong support for the strategic integration of sustainability and ecological considerations into system design. The integration of ecological data and sustainability goals into systems engineering is no longer optional—it is an imperative for ensuring long-term viability and resilience. I will highlight the importance of embedding sustainability at every stage of the systems engineering lifecycle, from concept and design through deployment and maintenance. This approach requires systems engineers to think holistically, considering not just the technical requirements of the system, but its broader environmental and societal impacts as well. Moreover, I will emphasize the need for a diverse group of professionals to be involved in the conversation surrounding sustainable engineering solutions. Given the complexity of the challenges we face, it is essential that systems engineers collaborate with experts from various disciplines—ecologists, economists, sociologists, and policymakers—while maintaining a strong commitment to systems engineering best practices. Successful integration of sustainability into systems design requires input from all relevant stakeholders to ensure that solutions are both technically feasible and aligned with environmental, economic, and social goals. At the same time, we must remain grounded in the principles of systems engineering to ensure that the solutions we develop are robust, efficient, and scalable. Ultimately, my goal is to foster a conversation that highlights the critical role of systems engineers in shaping a sustainable future, while also reinforcing the importance of maintaining high standards of technical excellence in every aspect of our work.

Tutorials

Tutorial#325

Approaches and Concepts to facilitate Digital Transformation in Systems Engineering

Alexander Busch (Ansys / NAFEMS INCOSE SMSWG) - alexander.busch@ansys.com
Alexandre Luc (Ansys) - alexandre.luc@ansys.com
Subodh Chaudhari (Ansys) - subodh.chaudhari@ansys.com

Presented on: Sunday, 08:00-17:00 EDT

Keywords. Digital Transformation;Systems Engineering;Model-Based Systems Engineering (MBSE);Simulation Process and Data Management (SPDM);Multi-Disciplinary Analysis and Optimization (MDAO);Solver Orchestration;Trade Studies;Sensitivity Analysis;Virtual Verification and Validation (V&V);System Architecture;Collaborative Engineering;Digital Engineering (DE);Requirements Verification;Real-Time Collaboration;Systems Modeling

Topics. 2.4. System Architecture/Design Definition; 2.6. Verification/Validation; 3.3. Decision Analysis and/or Decision Management; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis;

Abstract. This tutorial explores the core concepts and approaches driving the Digital Transformation of Systems Engineering, focusing on Model-Based Systems Engineering (MBSE), Simulation Process and Data Management (SPDM), and Multi-Disciplinary Analysis and Optimization (MDAO). Participants will learn to integrate these methodologies to streamline workflows, optimize designs, and foster collaboration. The session blends educational concepts with hands-on activities, providing practical experience through tool-based workflows. Topics include real-time SysMLv2 modeling, connectivity to analysis and simulation tools, trade studies, virtual verification, and SPDM governance to ensure traceability. Participants will gain insights into how these approaches enhance efficiency and decision-making across various tools and systems in system design and analysis.
All tools utilized (except the SPDM system) are available in the INCOSE SE Lab.

Tutorial#346

Beyond Traditional Engineering: Transformative Approaches for a Changing World

Elena Gallego Palacios (Spain - AEIS) - elena.egp@gmail.com

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

Keywords. Systems Engineering (SE);Complexity;Transformation;Model-Based Systems Engineering (MBSE);Artificial Intelligence (AI);Product Line Engineering (PLE);Agility;Digital Infrastructure;Interoperability;Collaboration;Systems-of-Systems

Topics. 1.1. Complexity; 2. Aerospace; 5.5. Processes; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. As systems grow more complex, traditional engineering practices can no longer keep up. This tutorial will explore how modern methodologies—such as Model-Based Systems Engineering (MBSE), Product Line Engineering (PLE), Agile practices, and Artificial Intelligence (AI)—can drive the transformation of Systems Engineering (SE) to address these challenges. The session will delve into the evolution of systems from standalone assets to interconnected systems-of-systems, particularly focusing on how advancements in defense technology exemplify these shifts. Real-world examples will highlight the challenges of interoperability, evolving architectures, and cross-team collaboration.

We will discuss how AI enhances MBSE by automating model validation and optimizing system configurations, and how PLE supports efficient management of product families using AI-driven analysis. Agile SE principles will be explored for adapting to dynamic requirements. Additionally, we will cover the importance of digital infrastructure, and collaborative platforms, to support decision-making and optimize system configurations.

Participants will gain actionable insights on how to transform traditional SE practices, align them with organizational goals, and foster innovation. By the end of the session, attendees will have a deeper understanding of how to manage increasing complexity in system development and improve efficiency, agility, and collaboration across organizations.

Tutorial#200

Cybersecurity Tutorial: A Model-Base Approach to Risk Analysis and Mitigation

Marco Bimbi (The MathWorks) - marcob@mathworks.com
Martin Becker (The MathWorks) - mbecker@mathworks.com
Josh Kahn (The MathWorks) - joshkahn@mathworks.com

Presented on: Saturday, 08:00-12:00 EDT

Keywords. Cybersecurity; MBSE; TARA; SRA; STRIDE; Attack Injection; security goal; DO-356; ISO/SAE 21434

Topics. 14. Autonomous Systems; 2. Aerospace; 3. Automotive; 4.6. System Safety; 4.7. System Security (cyber-attack, anti-tamper, etc.); 5.3. MBSE

Abstract.

Cyberattacks are on the rise, targeting embedded systems in industries such as consumer electronics, cars, and critical infrastructure. For example, several car brands had weaknesses allowing anything from remote-controlling the brakes during driving to theft of a vehicle within 30 seconds. As a result, many industries have now established cybersecurity standards (e.g., DO-356, ISO/SAE 21434, IEC 62443, and the Cyber Resilience Act) that require a structured security risk analysis to anticipate weaknesses during early development and define security features that protect these systems from attacks.

A wealth of metadata including threats, attack vectors, and impact rating must be captured, analyzed to deduce risk factors, and kept consistent throughout the development phase. This data must also be updated over the whole product life cycle in response to security incidents after production.

This hands-on workshop walks the attendees through a full workflow that manages security risks efficiently and consistently with a Model-Based Approach. Participants will learn:

• Fundamentals of Model-Based Design in the context of security risk analysis

• Asset and threat identification (STRIDE method)

• Feasibility estimation (attack potential method)

• Severity assessment (attack simulation method)

• Integration with safety data like FHA and FMEA

• Countermeasure definition, goal allocation, and residual risk calculation

• Verification and validation of security goals

• Change analysis to track design changes and keeping risk data consistent

Biography

Marco Bimbi (The MathWorks) - marcob@mathworks.com

Marco Bimbi is a Principal Application Engineer focusing on Model Based Systems Engineering workflows for safety critical applications. Marco joined MathWorks in 2022. Before joining The MathWorks, he has worked for 10+ years in aerospace as well as rails industries such as Rolls-Royce and Deutsche Bahn, focusing on Systems Engineering workflows for safety critical applications. During his career he held various roles such as Control Systems Architect, Model Based Systems Engineering Specialist and Requirements Manager. At MathWorks Marco helps customers to leverage MathWorks toolchain, including System Composer, for their Systems Engineering workflow. Moreover, Marco provides industry insight to the MathWorks development team to drive future product capabilities.

Position Paper

Marco Bimbi: M.Sc. Aerospace Engineering (Flight Dynamics & Control Theory), University of Pisa B.Sc. Aerospace Engineering, University of Pisa

Marco Bimbi is a Principal Application Engineer focusing on Model Based Systems Engineering workflows for safety critical applications. During his career he held various roles such as Control Systems Architect, Model

Based Systems Engineering Specialist and Requirements Manager. At MathWorks Marco helps customers to leverage MathWorks toolchain, including System Composer, for their Systems Engineering workflow.

Martin Becker (The MathWorks) - mbecker@mathworks.com

Martin Becker is a Principal Application Engineer at The MathWorks and an independent security researcher. He received his Ph.D. in software verification from Technical University of Munich for his work on real-time computer systems, and has 20 years of experience in embedded systems, amongst others working as avionics engineer at Airbus Defense & Space, Research Engineer at Tata Consultancy Services, and Lecturer at Singapore Institute of Technology. In his daily work, he supports customers from all industries in the efficient development of safety-critical software and certification according to industrial standards, accompanies the development of innovative verification tools, and uses them himself as an ethical hacker in the field of FOSS software.

Position Paper

Martin Becker: Dr.-Ing. (PhD) Electrical and Computer Engineering, Technical University of Munich. M.Sc. Electrical Engineering, Technical University of Munich. B.Sc. Electrical Engineering, University of Cooperative Education, Ravensburg. CyberSecurity Specialist, TÜV Rheinland, #872/23,

Martin Becker is a Principal Application Engineer at The MathWorks and an independent security researcher. In his daily work, he supports customers from all industries in the efficient development of safety-critical software and certification according to industrial standards, accompanies the development of innovative verification tools, and uses them himself as an ethical hacker in the field of FOSS software.

Josh Kahn (The MathWorks) - joshkahn@mathworks.com

Josh Kahn is a Senior Application Engineer focused on Model-Based Systems Engineering at MathWorks. Josh joined MathWorks in 2020, bringing with him ten years of experience in the aviation industry, including leading system development and integration of both military and commercial avionics systems and qualification and test of mechanical and software components. Josh has two primary responsibilities at MathWorks with the first being collaborating with trusted business partners to refine and drive systems engineering best practices, leveraging integrated tools, including System Composer, and the second providing industry insight to development to further drive product capabilities. Most recently, Josh co-authored a paper based on the Electronic System Architecture Modeling (eSAM) methodology being jointly developed with Gulfstream Aerospace Corporation that won Best of Session at the 2023 Digital Avionics Systems Conference and last year co-authored a paper that won Best of Conference.

Position Paper

Josh Kahn: ME Space Systems Engineering, University of Michigan BS Mechanical Engineering, Florida Atlantic University

Josh Kahn is a Senior Application Engineer focused on Model-Based Systems Engineering at MathWorks. He brings with him ten years of experience in the aviation industry, including leading system development and integration of both military and commercial avionics systems and qualification and test of mechanical and software components.

Tutorial#35

Decision Making Strategies for Systems Engineers

Ricardo Valerdi (University of Arizona) - rvalerdi@arizona.edu
Alejandro Salado (University of Arizona) - alejandrosalado@arizona.edu

Presented on: Sunday, 08:00-17:00 EDT

Keywords. Decision making; biases emotional; intelligence

Topics. 1.6. Systems Thinking; 3.3. Decision Analysis and/or Decision Management; 9. Enterprise SE (organization, policies, knowledge, etc.); Other domain

Abstract.

In today's fast-paced and complex world, the ability to make informed decisions is crucial for personal and professional success. Systems engineers are often involved with key decisions that have the potential to make or break a project.

Despite their best intentions, people continue to make bad decisions. The challenge is that we often don't know why or how to become better at decision making.

This tutorial will focus on essential tools and techniques to navigate the range of decisions that systems engineers face in their workplace—from selecting a subcontractor to hiring key personnel or assessing a business case.

This will be a highly interactive tutorial. Specifically, participants will apply various decision-making models, cognitive biases, and emotional influences that can impact their choices. By design, sufficient time will be included in the tutorial for participants to share their experiences with others and obtain feedback on their approaches. Participants will be provided with a short workbook where they can document insights from case studies discussed during the tutorial and tools that they can apply to their personal and professional lives.

The main learning objectives of this tutorial are (1) participants will sharpen their critical thinking skills and (2) participants will enhance their ability to analyze situations effectively.

This tutorial aligns with SEBoK "Decision Management" topic (Part 3: SE and Management/Systems Engineering Management/Decision Management)

https://sebokwiki.org/wiki/Decision_Management

This tutorial also aligns with Chapter 5.3 of the INCOSE Handbook, Decision Management Process which is part of the Systems Engineering Professional Exam (ASEP/CSEP).

Biography

Ricardo Valerdi (University of Arizona) - rvalerdi@arizona.edu

Ricardo Valerdi, Ph.D. University of Southern California, is a Distinguished Outreach Professor and Head of the Department of Systems & Industrial Engineering. He is a Fellow of INCOSE.

Ricardo Valerdi has helped a variety of organizations make decisions, including SpaceX, U.S. Army, Major

League Baseball, and the National Collegiate Athletics Association. He recently finished writing a book on decisions making titled “Five Tools for Great Decision Making” and is co-teaching a university course (with Salado) on decision making.

Alejandro Salado (University of Arizona) - alejandrosalado@arizona.edu

Alejandro Salado, Ph.D. Stevens Institute of Technology, is an Associate Professor and Director of Systems Engineering in the Department of Systems & Industrial Engineering at the University of Arizona. He is INCOSE Director of Academic Matters.

Alejandro Salado has been teaching decision making at the undergraduate and graduate level for over 7 years. He has also provided corporate training and/or consulting related to decision making to a variety of organizations, including the U.S. Army, Apple, Grupo Oesia, and Thales Alenia Space. He recently finished writing a book on decision making titled “Principles of Decision Analysis for Engineers.”

Tutorial#95

Developing Custom LLMs for Systems Engineering

Ryan Bell (Naval Postgraduate School) - ryan.bell@nps.edu
Raymond Madachy (Naval Postgraduate School) - rjmadach@nps.edu
Ryan Longshore (Naval Postgraduate School) - ryan.longshore@nps.edu

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

Keywords. Systems Engineering; AI; Large Language Model (LLM); Custom LLMs; Fine-tuning; Domain-Specific AI

Topics. 1. Academia (curricula, course life cycle, etc.); 2. Aerospace; 5.11 Artificial Intelligence; Machine Learning; 5.12 Automation; 5.4. Modeling/Simulation/Analysis; 6. Defense

Abstract.

Accessible large language models (LLMs) are a much needed tool in the systems engineer's arsenal for managing, modeling, and understanding complex sociotechnical systems. This tutorial focuses on developing custom LLMs designed to perform systems engineering specific tasks to address domain-specific needs and workflows. Attendees will gain hands-on experience in designing and evaluating fine-tuned LLMs. Using Llama factory, participants will create their own fine-tuned models, trained on a systems engineering specific dataset. Participants will collaboratively structure evaluation datasets—such as multiple-choice questions, fill-in-the-blank tasks, or textual response prompts for model evaluation.

The tutorial culminates with a comprehensive evaluation of the custom LLM versus the fine-tuned LLM with a custom benchmark or SysEngBench, a systems engineering domain specific benchmark. Participants will gain practical insights into optimizing model performance, balancing accuracy with computational efficiency, and tailoring LLMs to meet the nuanced demands of systems engineering. By the end of the workshop, attendees will possess the practical technical expertise and methodological framework necessary to create impactful AI solutions that advance the practice of systems engineering.

Biography

Ryan Bell (Naval Postgraduate School) - ryan.bell@nps.edu

Ryan Bell is an 8 year experienced engineer in the defense industry. In his current role at Naval Information Warfare Center Atlantic (NIWC LANT), Ryan provides modeling and simulation expertise to a variety of programs for the Navy and USMC. He specializes in simulating communication systems in complex environments. Ryan earned a BS in Electrical Engineering from Clemson University, a MS in Electrical Engineering from Clemson University with a focus on Electronics, and is currently pursuing his PhD in Systems Engineering at the Naval Postgraduate School. He is a South Carolina registered Professional Engineer (PE), published author, and teacher.

Mr. Bell is a practicing systems engineer who has developed, taught, and led hundreds of students across several sessions of a Fundamentals of Engineering (FE) review course for electrical and computer systems. He is a published author that has contributed to electrical analysis and devices and power electronic circuits chapters to Professional Engineer (PE) exam books. He has also taught hundreds of students at all levels of circuits laboratories as a teaching assistant (TA). He is conducting his graduate research on the use of language models for systems engineering. He has presented research at INCOSE IS 2024 and other forums.

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; modeling and simulation of systems and software engineering processes; affordability and tradespace analysis; 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.

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. His upcoming book What Every Engineer Should Know about Python is in press, and he is writing Systems Engineering Principles for Software Engineers.

Dr. Madachy is a full tenured Professor at NPS. His current research focuses on using generative AI in systems engineering. He teaches modeling and simulation, system software engineering, engineering economics and cost estimation. 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 include five books.

He has presented conference tutorials at IS and others for open source system modeling, cost modeling, process simulation and system dynamics.

He is also lead developer for the open-source Systems Engineering Library (se-lib).

Ryan Longshore (Naval Postgraduate School) - ryan.longshore@nps.edu

Ryan Longshore is a 19 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 Postgraduate 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.

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#12

Enterprise SE: A New Discipline for Transforming the Enterprise

James Martin (Aerospace Corporation) - martinqzx@gmail.com

Presented on: Saturday, 08:00-12:00 EDT

Keywords. enterprise transformation;enterprise systems engineering;enterprise architecture;systems approach;portfolio management;capability roadmapping

Topics. 2.1. Business or Mission Analysis; 20. Industry 4.0 & Society 5.0; 22. Social/Sociotechnical and Economic Systems; 3.3. Decision Analysis and/or Decision Management; 3.7. Project Planning, Project Assessment, and/or Project Control; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Systems Engineering as a profession is failing to keep pace with the rapidly changing world situation, and we need to embrace enterprise transformation as a way to address these challenges. Enterprise Systems Engineering (ESE) processes and methods can provide the ways and means that are essential for helping us manage increasing complexity, as well as improve the quality and timeliness of key decisions regarding enterprise capabilities, and adjust the portfolios of programs, projects, systems, services, and organizations that underpin those capabilities. Enabling the cost-effective and timely resolution of strategic and operational capability gaps and shortfalls will ensure more efficient use of limited time and resources and will increase the likelihood of achieving enterprise goals and objectives.

An ESE-enabled enterprise is better able to conduct trades across competing concerns about strategy, policy, capability, operations, and implementation, in a similar way that traditional SE practice performs tradeoff analyses among the functions, performance, physical parameters and structure to help realize more effective systems. This approach will result in more robust business and mission analyses, more balanced plans and deliveries, and more highly integrated collections of systems, products, and services to rapidly meet evolving enterprise objectives. This tutorial explores the nature of Enterprise Systems Engineering, the various roles that ESE can play in enterprise transformation, and the value and application of Enterprise Architecture at the Enterprise level.

Tutorial#113

From Legacy to Product Lines: A hands-on journey on Product Line Engineering for Multi-Level Systems

Marco Forlingieri (INCOSE PLE WG) - marco.forlingieri@gmail.com
Rachna Harsh (PTC) - rharsh@ptc.com
Davi Henrique de Sousa Pinto (Airbus) - davihenrique.sousa@outlook.com
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Presented on: Saturday, 13:00-17:00 EDT

Keywords. Legacy Systems;Product Lines;Feature Modeling;Model Based Product Line Engineering (MBPLE);Multi-level systems;Variant Modeling

Topics. 2. Aerospace; 3. Automotive; 5.4. Modeling/Simulation/Analysis; 5.5. Processes; 5.6. Product Line Engineering; 6. Defense;

Abstract. This tutorial provides a comprehensive, hands-on introduction to feature-based Product Line Engineering (PLE) with a focus on transforming legacy systems into product lines.

Participants will explore foundational concepts in PLE and feature modeling, particularly how to initiate the process when working with legacy systems, under the assumption “ almost no companies build products entirely from scratch”. Through structured exercises, attendees will learn how to extract and model features from legacy artifacts, identify variation points, and understand their impact on existing requirements and SysML (and SysML v2) models.

The tutorial then goes beyond a simple system example, but expands to multi-level feature modeling techniques for complex systems. Participants will engage in advanced exercises to create feature models that cover the variability of multiple system composition levels, allowing for modular scalability and easier maintenance of variant configurations.

In addition, demonstrations on multi-level model transformations illustrate practical applications of these techniques. The session concludes with a wrap-up and Q&A, equipping participants with both foundational knowledge and actionable skills for implementing feature-based PLE in legacy and multi-level system environments.

Tutorial#170

Fundamentals of Model-based Enterprise Systems Engineering

Aurelijus Morkevicius (Dassault Systemes and Department of Information Systems Kaunas University of Technology) - aurelijus.morkevicius@3ds.com

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

Keywords. System of Systems;MBSE;Enterprise Architecture;Enterprise Systems Engineering;UAF

Topics. 5.3. MBSE; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Engineered systems encompass products, services, and enterprises. Today, systems engineering (SE) efforts frequently extend beyond the scope of engineering individual products. Many SE initiatives involve a combination of multiple products, services, and risks, effectively making their focus enterprise systems. Due to their distinct characteristics, the engineering processes, methodologies, languages, and tools used for products and enterprises differ significantly. For instance, product life cycle management (PLM) often relies on specialized PLM software, while enterprise systems typically use Enterprise Resource Planning (ERP) tools.
Similarly, the architectural frameworks employed for these systems vary. However, a common challenge arises when engineers model enterprise systems using SysML, a tool primarily designed for products. They often resort to extensive customizations to align SysML with enterprise-specific vocabularies and processes. This approach requires significant effort and financial investment to maintain and, in many cases, results in outcomes similar to what established standards like the Unified Architecture Framework (UAF) can deliver out of the box.
The goal of this tutorial is to introduce the audience to key INCOSE terminology, contemporary practices in enterprise systems engineering, and a high-level workflow leveraging UAF as a standardized tool for modeling enterprise systems.

Tutorial#64

How to Use Opaque Behaviors to Simulate Model Data

Sean Densford (3DS) - sean.densford@3ds.com
Saulius Pavalkis (Dassault Systemes) - saulius.pavalkis@3ds.com

Presented on: Sunday, 08:00-17:00 EDT

Keywords. MBSE;Parametric Diagrams;Trade Study;Opaque Behaviors;Simulation;CATIA Magic;Simulation Toolkit

Topics. 2. Aerospace; 2.1. Business or Mission Analysis; 2.4. System Architecture/Design Definition; 2.6. Verification/Validation; 3. Automotive; 3.3. Decision Analysis and/or Decision Management; 5.12 Automation; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 5.5. Processes; 6. Defense;

Abstract. Building on the presentation last year for Enhancing Parametric Diagrams using Opaque Behaviors, there has been much outreach for additional instruction. Previously, simulations needed manual input for values determined by script. This tutorial will walk users through how to take a simple trade study model and use opaque behaviors to automatically bind the calculated values during simulation removing the need for manual inputs.

Tutorial#298

Introduction to STAMP-based methods, STPA and CAST

Meaghan O'Neil (INCOSE) - meaghan.oneil@gmail.com

Presented on: Sunday, 08:00-17:00 EDT

Keywords. System Safety;STAMP;System Theoretic Accident Model and Processes;STPA;System-Theoretic Process Analysis;CAST;Causal Analysis Based on Systems Theory

Topics. 14. Autonomous Systems; 2. Aerospace; 22. Social/Sociotechnical and Economic Systems; 4.1. Human-Systems Integration; 4.6. System Safety; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.);

Abstract. This advanced full day systems engineering tutorial will introduce the STAMP (System Theoretic Accident Model and Processes) and provide hands on experience with two STAMP-based methods, STPA (System-Theoretic Process Analysis) and CAST (Causal Analysis Based on Systems Theory). STAMP is a model for accident causality that is founded in systems theory and controls theory. STAMP allows for a top-down, systems approach to safety. Alternative accident models primarily focus on reliability, failures of components and human-error. STAMP based methods provide the ability to evaluate safety considering the level of interactivity and interdependence exhibited by highly complicated or complex systems. Participants in this highly interactive tutorial will learn the foundations of STAMP and learn how to apply the CAST and STPA methods.

Tutorial#156

Introduction to SysML v2

Sanford Friedenthal (SAF Consulting) - safriedenthal@gmail.com
Frank Salvatore (SAIC) - FRANK.SALVATORE@SAIC.COM

Presented on: Saturday, 08:00-17:00 EDT

Keywords. Model Based Systems Engineering;Systems Modeling Language;Tutorial;SysML v2

Topics. 2.3. Needs and Requirements Definition; 2.4. System Architecture/Design Definition; 2.6. Verification/Validation; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 5.5. Processes; 5.9. Teaching and Training; Other domain;

Abstract. Model-based systems engineering (MBSE) formalizes the practice of systems engineering through the use of models. The Systems Modeling Language (SysML) v2 is the next-generation Systems Modeling Language to support the evolving practice of MBSE and address the challenges of increasing system complexity and technology changes. SysML v2 provides significant enhancements over SysML v1 in terms of language precision, expressiveness, regularity, interoperability, usability, and extensibility.

This tutorial provides students with an introduction to SysMl v2 language concepts using both the graphical and textual notation. The language concepts include model organization, system structure, behavior, requirements, analysis, and verification. The instructor will demonstrate the application of the language concepts to modeling a simple system with a modeling tool. This tutorial provides the student with a basic understanding of SysML v2 that will enable them to use the language to develop simple models. It also provides the foundation for the student to explore the language in more detail.

(A modeling tool will be demonstrated by the instructor and the students will be introduced to SysML v2 tools available in the INCOSE SE Tool Lab.)

Tutorial#326

Leading Modelling in Systems Engineering: From Modeller to Leader

Duncan Kemp (Ministry of Defence) - duncan@17media.co.uk
Meaghan Oneil (System Design and Strategy Ltd) - meaghan.oneil@gmail.com

Presented on: Saturday, 08:00-12:00 EDT

Keywords. Modelling;Leadership;MBSE;Cynefin;Systems Thinking

Topics. 3.5. Technical Leadership; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis;

Abstract. The Systems Engineering Vision 2035 declared that the future of SE is model based. This followed similar statements in the vision 2025 and vision 2020. Over the last 15 years we have seen significant improvements in modelling languages, tools and technical processes. Despite this the real-world application is stubbornly behind the theoretical potential.
This is recognised in the Vision 2035 that states “the adoption is uneven across industry sectors and within organizations”. As noted in [Kemp, 2024] “Growing an effective modeling capability requires clear leadership, an honest understanding of your current capability and effective organizational change management.”. It is not the technical skills that are holding back model adoption, it is the lack of effective leadership of modelling projects.
This tutorial will help experienced modellers to become effective modelling leaders.

Tutorial#149

Open Source System Modeling with Python and Generative AI

Raymond Madachy (Naval Postgraduate School) - rjmadach@nps.edu
Ryan Longshore (Naval Postgraduate School) - ryan.longshore@nps.edu
Ryan Bell (Naval Postgraduate School) - ryan.bell@nps.edu

Presented on: Saturday, 08:00-17:00 EDT

Keywords. System modeling;generative AI;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;

Abstract. The tutorial will cover open-source system modeling capabilities using Python, and immediately enable participants to implement them. Participants will rapidly model, analyze, and automatically document systems with naturally integrated models even without prior Python experience. Furthermore, they will learn best practices to leverage generative AI in the process.

The extensive Python scientific computing ecosystem lowers barriers to system modeling. It is the predominant language for systems engineering applications and serves as modeling glue. The open-source environment provides integrated capabilities for system modeling, analysis, and automatic documentation.

Modeling will include SysML v.1 and v.2, continuous and discrete event simulation, reliability, network, risk, cost, project management, and others. Models and data are integrated with a few lines of code.

Numerous examples, templates, and case studies will be provided using domain specific libraries and general utilities for computational system models and diagrams. The interoperable libraries include Systems Engineering Library (se-lib), NumPy, NetworkX, SciPy, Pandas, Matplotlib, and more. Model and data interchange with other external SysML and simulation tools will be covered.

New guidance and examples using AI assistance to support the modeling process will be presented. Participants will also learn how to incorporate open source modeling in system engineering processes and toolsets. They will understand how open source tools support rapid iterative processes and automate round-trip digital engineering while reconciling single-source truth models.

Students only need basic computer skills to modify the examples or create new models. Exercises will be simple short code statements based on self-evident and highly readable examples.

Tutorial#216

Practical Systems Engineering: Principles and Methods for Success

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

Presented on: Saturday, 08:00-17:00 EDT

Keywords. Fundamentals;Requirements analysis;Systems architecture;MBSE

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

Abstract. “I know how to draw the diagrams” … “we’ve defined our requirements” … “I applied the processes” … “we have selected a tool” … “it’s all checklists, documents, and overhead.” Systems engineering is a rich practice leveraging an evolving set of processes, methods, and tools to address problems complicated and complex. With this richness, it is easy to become lost in nuance, details, and disconnected processes. In reality, the path to systems engineering success lies in perspective, the big picture, and integration.

This tutorial demonstrates a practical approach to foundational principles and methods of systems engineering within a framework for overall project success. We focus on both understanding the problem and defining the solution as we address requirements, behavior, architecture, and V&V. Rather than treating these in isolation, the fundamentals are positioned within a flexible systems engineering framework suitable for system development tasks across the complexity spectrum. Our focus will be on eliciting the right requirements, understanding the problem and solution, enhancing communication amongst the design team and the stakeholders, and satisfying the system need, all underpinned by a model-based approach. Through discussions of the fundamental concepts integrated with sample exercises, we will maintain our focus upon the true deliverables – the system itself and overall project success.

Tutorial#241

SysML V2 Finally in Practice: An Interactive Beginner's Tutorial

Stephane Lacrampe (Obeo) - stephane.lacrampe@obeosoft.ca

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

Keywords. Hands-on;SysML v2;Modeling;MBSE;SysON

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

Abstract. This submission is made under the category "Advanced Technology Tutorial".

This half-day tutorial provides a comprehensive introduction to SysML V2, the next-generation systems modeling language, which addresses key challenges in Model-Based Systems Engineering (MBSE). Developed collaboratively by over 80 organizations since 2015, SysML V2 introduces groundbreaking innovations that enhance precision, usability, interoperability, and extensibility, making it a critical enabler of the Digital Engineering transformation.

The tutorial begins with an overview of SysML V2's key innovations, including:
- A new metamodel (KerML) that replaces UML as the foundation, offering improved formalism and flexibility.
- Dual textual and graphical syntax, enabling users to model systems in their preferred format.
- Standardized APIs to support seamless integration with other engineering tools.
- Advanced extensibility features, including predefined model libraries for domain-specific customization.
- Enhanced support for concepts such as variability, modularity, and 4D modeling.

Following this overview, participants will engage in a practical, hands-on session designed for beginners, including systems engineering practitioners with no prior experience in SysML. Using SysON, an open-source, web-based SysML V2 modeling tool, attendees will create and refine their own SysML V2 models through guided exercises. The hands-on portion will cover:
- Structure and Requirement Modeling: Using General and Interconnection Views to define system components and requirements.
- Behavior Modeling: Creating Action Flow and State Transition Views to represent dynamic system behaviors.
- Customization and Extensions: Introducing SysML V2's extensibility for domain-specific modeling needs.

The tutorial uses a flashlight system example to guide participants through modeling exercises, ensuring practical engagement with SysML V2 concepts. While the emphasis is on graphical modeling, participants will also receive a brief overview of the textual syntax to contextualize SysML V2's dual-format capabilities.

By the end of this session, participants will:
- Gain an understanding of SysML V2's innovations and how they address the limitations of SysML V1.
- Develop foundational skills for creating and reading SysML V2 models.
- Learn how tools like SysON facilitate the adoption of SysML V2 and support accessible, collaborative modeling workflows.

Participation Requirements: Attendees should bring a laptop with an internet connection (provided by the conference). No software installation is needed, as all activities will be conducted using SysON's browser-based platform.

Tutorial#139

Understanding and Applying the INCOSE SE Handbook Fifth Edition

David Walden (Sysnovation, LLC) - Dave@sysnovation.com

Presented on: Sunday, 08:00-17:00 EDT

Keywords. handbook;process;best practices;INCOSE;SE Fundamental

Topics. 5.5. Processes; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. The objective of the International Council on Systems Engineering (INCOSE) Systems Engineering Handbook (SEH) is to describe the state-of-the-good-practice for Systems Engineering (SE). It also serves as the basis for the INCOSE certification examination. The Fifth Edition of the INCOSE SEH was released in July of 2023.

The objective of this one-day tutorial is to provide a top-level overview of the latest edition of the SEH and explain how it can be used to plan, manage, and realize complex systems within the context of demanding business constraints. Participants are introduced to key SE terminology, concepts, and principles in the handbook. The participants will complete several team-based exercises to solidify the concepts being presented. Each student will receive a complete set of lecture notes and an annotated bibliography, but will not be provided a copy of the handbook.

Note: this tutorial is an overview of the handbook and does not include the level of detail typically presented in an INCOSE Systems Engineering Professional (SEP) preparation course.

INCOSE Contents

INCOSE Content#1019

'Systems of Systems': What they are and why they need 'special treatment' from System Engineers

Dr. Dan DeLaurentis (Discovery Park District Institutes) - ddelaure@purdue.edu

Presented on: Monday, 14:15-14:55 EDT

Abstract.

A System-of-Systems (SoS) is a special kind of complex system in which new capabilities arise from interacting components that are controlled with varying degrees of independence by multiple owner / operators. Sounds cool! But applying systems engineering (SE) methods and practices to SoS creates challenges, especially in building effective decision-support tools and managing interfaces that lie at the heart of making SoS valuable. This talk will present the “What, Why, and How” of SoS- at a fundamental and accessible level- and give examples of the unique challenges facing 'systems-of-systems engineers'. Next, the talk will describe key advancements made in recent years in the understanding, science, and engineering of SE at the SoS level. Finally, the talk will portray the many types of professions and expertise domains (beyond SE!) that tackling SoS...successfully!...entails.

Biography

Dr. Dan DeLaurentis (Discovery Park District Institutes) - ddelaure@purdue.edu

Dr. Daniel DeLaurentis is Vice President for Discovery Park District (DPD) Institutes at Purdue University. He researches problem formulation, modeling, design and system engineering methods for aerospace systems and especially 'systems-of-systems'. Applications have included civil and military transportation (e.g., urban air mobility, supersonic fleets), command and control for air / missile defense (e.g., hypersonic vehicles and missions), space exploration architectures, and even corn production systems. From 2018-2024, DeLaurentis served as Chief Scientist of the DoD’s Systems Engineering Research Center (SERC) UARC, addressing the systems engineering research needs of the defense community He is Senior Research Fellow at the Krach Institute for Tech Diplomacy at Purdue and a Fellow of both the International Council on Systems Engineering (INCOSE) and the American Institute of Aeronautics and Astronautics (AIAA).

INCOSE Content#1042

Addressing Sustainability through a new INCOSE Working Group

Alan Harding - alan.harding@incose.net

Presented on: Wednesday, 15:30-15:55 EDT

Abstract.

INCOSE Content#1041

AI for SE and SE for AI

Ali Raz - araz@gmu.edu

Presented on: Wednesday, 11:30-12:10 EDT

Abstract.

Building your future: Competency and career pathways in Systems Engineering

Prof. Emma Sparks (University of New South Wales Canberra) - emma.sparks@unsw.edu.au

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

Abstract.

In the dynamic field of systems engineering, early career professionals face unique challenges and opportunities. This presentation will explore the critical competencies required for success and the diverse career pathways available. We will delve into Part 5 of the Systems Engineering Body of Knowledge, focusing on how individuals can develop their skills, how teams can enhance their collective expertise, and how businesses and enterprises can foster a culture of continuous improvement. Practical approaches to competency development, including mentorship, continuous learning, and hands-on experience will be discussed. Additionally, the presentation will highlight the role of leadership in nurturing talent and driving team performance, as well as the impact of organisational support in creating an environment conducive to growth and excellence.

Biography

Prof. Emma Sparks (University of New South Wales Canberra) - emma.sparks@unsw.edu.au

Professor Emma Sparks is the Rector and Dean at UNSW Canberra. She has over 20 years' experience of working within Defence and Higher Education and is particularly passionate about innovation in educational practice. As a systems engineer focused particularly on systems thinking and human systems Emma has championed the development of non- traditional routes to higher education and the importance of STEM pipelines, leading creation of the first Level 7 apprenticeship in Systems Engineering in the UK. Her early research in the UK at the Defence Science and Technology Laboratory (DSTL), focused on human protection and performance, developing next generation soldier systems. PhD research on future soldier capability led to a long-standing relationship with DSTG in Adelaide working on the Australian Soldier Modernisation Program, part of a $35 million package to boost the Army's combat capability. She is a member of the International Council on Systems Engineering, part of the SEBOK governing board and was a contributor to the INCOSE 2035 vision. She is a Senior Fellow of the Higher Education Academy and was recognised as one of the Top 50 Women in Engineering in the UK in 2018.

INCOSE Content#1043

Conserving Energy as a Strategy for Dealing with Uncertainty and Dynamics in SE

Rick Dove - dove@parshift.com

Presented on: Wednesday, 14:30-15:00 EDT

Abstract.

INCOSE Content#1015

Deciding what to build and why…

Dinesh Verma (Stevens Institute of Technology, Systems Engineering Research Center (SERC)) - dverma@research.stevens.edu

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

Abstract.

Likely the best articulation of systems engineering was by Dr. Mike Griffin in his March 2007 Boeing Lecture "Systems Engineering and the "Two Cultures" of Engineering." An excellent systems engineer in his own right, Dr. Griffin has the ability to communicate and engage at the highest levels of leadership in government and industry.

This talk for me is personal. From my time as the Founding Dean of a new School of Systems and Enterprises at Stevens Institute of Technology to leading the Systems Engineering Research Center (the largest research center focused on Systems Engineering in the world), I try to embody the message as I speak to diverse audiences ranging from potential students to practitioners, corporate executives, and Congressional leaders. The discipline of systems engineering is relatively young from an academic perspective. Yet modern societies depend more on robust execution of systems engineering than most in society realize. How do we better frame the why, what, and how of systems engineering from the viewpoint of an audience that is non-technical – program and project managers, policy wonks, legislative staffers and leaders, and business leaders – to effectively communicate and enlist their support as we seek "a better world through a systems approach."

Biography

Dinesh Verma (Stevens Institute of Technology, Systems Engineering Research Center (SERC)) - dverma@research.stevens.edu

Dinesh Verma served as the Founding Dean of the School of Systems and Enterprises at Stevens Institute of Technology from 2007 through 2016. He currently serves as the Executive Director of the Systems Engineering Research Center (SERC), a US Department of Defense sponsored University Affiliated Research Center (UARC) along with the Acquisition Innovation Research Center (AIRC). During his twenty years at Stevens he has successfully proposed research and academic programs exceeding $200m in value. Prior to this role, he served as Technical Director at Lockheed Martin Undersea Systems in the area of adapted systems and supportability engineering. Dinesh received his PhD and M.S. in Industrial and Systems Engineering from Virginia Tech.

INCOSE Content#1020

Foundations for MBSE and Digital Engineering: Why DE is not a 101

Stephanie Chiesi (General Atomics) - schiesi@gmail.com

Presented on: Monday, 15:30-16:10 EDT

Abstract.

Digital Engineering and Digital Transformation are central themes to concepts that include model based systems engineering, model based definition, data driven decision making, and more. Where MBSE is the application of systems engineering with methodology, language, and tools to support the discipline, Digital Engineering involves multi-disciplinary practices and domains. This presentation reviews the foundations of Digital Engineering and the desired outcomes of Digital Engineering implementation to address why there is not a specific entry level, or 101, approach to starting this journey at an organization.

Biography

Stephanie Chiesi (General Atomics) - schiesi@gmail.com

Stephanie Sharo Chiesi is a SERC doctoral fellow at Stevens Institute of Technology in the School of Systems and Enterprises. She is currently the Senior Director of Engineering for the ALRE program at General Atomics Electromagnetic Systems as well as a leader in Digital Engineering and Transformation, advancing multiple startup endeavors in stealth mode. Prior to this she has held several roles in aerospace and defense including Director of Digital Engineering for Design & Prototype at Blue Origin, Chief Digital Engineer at SAIC, Senior Principal Systems Engineer at Raytheon Missiles and Defense, and senior systems engineering roles at Paragon Space Development Corporation and Draper Laboratory. Ms. Chiesi is a CSEP and member of the first cohort of the INCOSE Technical Leadership Institute, as well as an inventor with 5 awarded patents. Ms. Chiesi holds two bachelor’s degrees (Aeronautics/Astronautics and Biology) and a master’s degree in Aeronautics and Astronautics all from MIT.

INCOSE Content#1038

How are We Doing? FuSE Report Card on Realizing the Systems Engineering Vision 2035

Bill Miller - william.miller@incose.net

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

Abstract.

INCOSE Content#1047

How INCOSE is Advancing the Practice of Systems Engineering

Tami Katz - tami.katz@incose.net

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

INCOSE Content#1045

Rally the Troops! The Secret Energy Driving All Innovation Ecosystems

Bill Schindel - schindel@ictt.com

Presented on: Wednesday, 16:00-16:25 EDT

Abstract.

INCOSE Content#1039

Shaping the Future with Complex and Adaptive Systems

Mike Watson - michael.watson@incose.net
Andy Pickard (Co-Chair of the Complex Systems Working Group) - andy.pickard@incose.net
Rob Vingerhoeds - r.vingerhoeds@isae.fr
Bill Brooks

Presented on: Wednesday, 13:30-14:30 EDT

Biography

Mike Watson - michael.watson@incose.net

INCOSE Content#1044

Smarter Delivery of Infrastructure

Dale Brown - dale.brown@incose.net

Presented on: Wednesday, 16:30-16:55 EDT

Abstract.

INCOSE Content#1016

The Art of Systems Thinking

Dr. Tami Katz (BAE Systems, Inc.) - tami.katz@incose.net

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

Abstract.

The INCOSE Systems Competency Framework identifies Systems Thinking as a core systems engineering competency, and the INCOSE Systems Engineering Handbook asserts that it is a key enabler for the practice of systems engineering. Based on this, it is apparent that Systems Thinking is a foundational principle and skill for anyone aspiring to practice systems engineering. Yet, how does a new systems engineer understand how to apply this skill? This presentation provides an overview of what Systems Thinking is, methods of application in problem solving and organizational situations, and examples of good (and in some cases, not so good) applications of systems thinking in the real world.

Biography

Dr. Tami Katz (BAE Systems, Inc.) - tami.katz@incose.net

Dr. Tami Katz is a Senior Principal Systems Engineer at BAE Systems, Inc., located in Colorado, USA. Dr. Katz is certified as an International Council on Systems Engineering (INCOSE) Expert Systems Engineering Professional (ESEP) and has a Doctor of Philosophy in Systems Engineering from Colorado State University.

Dr. Katz is active in the INCOSE community, serving as Director of Technical Operations, and previously as co-chair of the INCOSE Requirements Working Group.

During her career, Dr. Katz has worked in systems and test engineering of space vehicles, performing a range of activities from design, requirements development, verification, validation, test, functional management as well as technical leadership. Over the last several years, Dr. Katz has performed extensive research into techniques towards optimizing the requirements management process, publishing multiple papers, and is a contributing author of the INCOSE Needs and Requirements Manual.

INCOSE Content#1017

The Never Ending Story of Requirements Across the Life Cycle

Jeffery Williams (University of Alabama Huntsville) - jeffery.williams@incose.net

Presented on: Monday, 11:30-12:10 EDT

Abstract.

A discussion of requirements is much more that a discussion about writing requirements. To talk requirements, we must understand the needs driving the development and evolution of systems. The solution space is driven by budget and schedule constraints that may limit options. Manufacturing capabilities and operational constraints on supportability and maintainability are constraining conditions on the solution space. As solution architectures and requirements are developed these constraints must be taken into consideration. As systems are fielded and needed changes are implemented the importance of requirements management and change impact analysis is grows importance. The tools developed because of the digital transformation will greatly in hance the system engineering responsibilities and tasks associated with requirements.

Biography

Jeffery Williams (University of Alabama Huntsville) - jeffery.williams@incose.net

Jeffery Williams is a lecturer at the University of Alabama in Huntsville where he teaches model-based systems engineering courses as well as systems engineering fundamentals and other core engineering courses. Dr. Williams retired from industry after almost 49 years with experience that spans Aerospace & Defense, Rail, and Commercial Aircraft Systems Development. Dr. Williams has stood up SE organizations from scratch while maintaining ongoing development programs. Dr. Williams has experience in program management, functional (SE) management, and engineering leadership. His experience is with both major development programs and smaller supplier development programs.

Dr. Williams has BA and MA degrees in Mathematics from the University of West Florida and Ph.D. in Applied Science from Lyle School of Engineering at Southern Methodist University.

Dr. Williams has been an INCOSE member since 2002 and continues to be engaged.

INCOSE Content#1018

Unleash the Power of Systems: A 30-Minute Introduction to Systems Engineering Architecture

Chris Hoffman (Cummins) - christopher.hoffman@incose.net

Presented on: Monday, 13:30-14:10 EDT

Abstract.

This session demystifies Systems Engineering Architecture, guiding you through its essence and purpose. Discover what architecture truly is (and isn't!), explore its critical role in successful systems, and learn how to recognize and achieve "good" architecture. We'll delve into key principles that empower you to make informed decisions throughout the system lifecycle.

This session is for but not limited to those new to the field, providing a concise and engaging introduction to the fundamentals of Systems Engineering Architecture. Leave with a deeper understanding of this crucial discipline and improved confidence to apply these concepts to your own projects.

Biography

Chris Hoffman (Cummins) - christopher.hoffman@incose.net

Chris Hoffman, a certified Expert Systems Engineering Professional with 27+ years at Cummins, is a strategic thinker who translates vision into reality. He has a proven track record of leading multi-disciplinary teams to develop complex product systems in multiple domains and guiding the strategy for over 1300 software tools, improving that portfolio's effective value year over year. As Senior Principal Enterprise Architect, Chris is currently spearheading the development of a modernized Enterprise Architecture strategy, fostering collaboration across IT and the business, and mentoring architects. A lifelong learner, Chris is the current sebokwiki.org Managing Editor and INCOSE CAB Representative for Cummins.

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