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Keynote - Plenary

Keynote - Plenary#K1

Architecting the Future: The Role of SE and DE at the NRO

Dr. Christopher J. Scolese (Director, NRO) - publicaffairs@nro.mil

Abstract.

Since its inception more than 60 years ago, the National Reconnaissance Office has worked to secure and expand the U.S. intelligence advantage by developing, acquiring, launching, and operating the world's best space-based intelligence, surveillance, and reconnaissance, or ISR, capabilities. That mission is unwavering. But the world in which we operate has changed. Over the past two years, we learned we could no longer take anything for granted. Some of the processes and systems we relied on proved unreliable. The pandemic showed that the global supply chain is fragile, and Russia's assault on Ukraine made it harder to access raw materials. Rather than bemoaning the fact that what worked in the past may not work in the future, we can embrace this changing world as an opportunity. This presentation will explore how the NRO aims to take advantage of new capabilities to be faster and more efficient, relying on systems engineers and their digital engineering tool box to mitigate risks and architect the future.

Biography

Dr. Christopher J. Scolese (Director, NRO) - publicaffairs@nro.mil
Dr. Christopher J. Scolese was sworn-in as Director, National Reconnaissance Office (NRO) on 5 August 2019. He is the 19th Director, and the first to be Presidentially Appointed and Senate Confirmed. Dr. Scolese provides direction, guidance, and supervision on matters pertaining to the NRO and executes other authorities specifically delegated by the Secretary of Defense and the Director of National Intelligence. Dr. Scolese began his government career as a United States Naval Officer in 1978, supporting a variety of Naval Nuclear Propulsion Programs for the U.S. Navy and the Department of Energy. In 1987, following a brief period of service working in government and industry, Dr. Scolese joined the National Aeronautics and Space Administration (NASA) where he was assigned to the Goddard Space Flight Center in Greenbelt, Maryland. During this period, he served in a variety of senior management positions including: Earth Observing System (EOS) Systems Manager, EOS Terra Project Manager, EOS Program Manager, and Deputy Director of Flight Programs and Projects for Earth Science. In 2001, Dr. Scolese was assigned to NASA Headquarters in Washington, D.C. where he served as the Deputy Associate Administrator in the Office of Space Science. In this position, he was responsible for the management, direction, and oversight of NASA's Space Science Flight Program, mission studies, technology development, and overall contract management of the Jet Propulsion Laboratory. In 2004, he went on to become Deputy Director, Goddard Space Flight Center, where he assisted the Director in overseeing all activities, before returning to Washington, D.C. to become NASA's Chief Engineer in 2005. As Chief Engineer, he was responsible for ensuring all development and mission operations were planned and conducted on a sound engineering basis. In 2007, he was appointed the Associate Administrator, responsible for the oversight and integration of NASA's programmatic and technical efforts. From January-July 2009, Dr. Scolese served as NASA's Acting Administrator, responsible for leading the development, design, and implementation of the nation's civil space program. In 2012, Dr. Scolese became the Director, Goddard Space Flight Center, where he led the nation's largest organization of scientists, engineers, and technologists responsible for building spacecraft, instruments, and new technology to study Earth, the sun, our solar system, and the universe. On 31 July 2019, he retired from NASA to become the Director, NRO. Dr. Scolese holds a Bachelor of Sciences degree in Electrical and Computer Engineering from the State University of New York at Buffalo, Buffalo, New York; a Master's degree in Electrical and Computer Engineering from George Washington University, Washington, DC; and a Ph.D. in Systems Engineering from George Washington University, Washington, DC. Originally from Buffalo, New York, Dr. Scolese and his wife, Dianne, currently reside in Springfield, Virginia.

Keynote - Plenary#K4

Ford’s Connected-Agile, Model Based Systems Engineering and Simulation Journey....so far.

Christopher Davey (Ford Motor Company) - cdavey2@ford.com

Abstract.

Ford Motor Company is committed to helping build a better world, where every person is free to move and pursue their dreams. This will be advanced through the delivery of outstanding Electric Vehicles (EVs) with compelling connected vehicle services, Advanced Driver Assistance Systems (ADAS) and mobility solutions including self-driving Autonomous Vehicle (AV) technologies. These System-of-System (SoS) solutions will require that we leverage a diverse, global, agile Systems Engineering team that can extract actionable information from, and respond to, real-time connected customer experience data. This presentation will describe the Ford Model Based Systems Engineering (MBSE) journey. It will describe how our MBSE solutions have evolved and adapted to different system, software and technology complexity challenges, resulting in a Connected and Integrated, Agile, Model Based Systems Engineering & Simulation solution. The presentation will provide examples of how this Systems Engineering approach has been successfully applied to EV, ADAS and AV systems analysis and design. It will discuss some lessons learned on the trade-offs encountered when balancing “just enough” formalism (ontologies and standards) with scaled agility and risk. It will conclude by discussing the power of a harmonized systems engineering-enterprise-wide, AI/ML powered, digital-twin/digital thread solution. It is a fantastic time to be a system engineer. It is also an important time for us all to contribute where-ever and how-ever we can to help solve the many significant societal challenges.

Biography

Christopher Davey (Ford Motor Company) - cdavey2@ford.com

Christopher Davey is currently Global R&A Senior Global Manager for Systems Engineering, System Safety, Modelling & Simulation and Senior Technical Leader in Software & Control Systems Engineering. He has a bachelors in Controls Systems Engineering and Masters' degrees in Advanced Systems Engineering and Engineering Management. Christopher has over 30 years of automotive experience working across global regions in diverse engineering teams such as Research, Electrical Systems, Powertrain Systems and Vehicle Program Launch. Christopher has a passion for applying advanced systems engineering and simulation methods to all aspects of innovation, design, implementation, and validation. He currently leads the application of SE, Safety and Simulation to advanced ADAS, AV and EV systems using an Integrated AI/ML based SE-Modelling & Simulation Framework. He led the team that successfully applied these agile MBSE capabilities to develop the real-time control systems for the F150 Lightening and Mustang Mach-E Electric prototypes. Previously, Mr. Davey developed and deployed Ford’s Model Based Design (MBD) and Autocode process and Ford's global In-Vehicle Software (IVS) Releasing & Updates solution. The IVS solution was launched across all global assembly plants and dealerships, delivering in a warranty avoidance of over $2Billion. He also led the development and deployment of an industry first, Global Vehicle Systems & Software Engineering Management solution (VSEM). This enterprise wide, systems engineering solution provided a functional architecture driven, fully traceability EE and SW management capability, enabling re-use and impact analysis. Mr. Davey was also a US expert in the development of the ISO26262 functional safety standard and has led Ford's roll-out of both ISO26262 & Safety of the Intended Function (SoTIF) standards. Mr. Davey is a member of INCOSE and IET, a regular contributor to NAFEMS and a Professional-Chartered Engineer with 30+ US Patents.

Keynote - Plenary#K2

Mobility and System Engineering Integration

Carla Bailo (Center for Automotive Research (CAR)) - cbailo@cargroup.org

Abstract.

The automotive and mobility industries have been experiencing undergoing dramatic shifts in the last decades. Emerging modern methodologies such as electrification, digitalization, artificial intelligence (AI), connectivity, automation, and shared mobility have collided with new ways to move people and goods. This technology is driving innovations such as mobility charging solutions, ride-hailing and sharing, and robotics. This is totally disrupting the mobility ecosystem of today and creating a much more equitable future. This presentation will review the industry and technology updates its systems engineering impact on product development, infrastructure, and more.

Biography

Carla Bailo (Center for Automotive Research (CAR)) - cbailo@cargroup.org
Carla Bailo is the President and CEO of the Center for Automotive Research (CAR), and is a leader in engineering and vehicle program management with 42 years of experience in the automotive industry. Under her leadership, CAR continues to be a preeminent resource of objective and unbiased research, analysis, and information regarding the North American automotive industry. In addition to her role at CAR, Ms. Bailo is currently an Independent Director on the corporate boards for SM Energy (SM) and Advance Auto Parts (AAP). Prior to joining CAR, she was most recently the assistant vice president for mobility research and business development at The Ohio State University. She also has 25 years of experience at Nissan North America, Inc., where she served as senior vice president of research and development. Ms. Bailo also spent 10 years at General Motors. She has a MS degree in mechanical engineering from the University of Michigan and a BS degree in mechanical engineering from Kettering University.

Keynote - Plenary#K3

The Power of connection: The power of influencing and how to do it

Laura Doughty (Director Peakfield Consultancy Ltd and currently Head of Culture and Engagement, Project Delivery Directorate, Sellafield Ltd) - laura@peakfield.com

Abstract.

It can be frustrating, even demoralising, to develop technically excellent and highly useful ideas to then have them disregarded without due consideration – sometimes without any consideration. In her talk, Laura will explain why what you develop is only part of the solution. Knowing who you need and how to connect them to your ideas is key to achieving them. She will go on to share tips and techniques for how to achieve this in a range of situations with a range of personalities. Spoiler alert, the key to influencing starts with you doing the listening. Knowing who to listen to, how to engage them and what to do with what they tell you can help you create better solutions and foster the commitment to ensure their delivery.

Biography

Laura Doughty (Director Peakfield Consultancy Ltd and currently Head of Culture and Engagement, Project Delivery Directorate, Sellafield Ltd) - laura@peakfield.com
Laura has over 25 years' experience in designing, building and leading multi-agency teams to achieve results from strategy, inception and planning through to delivery and operations. Her delivery track record reflects her approach which is centred on stakeholder engagement and the ability to foster robust relationships with multiple parties. Laura is currently supporting Sellafield Ltd, Europe's largest nuclear site, to foster the culture and stakeholder environment needed to support a 20-year industry partnership that will deliver £7 billion (GBP) of major projects. Previously she assisted High Speed 2 Ltd with the unprecedented stakeholder programme associated with a £40+ billion (GBP) new railway. She led the business change strategy and architecture for the Digital Railway, an industry-wide initiative to transform and modernise Great Britain's railway. As part of the London 2012 Olympic and Paralympic Games, Laura led multi-agency teams that saw operators, government, security and organisers come together and work in new ways to perform as 'one team transport'. She also established and led a pan-Government office for a $107 billion (AUD) sustainable urban growth infrastructure programme for Queensland, including advising Cabinet Ministers and Construction CEOs. Laura is also an Executive Coach and Mental Health First Aid Instructor. She has undertaken reviews and provided advice, facilitation and stakeholder engagement support to a wide range of organisations, including HM Treasury on the £375 billion (GBP) 2013 UK National Infrastructure Plan.

Paper

Paper#30

A 4-Box Development Model for Complex Systems Engineering

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Keywords. Development process;Vee model;System integration

Topics. 2. Aerospace; 2.5. System Integration; 5.1. Agile Systems Engineering; 5.5. Processes;

Abstract.

Over the years much Systems Engineering effort has been focused on making development activi-ties predictable. Yet, with increasing system complexity methodology improvements have a hard time keeping up. In this paper we argue that there is a need to ensure that development methodolo-gy is flexible and that development models must be crafted for ensuring that an organization has many options open if parts of the development activities becomes delayed.

This paper addresses the challenges in crafting a model that provides an adequate representation development and meets the desired level of flexibility. The underlying case is that of fighter aircraft development. The dual-Vee model is used as a baseline, weaknesses in that model are identified and the models developed within Saab Aeronautics for fighter aircraft development are introduced and illustrated. The key element highlighted in the paper is that in order to ensure flexibility, de-velopment has to be asynchronous with integration. Lessons learned are identified and the applica-bility of the proposed models are discussed.

Paper#91

A Data-Centric System Architecture Model Development Process Emphasizing Rapid Tempo and Quality

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Heidi Jugovic (SAIC) - heidi.j.jugovic@saic.com

Keywords. Systems Modeling Language (SysML);System Architecture;Model Based Systems Engineering (MBSE);Digital Engineering;Architecture Development Process

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

Abstract.

For years the Model Based Systems Engineering (MBSE) community has been armed with the Systems Modeling Language (SysML) and a host of vendor provided tools to facilitate require-ments, architecture and design development. Nonetheless, teams repeatedly struggle to apply these tools in practice because they do not have a powerful style to enable teamwork in a model and set of flexible methods to guide work which is consistent with that style. This paper seeks to offer an easy to use process for building a System Architecture Model (SAM), allowing for tai-loring to meet program-specific needs. The paper identifies and encourages the use of a variety of SAM development methods which are focused on the themes of data centricity, consistency, commonality in style, and efficiently creating content that will answer most engineering ques-tions related to architecture. This process is implemented in SysML as a “One Page Process”, and made openly available for download. Furthermore, automated validation via a rules-based engine is leveraged to catch and correct defects nearly as quickly as they are generated as well as scale SAM development across a large diverse team of contributors. By leveraging and tailoring this process to meet program needs, one may improve the quality, development tempo, and rigor of their SAM.

Paper#36

A Pragmatic MBSE Approach of Nissan Powertrain Team to Minimizing Document-Based SE

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Keywords. Model-Based System Engineering;MBSE;SysML;Functional Analysis;Performance Analysis;Verification & Validation;Functional FMEA;Simulation

Topics. 17. Sustainment (legacy systems, re-engineering, etc.); 2.4. System Architecture/Design Definition; 2.6. Verification/Validation; 3. Automotive; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract.

This paper describes a pragmatic Model-Based Systems Engineering (MBSE) approach to reduce dependence on traditional documents and manage complexity of the electrified powertrain system. The approach enables requirements flow-down from an upper abstraction layer to the lower one(s) with stepwise analysis and design for a holistic system architecture of the system of interest. This approach is employed in the Nissan Powertrain development, which aims to solve challenges due to the traditional documents systems engineering (SE) approach to complex systems. This paper describes an MBSE approach developed for Nissan-7 methodology that focuses on knowledge cap-ture, fast feedback on requirements and design, and early verification and validation. The significant benefits of using an MBSE approach over a traditional documents SE approach are: a holistic view of system architecture, knowledge reusability, communicability, and adaptability to new technolo-gies. This paper presents proof of concept example projects that have demonstrated that it is viable to use this approach and apply it to an actual development for future work.

Paper#131

A Surrogate Model Approach for Studying Performance and Cycle Time in Complex System Development

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Keywords. System Performance;Development Cycle Time;Lifecycle Development;Digital Engineering;Surrogate Model

Topics. 1. Academia (curricula, course life cycle, etc.); 1.1. Complexity; 2. Aerospace; 5.4. Modeling/Simulation/Analysis; 5.5. Processes; 6. Defense;

Abstract.

This paper presents a surrogate model approach to advance fundamental research on understanding impacts of engineering decision-making on complex system performance and system development cycle times. The approach is motivated by digital transformation and advancement of the digital engineering strategy by the U.S. Department of Defense as part of acquisition modernization. The digital engineering strategy focuses on five goals as a means to reduce acquisition cycle times and increase capability deployment to the warfighter, but we lack the theory to understand the impact of the digital transformation on engineering processes, decision- making and the solution performance. The surrogate model approach discussed herein could provide a methodology for studying the impact of digital engineering on solution performance and lifecycle development time on a wide class of design problems with tunable complexity.

Paper#149

A SysML Profile for MIL-STD-882E (System Safety)

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Keywords. MIL-STD-882E;SysML;System Safety;SysML Profile

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

Abstract.

Abstract This paper presents a profile that extends the Systems Modeling Language (SysML) to support the requirements of MIL-STD-882E and facilitate the System Safety process. MIL-STD-882E is the U.S. Department of Defense (DoD) standard for System Safety Engineering (SSE). It mandates a series of analyses for hazard identification and tracking throughout system development, operation, sustainment, and disposal. These analyses are required to be documented in a series of reports set forth in the standard. For large systems, analyzing the system design and producing the mandated reports requires significant effort with a corresponding cost and resource impact on the overall program. Furthermore, while such analyses should be integrated with the development processes, they are often performed after design de-cisions are made and without the involvement of the primary development team. The System Safety Profile (SSP) presented here integrates the System Safety process with the design process by translating SSE concepts into structured elements within SysML, including representations of System Safety hazards, risks, mitigations, analysis activities, and the relations between them.

Paper#18

Academic application of trade-off studies to support a CubeSat project

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Keywords. academia;trade-off;trade study;cubesat

Topics. 1. Academia (curricula, course life cycle, etc.); 2. Aerospace; 3.3. Decision Analysis and/or Decision Management; 3.4. Information Management Process; 5.3. MBSE;

Abstract.

Academic CubeSat projects offer students and researchers hands-on engineering experience and can deliver cutting-edge research data. The CubeSat projects are highly multidisciplinary and require teamwork skills as well as engineering expertise. A challenge for academic CubeSat projects is the high turnover of graduating students, which makes knowledge management complicated. Model-Based Systems Engineering (MBSE) offers functionality that can address many of the challenges academic CubeSat teams experience. This paper presents a trade-off study using the Analytical Hierarchy Process (AHP) to select an MBSE software for use by students. Literature on academic application of formal trade-off studies in student teams is limited. The case study described here shows how tangible and intangible factors are addressed using the AHP method, and a discussion of the process and results is provided.

Paper#51

Advanced Statistical Methods in Spacecraft Flight Software Cost Estimation: Bayesian Regression and Nonlinear Principal Components Analysis to Support System Engineering in the Early Project Lifecycle

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Keywords. Flight Software Cost Estimation;Nonlinear PCA;k Nearest Neighbors;Clustering;Bayesian Statistics;web tools

Topics. 4.2. Life-Cycle Costing and/or Economic Evaluation; 5.4. Modeling/Simulation/Analysis;

Abstract.

This paper provides an overview of the new features and model updates in the upcoming release of the NASA Analogy Software Cost Tool (ASCoT). ASCoT, hosted within the Online NASA Space Estimation Tools (ONSET) on the One NASA Cost Engineering (ONCE) Database, is a web-based tool that provides a suite of estimation tools to support early lifecycle NASA flight software cost analysis. In addition to the traditional parametric flight software costing method COCOMO II, ASCoT contains a Bayesian linear regression to predict total flight software development cost as a function of total spacecraft cost, as well as four analogic methods: k-Nearest Neighbors (kNN) and Clustering models to predict Effort (in work-months) and total source lines of code (SLOC). These methods are designed to work primarily with system-level inputs such as mission type (orbiter, lander, etc.), mission destination (Earth, Inner Planetary, etc.), and the number of instruments and deployables. Nonlinear principal components analysis (NLPCA) is performed to find the principal features of the data composed of both categorical and numerical variables and is necessary prior to defining our analogic methods. Sensitivity analyses and in- and out-of-sample model performance results are presented for the Bayesian CER and the analogic models.

Paper#143

Agile Insight - Gating Alternatives for Agile Programs

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Keywords. Agile;Systems Engineering;Gates;Independent Reviews

Topics. 2. Aerospace; 3.7. Project Planning, Project Assessment, and/or Project Control; 5.1. Agile Systems Engineering; 5.7. Software-Intensive Systems; 6. Defense;

Abstract.

Abstract. Current technical oversight approaches (e.g. Stage-Gate reviews) are not agile – their expectations are not aligned with agile development cadences, and they are not adequately re-sponsive to continuous unpredictable change. These mismatches lead to the (incorrect) assertion that agile programs don't need technical oversight, and to more accurate concerns that current gate reviews do not effectively provide insight into gaps and risk on agile programs. Large complex agile programs need a light weight, interactive approach to technical oversight that provides insight in the form of good predictive feedback to agile programs with minimal burden of labor on the program and the reviewers. Fixed expectations of how oversight is done and non-agile oversight approaches written into contracts and processes impede the evolution of gating for agile programs. This paper explores ways to provide insight and responsive forward looking actionable guidance for agile programs and proposes a general oversight approach that produces minimal drag and disruption and keeps pace with agile product development.

Paper#54

An Introduction to Semantic Threat Analysis for Systems Security Engineering

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Keywords. systems security engineering;ontology;vulnerabilities;countermeasures

Topics. 1.6. Systems Thinking; 4.7. System Security (cyber-attack, anti-tamper, etc.); 6. Defense;

Abstract.

The objectives of this paper are (a) to motivate the adoption of semantic graphical models of threat relations and countermeasures in the design and operation of cyber-physical systems (CPS), and (b) to raise awareness of the various benefits which systems security engineers (SSEs) stand to gain by adopting such practices. Specifically, we propose that a Semantic Threat Analysis (STA) can endow SSEs with a comprehensive, extensible, machine-readable, and logically inferable model of system features. An STA shaped to the specific architecture and security requirements of a CPS environment can support the identification and visualization of system interdependencies and process flows among network, computing, mechanical, security, and access control components. The proposed STA process presupposes a team-oriented systems engineering approach employing a combination of subject matter experts (SMEs) and ontologists who can bring their respective expertise together to bear on the task.

Paper#72

An MBSE Architectural Framework for Inter-Satellite Communication in a Multiorbit Disaggregated System

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Keywords. Model Based Systems Engineering;Architectural Frameworks;Small Satellite Systems

Topics. 11. Information Technology/Telecommunication; 2. Aerospace; 2.3. Needs and Requirements Definition; 2.4. System Architecture/Design Definition; 5.3. MBSE; 6. Defense;

Abstract.

The Multi-Orbit Disaggregated System (MODS) concept is a disaggregation strategy geared towards improved resiliency and flexibility of space missions by dispersing payloads and/or functionality across multiple small satellites (SmallSats). Although SmallSats make good candidates for deployment as a MOD System, their success hinges on the ability to realize reliable Inter-Satellite Communication (ISC). To this end, we investigate the efficacy of developing a model-based systems engineering (MBSE) Architectural Framework for ISC to guide and con-strain instantiations of ISC architecture solutions. An MBSE architectural framework is a systems engineering artifact that defines a set of views required to describe an architecture based on MBSE principles and practices. It provides a standardized structure and guidance to capture architectural decisions while maximizing opportunities for commonality, consistency, and interoperability within the Domain of Interest. To achieve well-defined architecture descriptions, a MODS architectural framework pattern, and a comprehensive architectural framework for the ISC (sub)system are created and presented. The Systems Modeling Language SysML (OMG, 2019) serves as the modeling language for the framework design.

Paper#11

Applying A3AO to facilitate future working processes in the Oil and Gas Industry

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Keywords. Systems Engineering;A3 Architectural Overviews;Process Mapping;Process Architecting Tool

Topics. 15. Oil and Gas; 2.4. System Architecture/Design Definition; 5.5. Processes;

Abstract.

Companies in the oil and gas industry strive to increase their performance in Engineering, Procurement, Construction, and Installation projects. New responsibilities of the Company within this research, encounter unforeseen surprises in an early project phase called As-Is Engineering. No prioritization for documenting and communicating working processes and key-personnel dependency are the symptoms related to the Company’s challenges. To cope with the Company’s challenges, this research investigates the development of a process architecting tool to facilitate future working processes. Given a known method of A3 Architectural Overviews from Systems Engineering for communicating architectural knowledge, we applied it together with process mapping to develop a process architecting tool for the Company. Through literature review and workshop testing with loops of feedbacks in the Company, a process architecting tool - Operational A3 is proposed. Results from surveys and interviews show the Operational A3 benefits the Company in terms of increased project performance.

Paper#132

Applying Model-Based Systems Engineering Methods to a Novel Shared Systems Simulation Methodology

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Keywords. SysML;MBSE;Social/Sociotechnical and Economic Systems;space architecture

Topics. 22. Social/Sociotechnical and Economic Systems; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis;

Abstract.

The need to develop increasingly complex, integrated systems and multi-domain sys-tems-of-systems is initiating a transformation within the discipline of systems engineering. The critical trends of increasing interconnectivity, compressed development times, growing cyberse-curity concerns, and a rapidly changing workforce are driving current systems engineering prac-tices into obsolescence. Model-Based Systems Engineering (MBSE) is a formalized approach to systems engineering that uses models as an integral component of a system's technical definition with the objective of enhancing communication through rigor and precision and managing system complexity. This paper discusses the application of MBSE methods to the definition of a shared systems architecture and the development of novel methodologies for extending the model-based approach from the system definition space into the system simulation and analysis domain. Ap-proaches for interface management of design properties between a model-based architecture and system simulation will be reviewed, with the effectiveness of each approach discussed.

Paper#123

Artificial Intelligence Capabilities for Effective Model-Based Systems Engineering: A Vision Paper

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Keywords. Mode-Based Systems Engineering;Artificial Intelligence;AI4MBSE;AI4SE

Topics. 1. Academia (curricula, course life cycle, etc.); 5.11 Artificial Intelligence, Machine Learning; 5.3. MBSE; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract.

Both Model-Based Systems Engineering (MBSE) and Artificial Intelligence (AI) have been challenged for their successful deployment in real-world applications. Although MBSE remains the focal point of any systems engineering activities, its adoption still faces significant hurdles to demonstrate its return on investment. Recently, AI has received intensive attention, and its applications made their way into our daily life products. From an industrial perspective, within the context of the design and development of mechatronic systems, there is a lack of coherent foundation for enabling the application of AI in MBSE. This vision paper discusses the role of AI in solving a set of MBSE challenges. As a result, we contribute by describing the actual MBSE adoption challenges and follow up with the characterization of the capabilities of AI in solving these challenges. With this initial work, we aim to trigger both AI and MBSE communities for further research discussions and industrial applications to help in achieving an intelligent design and development environment.

Paper#141

Automatic text classification approach for aerospace pdf documents using NLP techniques

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Keywords. Systems Engineering;Artificial Intelligence;Aerospace

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

Abstract.

One of the regular activities performed by engineers during the design and development of the technical systems are to determine which statements in an engineering specification document rep-resent a requirement, functional architecture, design solution, variability, or other types of systems engineering (SE) information. Capturing such text from the document is still manually performed, which requires competence in the modeling language, high effort, and error prone. That is why automatic extraction and classification of such SE information is an important task. But understanding and extracting such information from big documents are still relatively scarce and a challenging task. By following suitable writing and markup conventions, it can provide an immediate and easy way to classify and analyze the document. However, such conventions are not always followed strictly. That is why we propose a solution that can label SE documents, categorize them, and classify each statement into predefined classes.

Paper#42

Automation through Digital Engineering and Digital Twins

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Keywords. digital engineering;systems engineering;digital twin;automation

Topics. 14. Autonomous Systems; 2.5. System Integration; 5.11 Artificial Intelligence, Machine Learning; 5.12 Automation; 8. Energy (renewable, nuclear, etc.);

Abstract.

Digital engineering is the practice of creating repeatable frameworks to bring the power of automation and information technologies to complex systems. Systems engineering is an essential part of the digital engineering practice. Autonomous and remote operation of physical assets can provide nu-merous benefits to organizations and industries that deal with complex and distributed systems. The automation of the operation of a physical asset can be achieved through a digital twin, connected to the inputs and outputs of the asset and using machine learning (ML) and artificial intelligence (AI). Development of the digital twin requires understanding of systems interfaces and incorporating this understanding in digital systems. The effort described herein aims to prove the feasibility and benefit of such a process through the development and evaluation of a digital twin connected to a heat-pipe test-bed environment.

Paper#57

Benefits of Systems Engineering in Large Infrastructure Projects: the much-anticipated empirical proof.

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Keywords. Systems Engineering;Infrastructure Projects;Return on Investment;Cost Analysis

Topics. 10. Environmental Systems & Sustainability; 12. Infrastructure (construction, maintenance, etc.); 13. Maritime (surface and sub-surface); 16. Rail; 2.3. Needs and Requirements Definition; 2.4. System Architecture/Design Definition; 2.5. System Integration; 2.6. Verification/Validation; 21. Urban Transportation Systems; 5.5. Processes;

Abstract.

Following successful deployment in the aerospace and automotive industries, the demand for a structured approach to Systems Engineering on large infrastructure projects is rapidly increasing in the current decade. However, there is still certain inertia on the part of some firms to adapt their processes within this engineering discipline, and hence an empirical demonstration of the benefits of systems engineering is needed. The purpose of this paper is twofold: on the one hand, it outlines an overall methodology to perform studies on Return on Investment of Systems Engineering (SE-ROI) in large infrastructure engineering companies; on the other hand, this paper presents the results of this methodology applied to calculate the SE-ROI in one such infrastructure engineering company.

Paper#21

By Any Other Name: Enabling Systems Engineering in an Unsupportive Environment

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Keywords. effective systems engineering;unsupportive environment;Individual influence;case studies;systems engineering practices;engineering culture;systems engineering management beliefs;initiating change;covert systems engineering;complacency

Topics. 19. Very Small Enterprises; 22. Social/Sociotechnical and Economic Systems; 3.5. Technical Leadership; 3.7. Project Planning, Project Assessment, and/or Project Control; 3.9. Risk and Opportunity Management; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract.

Engineers may find themselves in an organization which does not value systems engineering, or worse, in an organization which is hostile to systems engineering practices. The purpose of this paper is to help such engineers do effective systems engineering despite the lack of support. This paper offers a description of the variation found in top management beliefs and engineering cultures to aid in a diagnosis of the workplace environment. This paper then offers suggestions for appropriate actions suitable to each combination of top management belief and cultural support or hindrance for systems engineering practices. These actions can help individual engineers to implement effective systems engineering despite hindrances from the organizational culture or top management. Several case studies are included to illustrate how the approaches described have actually been implemented in their own experience.

Paper#50

Concept verification and validation using psychological scales through an "Eating-Together" System Enhancing Connectivity for Busy-Generation Urbanites with Neighborhood Community in Japan

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Keywords. Human-Centered system design;Society 5.0;psychological scales;wellbeing;social system;neighborhood connectivities

Topics. 2.6. Verification/Validation; 20. Industry 4.0 & Society 5.0; 22. Social/Sociotechnical and Economic Systems;

Abstract.

Recently, with the growing demand for qualitative values such as wellbeing, development and implementation of systems considering societal needs. This paper presents an approach of concept verification and validation for the proposed “Eating-Together” system that aims to enhance connectivity among neighbors of busy urbanites in Japan. The study utilized three psychological scales, including the Positive and Negative Affect Schedule (PANAS), General Self-Efficacy Scale (GSES), and Social Worth as Measures of Performance (MOP). In developing the concept of the System of Interest (SOI), four main aspects were identified as mission requirements. The prototype was built based on the final concept model, and nine tests were conducted with 15 hosts and 31 guests. The questionnaires were administrated three times: before, immediately after, and two weeks after the event. The results indicated that the prototype successfully met all of the mission requirements, providing an improved method to estimate the otherwise unmeasurable elements.

Paper#32

Conceptual Design for Resilience

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Keywords. Resilience;Systems Analysis;Model Based Conceptual Design

Topics. 10. Environmental Systems & Sustainability; 12. Infrastructure (construction, maintenance, etc.); 2.1. Business or Mission Analysis; 4.4. Resilience; 5.4. Modeling/Simulation/Analysis; 7. Emergency Management Systems;

Abstract.

The development of system concepts are always challenging to visualize as well as ana-lyze, particularly where design concepts such as resilience are a critical system attribute. We are motivated to extend our Model Based Conceptual Design (MBCD) approaches towards analyzing the resilience designed into systems in the Concept Phase. Using the example of a bushfire emergency response system, and specifically to the command and control (C2) systems, of the design concept of resilience is investigated. This paper explores the use of MBCD and its underlying framework to structure the modeling and analysis of C2 structures as they apply to various levels of severity in bushfire situations, and consider how designing for resilience can incorporated in the MBCD ap-proach.

Biography

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

Paper#70

Configuration Management for Model Based Systems Engineering - An example from the Aerospace Industry

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Keywords. Configuration Management;Model Based Systems Engineering;Landing Gear

Topics. 2. Aerospace; 3.2. Configuration Management; 5.3. MBSE;

Abstract.

Model Based Systems Engineering approach is increasingly used to manage the complexity of modern systems and to reduce costs of their development. In the Aerospace industry, modelling and simulation is not only a cost effective verification and validation strategy where test rigs and flight tests are far more expensive but also is increasingly used in the certification process. Nevertheless, as with any digital artefact, if the models aren’t configured and traceability isn’t assured, then the models are not of much use. Configuration Management comes into play as a key discipline to enable the use and maintenance of the models. This paper explores the use of Configuration Management for modelling and simulation in an aerospace setting, with a specific example involving landing gear and its surrounding systems.

Paper#46

Construction System Failures: Frame Notation of Project Pathogens and their Propagation Across Time and System Hierarchy

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Keywords. construction system failure;accident model;temporary multiple organization;system safety;resident pathogen

Topics. 3.7. Project Planning, Project Assessment, and/or Project Control; 4.6. System Safety; 5.4. Modeling/Simulation/Analysis;

Abstract.

A construction system is an organizational and technological system that produces buildings or civil engineering structures for human use by fabricating and installing materials into an integrated structure according to design specifications. Failures of such construction systems materialize in various forms, including defective design, rework, and dysfunctional building systems. Frequent accidents and building defects in the construction sector clearly indicate that our society still needs to improve the safety of construction systems. Research studies on how major accidents and minor defects occur are often conducted in isolation by different researchers, and existing system safety concepts and frameworks are not necessarily suited to handling the dynamic nature of temporary multiple organizations (TMOs) — a feature that characterizes the uniqueness of construction projects. We need a framework that can better describe failures specific to construction, and capture the wide spectrum of these failures. Here, we build on concepts from system safety research to develop a graphical notation with “frames” and system hierarchy as the main components to illustrate how pathogens are generated and propagated by defective processes and end up embedded in the physical structure.

Paper#125

Controlling the Digital Engineering Ecosystem: An Elastic Model Governance Guide for the Digital Thread

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Keywords. model governance;model management;model lifecycle management

Topics. 3.2. Configuration Management; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis;

Abstract.

As Digital Engineering employs a digital thread with a broad range of interconnected models, it can be difficult to govern linked models across disciplines and contractual boundaries. After an introduction to the challenges of model governance, a survey of related literature is provided. An Elastic Model Governance Guide for the digital thread is then described. Key features include: (1) model-based guidance with in-model work instructions; (2) integration of the overall Model Governance System, Digital Engineering Environment infrastructure, individual models, and composite models; (3) scoping of model purpose and resolution of technical debt; (4) automated validation for insight on compliance; (5) customization for flexibility and tailoring. Excerpts from the governance guide are provided and discussed, and next steps are given. Integrating model governance practices with additional mechanisms for flexibility, scalability, and automated validation provides robust control over the Digital Engineering ecosystem to enhance the value delivered to customers.

Paper#41

Crafting an Experience-Based Master's Program in Systems Engineering

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Keywords. Systems Engineering;education;degree;mentor;teams;diversity;applied learning;experiential

Topics. 1. Academia (curricula, course life cycle, etc.); 3.5. Technical Leadership; 5.10. Diversity (cultural boundaries, diverse engineering teams, training underserved groups, etc.); 5.9. Teaching and Training; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract.

The Professional Masters in Applied Systems Engineering (PMASE) program provides students with both practical and academic material in a setting as close to a typical work environment as possible. This paper describes the first course in the two-year program. It describes the approach used to provide students with a realistic environment, and both academic and practical experience; balancing work and studies in an intensive program culminating in a capstone project. The paper should be of interest to both companies and universities interested in a holistic, condensed systems engineering training program.

Paper#67

Developing a Human Performance Model Based Systems Engineering System Architecture (MBSE-SA) for Defense Application

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Keywords. Model Based Systems Engineering;MBSE;System of Systems;Defense Applications;Human Performance;capability needs analysis

Topics. 2.3. Needs and Requirements Definition; 2.4. System Architecture/Design Definition; 4. Biomed/Healthcare/Social Services; 4.1. Human-Systems Integration; 5.3. MBSE; 6. Defense;

Abstract.

The military has limited means to objectively evaluate soldier and squad performance, leading to sub-optimal operational, training, and acquisition decisions. Part of this limitation stems from the fact that the ability to monitor, predict, and enhance soldier and squad performance is a complex System of Systems (SoS) undertaking. To address this integration challenge, we developed a comprehensive conceptual framework that maps mission-level success to measures of task effectiveness and human performance that quantify the impact of emerging technologies and interventions. In addition, by leveraging a previous effort that developed a Wearables MBSE system architecture (MBSE-SA) and methodology for military health monitoring systems, we developed a Human Performance MBSE-SA to capture and apply the conceptual framework, which provides the foundation for several system-level and program-level analyses, including gap identification. This paper presents the Human Performance MBSE-SA and an illustration of its utility in showing the connections among ongoing military research efforts, strategic source requirements, and operational use cases.

Paper#104

Developing Competence in the Systems Engineering Professional Competencies

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Keywords. Competency;Communications;Ethics and Professionalism;Technical Leadership;Negotiation;Team Dynamics;Facilitation;Emotional Intelligence;Coaching and Mentoring

Topics. 22. Social/Sociotechnical and Economic Systems; 4.5. Competency/Resource Management; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract.

In 2018, the International Council on Systems Engineering (INCOSE) introduced a set of compe-tencies for systems engineers in a framework structure that gives guidance as to the knowledge, skills, abilities, and behaviors important to systems engineering effectiveness at each of five “levels” of competence. These levels range from awareness to expert. There are five categories of competencies: • Core Competencies that underpin both engineering and systems engineering • Technical Competencies that are associated with the systems engineering technical processes • Professional Competencies that reflect behaviors established within the human resources domain • Systems Engineering Management Competencies that relate to managing and controlling systems engineering activities • Integrating Competencies that recognize that the systems engineering discipline joins its ac-tivities with those of other disciplines, including project management and quality, to create project coherence The purpose of this paper is to provide research-grounded methods for improving one’s competence in the INCOSE Professional Competencies, while recognizing that improvement strategies may not be universally applicable due to gender- and culturally-based differences in strengths and weaknesses relative to the Professional Competencies. Specifically, the paper addresses ways that systems en-gineers can improve their own competence in these key areas.

Paper#108

Digital Engineering Environments: A Digital Engineering Perspective

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Keywords. Collaborative Environment;Digital Engineering;MBSE;Model Based System Engineering;Common Language;System Baseline;Program Security;System Security;System Architecture;Digital Threads;Logical Model;Physical Model;Behavioral Model

Topics. 2.4. System Architecture/Design Definition; 4.7. System Security (cyber-attack, anti-tamper, etc.); 5.3. MBSE;

Abstract.

Systems engineering is a discipline focused on managing and coordinating many domains, specialties, and lines of business, it also enables the successful realization, use, and retirement of engineered systems, using systems principles and concepts, and scientific, technological, and management methods. Systems engineering collaboration occurs when individuals unite in an effort too large or complex for any of them to perform independently. A digital collaborative environment facilitates the sharing, revision, storage, and publication of ideas, documents, and products through digital means. Until recently, efforts to assemble teams to solve the problems of large, complex systems focused primarily on technical infrastructure: think of digital trans-formation efforts, integrated modeling environments and efforts to connect tools and systems to model-based systems engineering (MBSE), digital engineering (DE) and model-centric acquisition. Today, however, new technologies offer opportunities to bring systems engineering collaboration into a new era, one in which is cloud-based, interdisciplinary, secure, and efficient to empower collaboration to design, deliver and sustain the next generation of advanced technical systems and capabilities. This paper introduces a framework for understanding the modern collaborative environment as well as its current technical limitations.

Paper#24

Digital Transformation in Acquisition: Using Modeling and Simulation to Advance the State of Practice

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Keywords. digital engineering;modeling and simulation;education

Topics. 1. Academia (curricula, course life cycle, etc.); 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 5.9. Teaching and Training;

Abstract.

Digital transformation is a key enabler for successful acquisition and sustainment in a rapidly changing environment of increasing threats and challenges. This paper provides an overview of digital transformation in acquisition and ongoing relevant work that contributes to the development of educational training for the acquisition workforce. One of the main contributions is the development of models and simulation for training purposes. The team researched on current uses of modeling and simulation before proposing models and simulation (“case studies”) that could be incorporated in the training materials at DAU and extend applicability beyond the DoD to contribute to the DE body of knowledge and DE community. The acquisition workforce must undergo significant transformation, which is not an easy transition, to overcome the challenges of digital transformation. Cultural change is an important shift that will have to happen in the workforce to enable digital transformation. This paper highlights the three-pronged approach for competency identification to support competency development. The research is centered on improving the acquisition workforce’s ability to support Digital Acquisition through the identification of critical competencies for individuals, and for program offices and the development of models and simulation in the DAU curriculum to enable effective digital transformation.

Paper#89

Don’t mix the tenses: Managing the present and the future in an MBSE context

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Keywords. MBSE;Architecture;Integration

Topics. 2.4. System Architecture/Design Definition; 2.5. System Integration; 5.3. MBSE;

Abstract.

When implementing MBSE in complex systems development, it is never about only ONE model or only ONE language. Instead, there is a need to be able to handle different aspects over time, i.e., to separate what it shall become at the end (the future) from what it is for each specific product con-figuration (the present). This is especially evident in large scale projects with complex products having very long life-cycles. Therefore, there is a need for models capturing the long-time perspective i.e., defining the desired future state of a system, together with models representing the current state of design, and models describing in detail how it will be in the near future. In the paper a structured way how to separate those tenses is presented in a context of complex systems development, allowing for representing multiple realisation models for a configuration item. Enablers for achieving this separation over tenses is discussed, where extensive configuration management is one key aspect.

Paper#66

Empowering Engineers in a Digital Engineering Transition: Applying organizational psychology and systems thinking approaches to define the problem and to develop recommended actions

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Keywords. Digital Engineering Transition;System Thinking;Empowering Engineers

Topics. 1.6. Systems Thinking; 2. Aerospace; 3.5. Technical Leadership; 5.9. Teaching and Training; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract.

As an organization implements an enterprise organizational change: transition from Traditional Document-based Systems Engineering (TDSE) to Digital Engineering (DE), engineers are critical in accepting and implementing the change. This DE transition impacts established engineering processes, tools and practices in which the engineers have confidence and know well. Engineers have spent their careers developing a level of competence in TDSE. Uncertainty associated with this organizational change increases stress, decreases job satisfaction, and impacts commitment among engineers. The engineering culture reflects attitudes of resistance and uncertainty.

This paper analyzes the DE transition from organizational psychology and systems thinking approaches. The combination of these two approaches enables the identification of an intervention and recommended actions to empower engineers in the DE transition. With consideration of the research findings in the organizational psychology literature search and applying systems thinking tools, three actions of the intervention are proposed focusing on knowledge transfer, training and communication.

Paper#142

Enabling the Systems Engineering Education Ecosystem (SEEE)

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Keywords. education ecosystem;engineering competencies;educational program feedback;systems engineering

Topics. 1. Academia (curricula, course life cycle, etc.); 20. Industry 4.0 & Society 5.0; 22. Social/Sociotechnical and Economic Systems; 4.5. Competency/Resource Management; 5.9. Teaching and Training;

Abstract.

System engineering education is challenged to address the need posed by rapidly changing technology epitomized by Industry 4.0 and the digital transformation. In particular, there are relatively slow and inaccurate feedback mechanisms between the needs of employers, students and universities at the level of educational program content development. To address this issue, the Systems Engineering Education Ecosystem (SEEE) was established to create and assess the feedback mechanisms by which educators, students and employers can communicate their specific educational capabilities, desires and needs, in order to provide the dynamic feedback necessary to accelerate the evolution of Systems Engineering (SE) educational programs, clearly communicate the characteristics of existing programs, provide access to relevant educational materials, and create a dynamic self-evolving educational system. This paper describes the vision, objectives, design and development process, current status and future developments, with the intention to support a global systems engineering education ecosystem.

Paper#25

Establishing Quality Metrics for Systems Engineering Process

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Keywords. Systems engineering;Metrics;Complexity Points;System Complexity;Dynamic Complexity;Social Complexity;Process Improvement;Lifecycle

Topics. 1.1. Complexity; 3.8. Quality Management Process; 5.5. Processes; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract.

Software engineering companies such as Motorola have clearly defined, robust processes to ensure overall process and system quality. Using Motorola's approach as a baseline, the authors established a process to determine system complexity to support the Systems Engineering & Integration (SE&I) lifecycle. To quantify complexity, the authors established a process including structural complexity (focused on system form), dynamic complexity (focused on system function), and social complexity (focused on identified stakeholders), the sum of which define complexity points. The authors further expanded the process by defining key metrics and parameters to support evaluation throughout the SE&I phases from concept to operationalization. This process, which the authors believe to be a first-of-its-kind as applied to the SE&I lifecycle, allows systems engineers (SEs) and program managers (PEs) to quantitatively compare SE&I phases, systems, or projects of different sizes and dollar values to categorize, assess, forecast lifecycle costs, and performance to improve performance with customer satisfaction in mind. Through a satellite system example, the authors present the metrics to support associated analysis through the SE&I lifecycle.

Biography

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Dr. Powell has served in positions focused on aircraft maintenance, research and development, operations sustainment, space acquisitions, and academia. He received certifications in Systems Engineering, Program Management, Test and Evaluation, and the Space Professional Development Program. He is currently VP & GM, Space Development & Integration with Axient LLC. He received a BS in Mechanical Engineering, an MS in Aeronautical Engineering, and a PhD in Engineering (Mechanical Specialty) from the Colorado School of Mines. He is also a licensed Professional Engineer (Mechanical) in Colorado. He has authored over 20 peer-reviewed articles in various publications and conferences on the topics of hypersonics, combustion, launch and range, and engineering education. He is a member of several professional societies including the American Institute of Aeronautics and Astronautics where he is an Associate Fellow.

Paper#101

Examination of Altshuller's Trends of Technical System Evolution in Automotive Passenger Vehicles

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Keywords. system evolution;trends of evolution;automotive engineering;system architecting

Topics. 2.4. System Architecture/Design Definition; 3. Automotive; 3.7. Project Planning, Project Assessment, and/or Project Control;

Abstract.

Although Genrich Altshuller is perhaps better known for his development of his Theory of Inventive Problem Solving (TRIZ), his work also includes eight trends of technical system evolution that he believed could be used to predict the future of products or systems. Those working in any high-tech industry have always sought techniques to better forecast the evolution of their product in order to pursue the most promising of multiple possible evolutionary paths and to make the most fruitful investments of time and money in new technologies. The authors are interested in including Altshuller's trends in their toolbox for predicting the future of the automobile but felt it would first be prudent to look back on the auto industry's approximately 160 year history to see if Altshuller's trends appear consistent with that history. The assumption is that if the past history of the evolution of the automobile is consistent with those trends, then increased confidence can be had in any future predictions made by applying those same trends to the current state of the automobile to predict the future. When the history of the automobile was examined in roughly decade-level time intervals, it was observed that, in each time interval considered, typically six or more of Altshuller's eight trends were apparent. Interestingly, the authors found that there were a number of unsuccessful products throughout history that were largely consistent with the trends. This suggested that satisfaction of the trends of system evolution may be a necessary condition for system evolution but is not a sufficient condition for success. This work proposes that consideration of context and satisfaction of some typical system architecting heuristics can largely differentiate past success vs. failure amongst various systems that satisfy the eight trends, and hence recommend a hybrid approach consisting of Altshuller's trends of system evolution with specific attention to system context along with application of system architecting heuristics as a potentially useful and valuable way to predict the future evolution of the automobile.

Paper#9

Extending UAF for Model-Based Capability Planning and Enterprise Portfolio Management

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Keywords. architecture;enterprise;MBSE;models;capabilities;capability roadmaps;portfolio management;unified architecture framework

Topics. 2. Aerospace; 2.1. Business or Mission Analysis; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract.

Capabilities, the lifeblood of an enterprise, can be managed effectively using portfolio management techniques. Capability roadmaps are commonly used to manage the deployment of new and improved capabilities to address key drivers and challenges that the enterprise faces. This paper shows how MBSE can enhance an organization's ability to plan for capability deployments, as well as the ability to more effectively manage its portfolios of systems, services, people, technologies, processes, facilities, and other key enablers for the fielded capabilities. Specific enterprise modeling elements that can facilitate capability planning and portfolio management are presented. These new modeling elements are being incorporated into an update of the Unified Architecture Framework, an OMG standard for modeling an enterprise.

Paper#121

Extracurricular projects - Teaching Systems architecting in a limited time-span

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Keywords. University;SE Engine;Systems architecting;Education;Teaching;Mission Analysis

Topics. 1. Academia (curricula, course life cycle, etc.); 1.6. Systems Thinking; 2.1. Business or Mission Analysis; 5.9. Teaching and Training;

Abstract.

University student projects experience high turnover, resulting in a loss of knowledge and experience. Turnover leads to increased project risk, development delays, and loss of institutional knowledge. These issues are particularly relevant for systems engineering teams as the discipline requires a broad range of competencies and expertise. This paper presents an experience report of a case study with results that suggest that it is possible to provide undergraduate students with a foundational body of SE knowledge using mission analysis as a learning platform. This activity can be completed within one semester and allows the undergrad students to continue learning independently.

Paper#124

Formalizing the Representativeness of Verification Models using Morphisms

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Keywords. SE theory;verification;systems theory;morphism

Topics. 1.1. Complexity; 1.5. Systems Science; 2.6. Verification/Validation;

Abstract.

With the increasing complexity that is being introduced to engineered systems, the literature suggests that verification may benefit from theoretical foundations. In practice and in teaching of system engineering (SE), we typically define a verification model (simulation, test article, etc.) under the assumption that the model is a valid representation of the system design. Is this assumption always true? In this article, we explore the use of system theoretic morphisms to mathematically characterize the validity of representativeness between verification models and corresponding system design.

Paper#87

Framework for Complex SoS Emergent Behavior Evolution Using Deep Reinforcement Learning

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Keywords. Complex System-of-Systems;Deep Reinforcement Learning;Emergent Behavior Evolution

Topics. 1.1. Complexity; 5.11 Artificial Intelligence, Machine Learning; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 8. Energy (renewable, nuclear, etc.);

Abstract.

Advances in technology have made it easy to integrate multiple modern systems to form complex system-of-systems (SoS) to achieve unparalleled levels of functionality that are otherwise not achievable by the constituent systems in isolation. In fact, with the recent explosion of machine learning techniques to build autonomous systems such as drones and self-driving cars, there is a pressing need to ensure that they collaboratively and safely operate in an SoS context. However, in general, the characteristic emergent behaviors of complex SoS -- that directly impact its operational measures of success or Measures of Effectiveness (MOEs) -- is very difficult, if not impossible, to manually explore, anticipate, and arbitrate just from knowledge of its underlying systems. Further, there are multiple scenarios of evolution in such complex SoS, including evolution in the emergent behavior of the SoS. The continuous, continual, and evolving nature of the SoS and constituent system environment's state and possible actions, adds further complexity. In this paper, we present a novel approach that leverages Reinforcement Learning, a machine learning approach, to inculcate adaptable intelligence in constituent systems to adapt their behaviors in tandem with the evolution of emergent behavior at the SoS level. By augmenting the reward mechanism of RL by leveraging SoS-Constituent System MOE Relationship, that relates and ranks System MOEs vs. SOS MOEs, we inculcate an Intelligent-Behavior Evolution Agent, with the necessary constraints to learn to maximize the SoS and system-level MOEs, while adapting itself to the evolution in SoS. We illustrate our approach and demonstrate its feasibility and potential by applying it to a power grid SoS case example. The effectiveness and performance of the approach are quantified.

Paper#128

From Model-based to Model and Simulation-based Systems Architectures – achieving quality engineering through descriptive and analytical models

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Keywords. Architecture;Design;MBSE;Model Based Systems Engineering;Simulation

Topics. 2. Aerospace; 2.4. System Architecture/Design Definition; 2.6. Verification/Validation; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 6. Defense;

Abstract.

Systems architecture design is a key activity that affect the overall systems engineering cost. It is hence fundamental to ensure that the system architecture reaches a proper quality. In this paper, we leverage on MBSE approaches and complement them with simulation techniques, as a prom-ising way to improve the quality of the system architecture definition, and to come up with inno-vative solutions while securing the systems engineering process.

Paper#40

From System Architecting to System Design and Optimization: A Link Between MBSE and MDAO

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Keywords. mbse;mdao;mdo;systems engineering;optimization;architecture;architecting

Topics. 2. Aerospace; 2.4. System Architecture/Design Definition; 5.12 Automation; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis;

Abstract.

Optimization of system architectures can help deal with finding better system architectures in a large design space plagued by combinatorial explosion of alternatives. To enable architecture optimization, the design space should therefore be formalized into a numerical optimization problem, and it should be possible to quantitatively evaluate architecture alternatives. This paper presents a methodology for generating and modeling architecture design spaces using the Architecture Design Space Graph (ADSG), and using collaborative Multidisciplinary Design Analysis and Optimization (MDAO) techniques to evaluate architectures. Collaborative MDAO leverages disciplinary expertise while ensuring that analysis tools exchange data consistently and correctly using a central data schema. The problem solved in this paper is the missing link between architecture optimization and collaborative MDAO: the reflection of generated architectures in the central data schema. It is solved by the authors by mapping architecture components and Quantities of Interest (QOIs) to the central data schema using Data Schema Operations (DSOs). Such a mapping also assists the user in identifying missing or redundant disciplinary analysis tools. Three web-based software tools implementing the methodology are presented. Finally, the methodology and tools are demonstrated using the design of a supersonic business jet as an example.

Paper#105

Gender-based Differences in the INCOSE Professional Competencies

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Keywords. Gender;Competency;Communications;Ethics and Professionalism;Technical Leadership;Negotiation;Team Dynamics;Facilitation;Emotional Intelligence;Coaching and Mentoring

Topics. 22. Social/Sociotechnical and Economic Systems; 4.5. Competency/Resource Management; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract.

In 2018, the International Council on Systems Engineering (INCOSE) introduced a set of compe-tencies for systems engineers in a framework structure that gives guidance as to the knowledge, skills, abilities, and behaviors important to systems engineering effectiveness at each of five “levels” of competence, ranging from awareness to expert. There are five categories of competencies: Core, Technical, Professional, Systems Engineering Management, and Integrating.

The purpose of this paper is to explore research-grounded gender-related differences in the INCOSE Professional Competencies and their implications for the ability of systems engineers of either gender to apply them in practice.

Paper#82

Genesis – an Architectural Pattern for Federated PLM

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Keywords. Product Lifecycle Management;OSLC;Integrated capability

Topics. 2. Aerospace; 5.12 Automation; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract.

Product Lifecycle Management is a key capability for any organization developing and/or main-taining complex systems. This paper presents a modular architectural pattern for realizing a federated PLM capability from integrating multiple engineering discipline specific development envi-ronments. This open the possibility for replacement of individual environments, while maintaining the overall development system landscape. Thus, providing a desired flexibility in adapting to future organizational challenges at comparatively low cost.

Paper#113

Git-based Model Management for Quality Monitoring of Systems Engineering Models

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Keywords. model-based systems engineering (MBSE);agile mbse;continuous integration;sustainability in systems engineering;quality monitoring;model management;git;gitops

Topics. 20. Industry 4.0 & Society 5.0; 3.8. Quality Management Process; 4.3. Reliability, Availability, and/or Maintainability; 5.3. MBSE;

Abstract.

The management of Systems Engineering Models is becoming a crucial requirement when developing complex systems. Particularly with the advance of agile MBSE, Systems Engineering Models evolve constantly. Therefore, for managing Systems Engineering Models, this evolution has to be supported, including concurrent work on one model. Therefore, Git-based solutions are emerging nowadays also in the Systems Engineering domain. Dedicated model differencing and conflict resolution approaches are provided by extensions of the base support of Git, which is mostly oriented to textual artefacts. However, the monitoring and management of the System Engineering Models hosted in Git repos-itories is still an open challenge.

In this paper, we present a Git-based model management approach for monitoring the quality of Systems Engineering Models. We outline the architecture of the approach as well as the proposed Git-based model management approach and discuss the realization based on (details omitted for double-blind reviewing). In addition, we demonstrate the approach by a running example and outline future directives.

Paper#26

Illustrating Business Relevance of Systems Engineering via Storytelling

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Keywords. Business value;storytelling;ecommerce;healthcare;non-traditional settings;SE-SW interface;digital

Topics. 1.6. Systems Thinking; 11. Information Technology/Telecommunication; 2. Aerospace; 2.1. Business or Mission Analysis; 3.3. Decision Analysis and/or Decision Management; 4. Biomed/Healthcare/Social Services;

Abstract.

Many software-centric organizations do not embrace Systems Engineering, whether lacking awareness or perceiving it too onerous for value delivered. Simultaneously, many embrace Digital Engineering, Design, and Innovation to advance their market position, yet continue to experience sub-optimal results and downstream consequences.

These realities show Systems Engineering becoming inconsequential in today's business settings, to the detriment of success and customer value. Effective storytelling, showcasing situational implementation of the right elements of Systems Engineering, can address this.

Stories engage, inspire, and create connection. When layered with multiple dimensions and meaning, they become timeless.

This paper describes four vignettes about enhancing success in software-intensive enterprises by leveraging Systems Engineering in context, flexibly and fit for use, and compatibly with other disciplines. The vignettes illustrate how Systems Engineering strengthens performance and positions for flexibility, adaptability, and resilience in a fast-changing, complex world.

The paper concludes with implications for Systems Engineering outreach, leadership, and influence.

Paper#8

Implementing Cognitive Work Analysis to Support Early Phases of Sociotechnical System Development

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Keywords. Cognitive Work Analysis;Sociotechnical System;Systems Engineering;Compexity;Work Domain analysis

Topics. 2.3. Needs and Requirements Definition; 22. Social/Sociotechnical and Economic Systems; 4.1. Human-Systems Integration;

Abstract.

Systems engineering (SE) is applied to bring about complex systems, such as sociotechnical systems (STS), based on stakeholder requirements. Introducing new technology into an existing STS may result in unexpected emergent behaviour when prevailing processes, procedures and information flows are challenged. Due to the complexity associated with emergence, the resultant system may fail to achieve the desired utility fully, or the work system produced may not be desirable. Cognitive work analysis (CWA) provides a framework for analyzing, modelling, and designing STS. This study proposes applying CWA modelling to requirement analysis for new technology introduction as part of a validation workflow in aid of SE. Work domain analysis (WDA), the first step in the CWA framework, is applied to a test case, and the resultant abstraction hierarchy (AH) models are analyzed to evaluate the perceived utility. This article shows how analysts were able to apply the method and uncover possible design emergence. We hope that the methods presented herein will aid more designers in applying CWA as part of the SE life-cycle toward successfully implementing complex STS.

Paper#99

Integration: More Than Interface Management

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Keywords. Integration;Interface Management;Systems

Topics. 2. Aerospace; 2.5. System Integration; 5. City Planning (smart cities, urban planning, etc.); 6. Defense;

Abstract.

Most descriptions of integration focus on interfaces and interface management. While this is necessary, it is not sufficient for successful integration. This paper will discuss additional technical and other concerns that must be dealt with in order to meet the objectives of systems integration.

Paper#27

Introducing Systems Thinking Techniques into an Undergraduate Engineering Education

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Keywords. System Thinking;Engineering Education;Complex Systems

Topics. 1. Academia (curricula, course life cycle, etc.); 1.6. Systems Thinking; 4.5. Competency/Resource Management; 5.9. Teaching and Training; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract.

The world is faced with producing more complex, interdependent systems, and systems of systems. Due to the complexity and interdependencies, these systems do not lend themselves to the traditional reductionist approach, which is feasible only for complicated systems. To architect and develop complex systems requires the use of systems thinking tools and competencies which are an enabler for developing complex engineered systems, humanitarian systems, organizational structures, business strategies, production optimization, solving socio-technical problems, etc. Because of the power of systems thinking and its global applicability, the question becomes; how can we better produce system thinkers? There are currently many effective systems thinking methods and tools which have been successfully adopted by practicing engineers. This paper will describe how we can introduce similar systems thinking elements into an existing undergraduate education through lectures/mentoring, labs/projects/experiments, case studies/background research, and multi-discipline capstone projects/internships. Some universities have recently added systems thinking elements to their curricula, and through INCOSE’s influence, the Accreditation Board for Engineering and Technology (ABET) now mandates systems thinking for all undergraduate engineering programs. This paper acts to describe a variety of implementation methods to serve as exemplars for those implementing systems thinking into existing curricula. The motivation of this work is to ultimately produce engineers who are better suited to engineering complex systems when they enter the workforce.

Paper#83

Investigating Systems Engineering Approaches in the Construction Industry: A Multi-Case Study

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Keywords. Systems Engineering approaches;Systematic Completion;Construction industry;Project management performance;Technical contractor

Topics. 12. Infrastructure (construction, maintenance, etc.); 18. Service Systems; 2.1. Business or Mission Analysis; 2.3. Needs and Requirements Definition; 3.7. Project Planning, Project Assessment, and/or Project Control; 5.5. Processes;

Abstract.

There is an increasing application of Systems Engineering in the construction industry. This paper investigates the effects of a Systems Engineering approach on project management performance, prerequisites for success, and which elements contribute to effectiveness from a technical contractor and sub-contractor perspective. First, we find a positive perception of Systems Engineering's effect on time, cost, and quality. Second, we provide and rank a list of 12 prerequisites for success. Third, we quantify the perceived importance of five elements of the systems engineering process. Finally, we find a disconnect between what seems to be essential processes and prerequisites and what gets done in practice. To improve Systems Engineering performance, we recommend improving Systems Engineering competence and capabilities, increasing the formality of requirements analysis and documentation, and front-loading the effort and allocation of resources in projects.

Paper#95

Leveraging the Systems Engineering Life Cycle Process for Reverse Engineering

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Keywords. Reverse Engineering;Requirements Changes;Sustainment

Topics. 17. Sustainment (legacy systems, re-engineering, etc.); 2. Aerospace; 2.3. Needs and Requirements Definition; 2.6. Verification/Validation; 4.3. Reliability, Availability, and/or Maintainability; 6. Defense;

Abstract.

Systems kept in service for extended periods may experience issues caused by changes to the original requirements. This can manifest as parts obsolescence issues caused by changes in mission scope, industry regulations, or technology used to support the system. This paper discusses best practices for using a systems engineering life cycle methodology to support reverse engineering processes in structural-mechanical aerospace/defense products. The concepts herein compare systems engineering methodologies to determine the best approach to identify changes in system requirements in the modern environment. The availability of operational data to inform the process is explored through three case studies of legacy components with requirements changes. Systems engineers that reverse engineer by beginning with existing requirements will fail to resolve com-plications that contributed to the original issue. Reverse engineering of aging subsystems and components to resolve a parts obsolescence issue warrants a full systems engineering approach beginning with requirements review.

Paper#120

Logics of irrational design of rational systems – systems modelling and human decision making

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Keywords. Systems Science;Knowledge Management;Model Based Development;Decision Making

Topics. 1.5. Systems Science; 3.4. Information Management Process; 5.3. MBSE;

Abstract.

The background for this paper is the rapid changes that currently manifests around the globe. The premise is that system science can provide a basis to enhance the capabilities of system engineering to meet these challenges. This paper explores with a few examples how system modelling, decision making and methods to manage complexity can draw on the science. Additionally, it will be explained that humans do not take all decisions on logical bases, hence, the framing of the question allowed by the system model is vital. The result of the paper is a proposal of a framework for knowledge management modelling based on the science and major lessons learned in modelling and methods to manage complexity.

Paper#129

Managing Complexity through Collaborative Intelligence

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Keywords. complexity;collaborative intelligence;collaborative engineering;sensemaking

Topics. 1.1. Complexity; 1.6. Systems Thinking; 2. Aerospace; 22. Social/Sociotechnical and Economic Systems; 5.9. Teaching and Training; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract.

Systems engineering needs new ways to visualize where and how the increasing complexity found in large-scale aerospace programs affects development processes. Following sensemaking principles provides a vector for comprehending confusing or roadblock events by enhancing communication and decision making to improve the organizational management of complexity. The sensemaking process can be applied through collaborative intelligence, an example being collaborative engineering principles that can guide team dynamics as a method of visualizing complexity in system development. The use of applied sensemaking can document personal interaction in beneficial ways. Communication styles are captured in a collaborative intelligence technique called thinking talents. Utilizing the collective thinking talents of the people who work within a team enables communication to be more effective for both the individual and the organization. Thinking talents are a simple organizational development tool to implement. Using its data enables a collaborative engineering environment that is proactive in focusing collective attention on uncovering potential failure earlier in the development process as a way to manage complexity.

Paper#33

Mindful Maturation Matters

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Keywords. Lifecycle;Information Model;Digital Engineering

Topics. 12. Infrastructure (construction, maintenance, etc.); 2. Aerospace; 3.4. Information Management Process; 3.7. Project Planning, Project Assessment, and/or Project Control; 5.5. Processes; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract.

The purpose of this paper is to explore how awareness and insight from the information associated with a system (requirements, analysis, solution, verification, risk) matures as understanding increases. This is done through a series of iterations between requirements and design within each system level, and between the levels of system, sub-systems, elements etc that make up the system as a whole.

To handle this maturation, it is important to mindfully manage this maturing information. One of the best ways to do this is to use the Systems Engineering V-Model.

This paper explores the ways the often-maligned V-Model is misunderstood and the barriers to its intended use and proposes a range of practices that can help tailor the model and achieve its intended purpose of supporting the creation of successful systems. This is illustrated with several analogies.

Chief amongst these is recognizing that whilst the V-Model shows process, it is not an instruction for the order of process, but a structural concept to help store, organize, update, and share the maturing awareness, insight and understanding achieved at a point in time. Key is understanding the system development, due to the interaction of parts to make wholes, has never been a linear (waterfall) flow. Understanding how this interaction works, how to recognize/handle uncertainty, how to communicate the developing understanding across the range of teams developing systems at multiple levels is critical.

Paper#127

Model-Based Analysis of Standard Operating Procedures' Role in Abnormal and Emergency Events

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Keywords. Standard Operating Procedures;Human Factors Design;Procedure Design and Test

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

Abstract.

Standard Operating Procedures (SOP) describe the desired flight-crew response to mission events including normal, abnormal, and emergency events. The SOPs define flight-crew step-by-step actions to perform the SOP appropriate for the mission event. Although the aircraft and automation are tested rigorously for certification, and the flight-crew are trained and qualified through simu-lator and flight check-rides, oversight of the SOPs is marginal. This is especially problematic for SOPs that must be completed in a short Allowable Operational Time Window (AOTW) prior to the occurrence of a hazardous event. The AOTW can be variable due to environmental conditions (e.g. wind, aircraft performance), as is the Time-on-Procedure (ToP) (e.g. simultaneous proce-dures/events, disruptions/distractions in the cockpit, variability in individual human performance). The variance motivates the need for modeling and analysis of SOPs.

This paper used a modeling language embedded in a System Engineering Model-Based tool to evaluate the execution performance of the SOPs for abnormal/emergency mission events with regard to ToP and AOTW. The analysis yielded a classification of the accident scenarios by: (1) Insufficient AOTW, (2) Excessive ToP, or (3) combination of excessive ToP and insufficient AOTW. For the excessive ToP, the analysis highlighted the issue of delay in initiating an SOP due to ambiguity in the triggering cue from the external environment, or missing associations between a cockpit alert and the SOP. The analysis also highlighted issues arising from the presence of memory items in the SOP, or cues that are out of the operator's Field of View (FoV). In all cases, the results highlighted the importance of a method for quantifying the performance of SOPs considering the variability in ToP and AOTW. The implications of these results are discussed.

Paper#126

Multi-Disciplinary Insights into Measurement and Assessment for SoS

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Keywords. System of Systems;SoS;Measurement;Assessment;Best Practice;Metrics;Methodology

Topics. 11. Information Technology/Telecommunication; 3.6. Measurement and Metrics; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract.

The assessment of performance and quality is essential to the engineering and evolution of Systems of Systems (SoS). However, there has been limited discussion of SoS measurement and evaluation in the literature. This paper reviews the measurement and assessment literature across multiple disciplines to address this gap. The review identifies relevant challenges and best practice elements within each discipline that are then compared against the nature and characteristics of SoS. Best practice elements are then synthesized into three key areas necessary for SoS evaluation: measurement, determination of good metrics, and assessment. While further work has been identified and initiated on the development of methods for the generation of such metrics, this study provides practitioners with the core practices and principles necessary to enable tailored and enhanced SoS assessment.

Paper#61

Multilayer Network Models for Coordinating Orchestration of Systems Security Engineering

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Keywords. Multilayer networks;System Security Engineering;Security Orchestration;Complex Systems

Topics. 12. Infrastructure (construction, maintenance, etc.); 4.4. Resilience; 4.7. System Security (cyber-attack, anti-tamper, etc.); 6. Defense;

Abstract.

Systems security engineering (SSE) faces new internal (e.g., increased digitization) and external (e.g., adversary capabilities) obstacles as systems increase in complexity and are deployed to increasingly challenging operating environments. Legacy approaches heavily rely on individ-ual, physical, digital, or personnel domain-specific strategies for security. Such segmented re-sponses helped initiate efforts by the INCOSE systems security working group to identify fun-damental elements of SSE. One of these fundamental elements is security orchestration, where the SSE goal is to coordinate between previously disparate security solutions. Multilayer net-work-based approaches seemingly provide the logical structure and mathematical foundation to conduct security orchestration for "tightly coupled coordinated system defense in cyber-relevant time." Within multilayer networks, the ability to identify and manipulate cross-domain (e.g., in-tralayer) connections that influence security performance measures demonstrates an enhanced level of security orchestration. As such, multilayer networks support the future of SSE efforts to mitigate real-world complexities, innovative adversaries, and disruptive technologies. After de-scribing security orchestration as a concept and foundational element, this paper explores how multilayer network models can enhance orchestration systems security engineering. Additionally, a demonstration case of systems security for a high consequence facility (as a complex system) is followed insights and implications for incorporating orchestration in the future of systems security.

Paper#145

Natural Language Understanding of Systems Engineering Artifacts

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Keywords. natural language processing;model-based systems engineering;semantic search

Topics. 2.1. Business or Mission Analysis; 2.4. System Architecture/Design Definition; 5.3. MBSE;

Abstract.

This paper examines in close relation two fields of growing importance: model-based systems engi-neering (MBSE) and natural language processing (NLP). System models provide a structured de-scription of engineering data, whose inherent semantics often remains hard to explore. Natural lan-guage understanding, an important field of NLP, focuses on semantic text comprehension but cannot directly account for structured information sources.

In this paper, we investigate natural language understanding of MBSE artifacts as they appear in industrial scenarios. In this context, the wide and heterogeneous knowledge space and user base calls for novel techniques to facilitate information retrieval from complex system models.

We thus propose to leverage domain-specific text generators to transform models into a descriptive text corpus on which we apply state-of-the-art semantic search and analysis techniques.

We illustrate the approach on relevant MBSE examples by performing a qualitative evaluation of intuitive text search and comprehension in textual descriptions obtained from system models.

Paper#45

Oversimplification of Systems Engineering Goals, Processes, and Criteria in NASA Space Life Support

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Keywords. Simplification of systems engineering;Space life support;Intuitive engineering

Topics. 1.6. Systems Thinking; 2. Aerospace; 2.4. System Architecture/Design Definition; 3.3. Decision Analysis and/or Decision Management; 5.5. Processes;

Abstract.

This paper investigates the oversimplification of the inherently complex systems engineering process in space life support. The standard systems engineering process steps are described. The International Space Station (ISS) life support system is explained with its goals and performance criteria. Although it is not usually emphasized, the essential function of developing a hierarchy of systems and subsystems is to simplify the design process. The System Complexity Metric (SCM) shows how this divide-and-conquer approach also reduces the system complexity. The complete systems engineering process has many detailed steps. It is often simplified because of the effort required and the human limitations on working memory and decision span. Systems analysis demands slow, logical, and focused thinking but is often bypassed in favor of quick, intuitive, subconscious “gut feel.” A study of 100 system designs found examples of 12 specific mental mistakes, such as ignoring stakeholder needs, and these mistakes are essentially oversimplifications of the systems engineering process. An analysis of space life support goals, options, criteria, and processes found 11 examples of oversimplifications in systems engineering, such as neglecting safety and cost. All these 11 oversimplifications could be traced to one or more of the 12 previously identified mental mistakes or other well-known ones, such as ignoring sunk costs. Oversimplification of the systems engineering process is rarely noticed but is a common and harmful problem. A study of failures in 50 different space systems found that problems in systems engineering caused failures and often led to errors in design, development, and test that further contributed to failure. It seems that more diligent systems engineering could prevent many project problems and failures, but projects seem to be more guided by “gut feel” based on tradition, authority, and consensus than on the logical, rational systems engineering approach.

Paper#92

Plug-and-Play Adaptive Approach to Integrating Model-Based Systems Engineering Concepts into Academic Curriculum

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Keywords. MBSE;Engineering education;Online learning

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

Abstract.

Model-based Systems Engineering (MBSE) is coveted for improving productivity and product quality. However, adoption is slow because the workforce lacks training. Therefore, a group of MBSE experts at an R-1 university developed a series of MBSE online learning modules that can be integrated into existing courses. Rather than adding courses to engineering programs, this project presents a “plug-and-play” adaptive approach to implementing new topics into existing courses. Faculty can select elements from the modules that best fit their courses and their students’ learning needs. To evaluate the effectiveness of the approach and content, parts of the first MBSE module were incorporated in a graduate level engineering course. Surveys and descriptive analysis revealed students’ learning experiences and feedback (n = 81). The research findings suggest students had positive experiences with the content and their interest in MBSE increased. Further module design improvement is included and discussed in the paper.

Paper#64

Practical Experience Applying Feature-based Product Line Engineering in a DevOps Environment: Achieving the Best of Both Worlds

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Keywords. Product line engineering;Feature-based product line engineering;DevOps

Topics. 5.6. Product Line Engineering; 5.7. Software-Intensive Systems; 6. Defense;

Abstract.

Systems and Software Product Line Engineering (PLE) is an engineering discipline to produce and maintain a family of similar products in an efficient manner. It has long been known that managing a product portfolio as a single entity, as opposed to a multitude of separate products, can bring substantial improvements in schedule, cost, and quality. DevOps is an engineering discipline, practiced within an infrastructure of test and deployment automation, that seeks to minimize the time that a change to a product is made, and the product is built, validated, deployed, and made available to the end users. Many organizations find themselves willing to employ both disciplines – that is, to employ DevOps for products in a product line. This paper shows how that can be done, relates a case where it was done, and reports on the substantial benefits that were realized.

Paper#93

Process Flow Modeling for an In-Time Aviation Safety Management System

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Keywords. In-time Aviation Safety Management System;Risk Management;Safety Assurance

Topics. 14. Autonomous Systems; 2. Aerospace; 3.9. Risk and Opportunity Management; 4.6. System Safety; 7. Emergency Management Systems;

Abstract.

In 2018, the National Academies challenged the National Aeronautics and Space Administration (NASA) to develop an In-Time Aviation Safety Management System (IASMS). This IASMS would enable increasingly autonomous aviation operations by automating the safety monitoring, assessment, and mitigation functions currently performed manually as part of the Safety Manage- ment System (SMS) process. In this paper, we detail today's SMS processes. We will also be drafting a process flow of today's SMS based on the International Civil Aviation Organization (ICAO)'s guidelines. Furthermore, we will be developing bowtie diagrams for two use case sce- narios identified by the Flight Safety Foundation (FSF) in their Disaster Monitoring and First Re- sponse studies.

Paper#119

Realizing the Promise of Digital Engineering: Planning, Implementing, and Evolving the Ecosystem

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Keywords. Digital Engineering;Digital Ecosystem;Digital Thread;Digital Twin;Model-Based Collaboration;MBSE;Model-Based Systems Engineering;Consistency Management;MBSE Patterns;PBSE

Topics. 20. Industry 4.0 & Society 5.0; 3.4. Information Management Process; 5.12 Automation; 5.3. MBSE; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract.

Gaining benefits of Digital Engineering is not only about implementing digital technologies. An ecosystem for innovation is a system of systems in its own right, only partly engineered, subject to risks and challenges of evolving socio-technical systems. This paper summarizes an aid to planning, analyzing, implementing, and improving innovation ecosystems. Represented as a configurable model-based reference pattern used by collaborating INCOSE working groups, it was initially applied in targeted INCOSE case studies, and subsequently elaborated and applied to diverse commercial and defense ecosystems. Explicating the recurrent theme of Consistency Management underlying all historical engineering, it is revealing of Digital Engineering's special promise, and enhances understanding of historical as well as future engineering and life cycle management. It includes preparation of human and technical resources to effectively consume and exploit digital information assets, not just create them, capability enhancements over incremental release trains, and evolutionary steering using feedback and group learning.

Paper#58

Red-Teaming as a Research Method for Systems Engineering Thesis Students

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Keywords. Systems engineering education;Research methods;Thesis validation

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

Abstract.

All research projects need a forward path method for performing the investigation, making findings and reaching conclusions. In addition, project methodology must include methods that test the truth of the knowledge claimed to have been developed through the project. We address the specific issue of validation in thesis projects in systems engineering (SE) programs where the intended outcome is either an application of SE method or an investigation of a topic in SE. We present red-teaming (RTing) as a validation method for results of SE research. We discuss two case studies of thesis projects which used a RTing method to evaluate a proposed method for doing something. From this we discuss the strengths and weaknesses of the RTing method in thesis projects and provide guidelines for use of RTing as a project outcomes evaluation method. We conclude RTing is a useful method to evaluate a thesis project which generates a design or a method because it uses a method not directly influenced by the student's assumptions in the design of the project. The RTing method is constrained by the challenges of finding willing red-team (RT) members, project schedule, and the RT member's knowledge of the subject.

Paper#75

Semantic Model-based Systems Engineering based on KARMA: A Research and Practice Roadmap 2025

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Keywords. MBSE;Semantic modeling;ontology

Topics. 5.3. MBSE;

Abstract.

Model-based Systems Engineering is proposed as a graphical approach to support for-malism of system artifacts across system lifecycle based on models since 1993. The previous moti-vation of graphical specification is to provide a unified graphical description on the perspective of systems engineering in order to formalize system architectural views, to promote communications among stakeholders and to support system analysis and verification. However, when different modeling tools are developed based on such graphical specifications, model and data interoperability across modeling tool is a biggest challenge faced by the tool venders and MBSE practitioner. Thus, semantic specification is proposed again to enhance data interoperability, such as SysML 2.0. In this paper, we propose a new semantic MBSE language and framework aiming to support complex sys-tem development using a two-core mechanism: KARMA language and Industrial Ontologies Foundry (IOF) SE and MBSE ontology. Then, we introduce the KARMA Roadmap 2025 including technical vision, organizational views and standardization. A new KARMA open-source environ-ment is planned to create in order to provide MBSE application for more MBSE practitioners.

Paper#44

Space Habitats Should Be 1 g Shielded Space Platforms, Not on Low Gravity, Radiation Exposed Moon or Mars

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Keywords. Space habitats;artificial gravity;radiation shielding

Topics. 2. Aerospace; 2.1. Business or Mission Analysis; 2.4. System Architecture/Design Definition;

Abstract.

Previous missions have subjected astronauts to confined space, weightlessness, and increased radiation. These impair astronaut comfort, performance, and future health. The exploration and future settlement of space will depend on the long-term presence of individual humans. This requires the development of space platforms where humans can work and live in health for many years, perhaps generations. A livable space platform must provide adequate volume, gravity, and radiation shielding. This seems easier to do in deep space or Low Earth Orbit (LEO) than on the surface of the moon or Mars. Permanently habitable deep space platforms will enable scientific and technical research, space tourism, space mission preparation, space industry development, and military surveillance and operations. The first fully habitable space station would probably be in LEO for convenience and lower cost.

Paper#23

Storytime, Audience to Authors: Enhancing Stakeholder Engagement

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Keywords. ConOps;OpsCon;Concept;Operations;Stakeholder;Engagement;Management;Transit;Rail

Topics. 12. Infrastructure (construction, maintenance, etc.); 16. Rail; 2.1. Business or Mission Analysis; 2.3. Needs and Requirements Definition; 2.4. System Architecture/Design Definition; 21. Urban Transportation Systems;

Abstract.

This paper is largely aimed at Public Agencies; such as Infrastructure and Transit authorities. The creation and development of projects at these agencies impacts multiple layers of stakeholders, who, in the collective experience of the authors, are often not involved in the project until the middle or end of the development phase or not until they have to use the system. These neglected end users and influencers of the system do not have a timely voice – they are effectively excluded.

This paper advocates for the early engagement of all defined stakeholders; the obvious and the unconventional, both internal and external to the agency. This paper does not provide a detailed ConOps process but rather defines what a ConOps is, why it is necessary, and at what stage in the project should one be developed. The principal conversation herein focuses on how to determine who the audience is for the system of interest (SOI) and ways to engage them. The paper describes a holistic approach to the creation and development of a ConOps deliverable by engaging the audience, who become stakeholders and effectively, authors. This paper concludes with a case study encompassing the discussion.

Paper#53

System Engineering as an effective approach for the fast development of space downstream applications in the health sector

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Keywords. System Engineering;Model Based System Engineering;Sanitation System;Sars-Cov-2;Space downstream application

Topics. 2. Aerospace; 2.2. Manufacturing Systems and Operational Aspects; 2.4. System Architecture/Design Definition; 2.6. Verification/Validation; 4. Biomed/Healthcare/Social Services; 5.3. MBSE; 5.5. Processes; 7. Emergency Management Systems;

Abstract.

The present paper illustrates how System Engineering was applied, step by step, to the development of a space downstream project whose scope was the development of a sanitation system for ambulances. The system was developed to respond to a specific need identified during the COVID-19 pandemic. The system is based on the germicidal effect of UVC radiation and exploits space-related technologies to provide a real-time monitoring of sanitation level within the ambulance and a geo-referenced traceability of sanitation performed. The multidisciplinary approach was a key-factor for the successful completion of the project because it ensured a high standardization level of the development process and high communicability within an heterogeneous team composed of Soft-ware/Electronic/Mechanical Engineers, Biologists, Virologist and Ambulance’s Operators. The project confirmed that system engineering can be effectively used for the fast development of every-day-life downstream service/system especially in case different technologies and competencies have to be synergically integrated.

Paper#34

System Engineering Heuristics for Complex Systems

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Keywords. Heuristics;Complex;Systems;Principles

Topics. 1.1. Complexity; 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.

Complex systems are challenging for engineers. In considering the challenges in addressing com-plex problems as well as designing and developing complex systems, the INCOSE Complex Sys-tems Working Group (CSWG) Heuristics Focus Team, in conjunction with the INCOSE Heuristics Team, has considered a range of systems engineering heuristics that guide the engineering of complex systems. These heuristics provide some initial insight for understanding the engineering of complex systems. This work aims to identify, develop, analyze and curate these heuristics and their potential use in dealing with complexity and developing complex systems. This paper con-cludes that a range of beneficial heuristics have been identified that cover the breadth of complex problems, as assessed from multiple perspectives. This initial or preliminary set of heuristics needs to be tested through practice and use across the INCOSE community before effort is expended to make them more memorable either individually or as a set.

Paper#81

System Verification and Validation Approach Using the MagicGrid Framework

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Keywords. System architecture;Validation and verification;Model-based Systems Engineering;Model-based Testing;SysML

Topics. 2.4. System Architecture/Design Definition; 2.6. Verification/Validation; 3. Automotive; 5.3. MBSE; 6. Defense;

Abstract.

The ongoing transformation in the industry from a document-based systems engineering to a mod-el-based systems engineering approach reveals a need for new methods of verifying and validating systems. Traditional methods of testing the actual system are getting more and more expensive. A model-based environment could significantly reduce testing and, most importantly, verification and validation processes costs. It allows testing on the system model by applying various techniques, such as simulation, analysis, review, mock-ups, etc. There are, however, very few approaches today detailing how verification and validation of the entire system (taking into count its components and subsystems) could be performed. This paper proposes an approach to perform verification and validation of a system using system models developed with Systems Modeling Language (SysML) and in accordance with the MagicGrid (formerly known as MBSE Grid) framework. The approach covers system testing activities beginning with verification of the lowest modeled system elements against system requirements and finishing with validation of the system as a whole, against stakeholder needs.

Paper#12

Systems Engineering applied in the construction industry to achieve a BREEAM certification

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Keywords. Systems Engineering;BREEAM Certification;Construction Management;Construction Planning and Control;Green Buildings;Sustainable Infrastructure

Topics. 12. Infrastructure (construction, maintenance, etc.); 2.3. Needs and Requirements Definition; 3.3. Decision Analysis and/or Decision Management; 4.2. Life-Cycle Costing and/or Economic Evaluation; 5. City Planning (smart cities, urban planning, etc.);

Abstract.

Buildings have environmental impacts over their entire life cycle, which often exceed 50 years. Today buildings are responsible for 40-50% of all energy usage and anthropogenic greenhouse gas emissions globally. Green constructions are gaining increased attention, and a variety of building certifications provide a rating system designed to help develop buildings that are more sustainable, i.e., energy efficient, with zero emissions. BREEAM is a well-known certificate with a clear outcome, and by satisfying different targets a building may gain points to achieve a certain benchmark rating. The construction industry in the last decade has shown an increased interest in Systems Engineering (SE). This thesis investigates the barriers to BREEAM and considers whether SE practices can help sys-tematize the assessment process and make it less resource intensive. The research shows that there is a desire in the industry for a more systematic approach to achieving a BREEAM certification. The results indicate that an early life phase investment with a high focus on the requirements, in addition to a systematic use of the V-model and hierarchy diagram, is useful.

Paper#144

Systems Engineering Competency Expectations, Gaps, and Program Analysis

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Keywords. engineering competencies;competency frameworks;systems engineering graduate programs;systems engineering education ecosystem

Topics. 1. Academia (curricula, course life cycle, etc.); 20. Industry 4.0 & Society 5.0; 22. Social/Sociotechnical and Economic Systems; 4.5. Competency/Resource Management; 5.9. Teaching and Training;

Abstract.

System engineering education is challenged to address the needs posed by rapidly changing technology epitomized by Industry 4.0 and the digital transformation. In particular, there are relatively slow and inaccurate feedback mechanisms between the needs of employers, students and universities at the level of educational program content development. This objective of this work is to use the SE competency framework developed by the Systems Engineering Education Ecosystem (SEEE) project to determine the competency needs of our sponsoring organizations, analyze the curricula of our current SE program for its evolution, and guide the development of our future SE program specializations. This paper presents the results of a methodology to improve the feedback between systems engineering employers and universities in academic program curricula development through survey and academic program analysis.

Paper#69

The ISO-15288 technical processes, system maturity and conceptual gaps

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Keywords. System Maturity;ISO 15288;Conceptual Gaps;Technical processes;State changes

Topics. 1.6. Systems Thinking; 5.5. Processes;

Abstract.

ISO 15288 and the INCOSE Systems Engineering Handbook define technical (and other) processes but do not really explain why we need all these processes. This paper formalizes the technical processes specifically in terms of the changes in maturity that each enacts and why these specific changes are necessary. This in turn clarifies the need for each process and places the processes on a sound philosophical footing.

Paper#68

The Soft Skills Challenge: The left brain’s search for its other half

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Keywords. Soft skills;education;competency

Topics. 1. Academia (curricula, course life cycle, etc.); 1.6. Systems Thinking; 20. Industry 4.0 & Society 5.0; 4.5. Competency/Resource Management; 5.9. Teaching and Training;

Abstract.

There is an accelerating need for soft skills in the 21st-century workplace. The need currently exceeds the level of those skills present in the workforce creating a recognized gap in soft skills. Despite the acknowledgment by industry and educators of the importance of soft skills and the gap, the structural causes of soft skill deficiencies persist. From negative attitudes about soft skills to the exclusion of their development from educational and industrial training programs, they are being neglected at the same time their importance to workplace success is climbing. This paper examines the soft skills gap, its causes, and some potential solutions for its remediation.

Paper#60

Tilting at Windmills: Drivers, Risk, Opportunity, Resilience and the 2021 Texas Electricity Grid Failure

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Keywords. MBSE;Strategy;UAF;Energy Systems;Infrastructure

Topics. 1.1. Complexity; 3.9. Risk and Opportunity Management; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.);

Abstract.

To put it very simply, but not at all clearly, the 2021 Texas electricity grid failure was both caused by and not caused by the use of renewable energy. In 2020, 46 percent of Texas's energy was generated by natural gas, coal 18 percent, nuclear 11 percent, and renewables wind power 23 percent, and solar 2 percent. During the winter months when power demand is lowest, renewables can rise to up to 55%. When the historic winter storms hit, the biggest problem was the lack of winterization of all types of generation systems and supporting infrastructure. All the of the systems failed to various degrees. So why weren’t these systems winterized? Mostly it was a lack of incentives. The government provided no financial incentives and did not mandate winterization. These winter storms were once in a century event, and companies could not make a business case with reasonable ROI to winterize. Companies that did manage to operate sold power and gas for up to 400% more than normal due to the lack of supply and increased demand. So, there was a built-in disincentive to not invest. What happened was a complex system of systems failure the size and scale of Texas and to explain it all would require a book. This paper will look at the risks, op-portunities, and drivers of Texas electric grid, what caused it to fail, and incentives to succeed in the future. We will also examine incentive systems gone wrong such as the Cobra Effect.

Paper#114

Two Variant Modeling Methods for MBPLE at Airbus

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Keywords. Model-Based Product Line Engineering (MBPLE);Variant Modeling Methods;Model-Based Systems Engineering;Airbus

Topics. 2. Aerospace; 5.3. MBSE; 5.6. Product Line Engineering;

Abstract.

Product Line Engineering (PLE) is a fundamental component of systems engineering. As postulated in INCOSE's Vision 2025, Model-Based Systems Engineering (MBSE) is becoming the norm for systems engineering. Thus, we need to integrate PLE into MBSE. An important aspect of this integration is the definition of model-based methods. This paper defines two possible approaches for variant modeling with SysML applied at Airbus and provides insights into their application in practice.

Paper#28

Using Design Structure Matrices (DSMs) to Derive System Architectures

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Keywords. Design Structure Matrix;Architecture Derivation;Modularity

Topics. 1. Academia (curricula, course life cycle, etc.); 1.6. Systems Thinking; 2. Aerospace; 2.4. System Architecture/Design Definition; 5.9. Teaching and Training; 6. Defense;

Abstract.

Design Structure Matrices (DSMs) have been used to find the optimal sequence for process tasks and for defining optimum team structures for many years. This paper proposes a novel approach of performing functional based DSMs. This approach aligns closely with several Architecture Development Methods (ADMs) and serves as a great way to both manually perform and to teach the architectural derivation of a system. An advantage of using the functional DSM method is that system modularity can easily be identified, which aligns with the Modular Open Systems Approach (MOSA) modular design tenets. This paper will demonstrate how the functional DSM method can be used to define the architecture of a Software Defined Radio (SDR) based system, for both a large and small platform. Further, it will be demonstrated how the DSM findings can also be combined with the MOSA Key Open Subsystem (KOSS) tool to further enhance modularity and ensure low cost growth and capability insertion over the entire system lifecycle. The author’s intent is to not imply that the detailed DSM approach replaces model based architecting. On the contrary, there are model based architectural derivation methodologies (e.g. Arcadia Capella) that have rich artifacts to support all steps of the architecture derivation process. However, this approach provides a means to synthesize a robust modular architecture without model based techniques and allows practitioners to gain a better understand the architectural development elements before a pure modeling approach is used.

Paper#15

Visual Lean planning tools in the construction industry: A case study

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Keywords. Visual planning boards;Lean construction;Last Planner System;Visual Lean planning

Topics. 12. Infrastructure (construction, maintenance, etc.); 20. Industry 4.0 & Society 5.0; 3.7. Project Planning, Project Assessment, and/or Project Control; 5. City Planning (smart cities, urban planning, etc.); 5.2. Lean Systems Engineering;

Abstract.

Despite being the world’s most significant contributor to the global Gross Domestic Product, the construction industry has untapped potential in its productivity, with frequent project delays and conflicts. Thus, a growing number of contractors implement visual Lean tools, such as the Last Planner® System (LPS). The paper explores the essential visual Lean planning elements to increase the cohesion between planning and production in construction projects through a project case study and lessons learned in the industry. The research indicates that look-ahead plans, soundness checks, early phase planning, BIM models, and applying visual Lean planning in both the design and production phases are critical success factors when using the LPS.

Paper#112

What Systems Engineers Should Know About Emergence

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Keywords. Emergence;Systems Engineering;Systems-of-systems;Soft systems;Complexity

Topics. 1.5. Systems Science; 22. Social/Sociotechnical and Economic Systems; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.);

Abstract.

The concept of emergence refers to phenomena that occur on a system-level without being present at the level of elements in the system. Since a system is created to achieve certain emergent system-level behavior, while avoiding other emergent properties, a deeper understanding of emergence is crucial to further the field of systems engineering. It has also been identified as one of the key aspects of systems-of-systems. However, the concept has been the topic of much debate in both philosophy, systems science, and complexity science for a long time, and there is yet no precise characterization on which there is general agreement. In this paper, a selection of the literature on emergence is reviewed to identify some key characteristics and disputes. The various philosophical points of view are ana-lyzed from the perspective of systems engineering, to sort out what characteristics have practical implications, and which philosophical quiddities are merely of theoretical interest. The paper also relates emergence to systems engineering practices and suggests some tactics for dealing with emergence. Key results are that the inclusion of an explicit observer is essential for understanding and handling emergence, and that emergence is closely related to the amount of information required to describe the system which is also a defining characteristic of complexity.

Paper#47

You Can't Touch This!: Logical Architectures in MBSE and the UAF

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Keywords. MBSE;UAF;Architecture;Logical Architecture;Operational Architecture;Systems of Systems

Topics. 1.1. Complexity; 14. Autonomous Systems; 17. Sustainment (legacy systems, re-engineering, etc.); 2.4. System Architecture/Design Definition; 20. Industry 4.0 & Society 5.0; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.);

Abstract.

Logical or abstract architectures are an essential concept in systems engineering. They are included in the systems engineering handbook, the OOSEM process, the SEBOK, several modeling languages, and the ISO 15288 process definition. A logical architecture is a solution-independent model of the problem domain used to understand "what" needs to be done, while avoiding de-fining "how" it will be done. The logical architecture includes all the related logical elements without constraining the architecture to a particular technology or environment. It traces to the physical architecture which defines how to implement the architecture using specific technologies. Logical architectures can be defined using MBSE languages such as the systems modeling language (SysML) and is implicit in architecture frameworks such as DoDAF, MODAF, NAF and their implementation in UAF using SysML. DoDAF and MODAF call this the Operational set of views. NAF has recently changed the title of the Operational views to Logical views to further emphasize the purpose of the views. This paper will define the benefits of using a logical architecture and provide guidance on how it can be implemented.

Panel

Panel#1

"Stop beating up on complexity"

Jawahar Bhalla (JB Engineering Systems / Shoal Group) - jb@engineeringsystems.com.au
Gary Smith (ISSS VP System Practice) - grs0036@gmail.com
Charlotte Dunford (Rolls Royce) - charlotte.dunford@rolls-royce.com
Suja Joseph-Malherbe (Letter27) - suja@letter27.co.za
Patrick Godfrey (University of Bristol) - Patrick.Godfrey@systems-thinking.co.uk

Keywords. Complexity;Systems Thinking;Sustainability;Emergence;Abstraction;Dialogue

Topics. 1.1. Complexity; 1.6. Systems Thinking; 10. Environmental Systems & Sustainability; 22. Social/Sociotechnical and Economic Systems; 5.10. Diversity (cultural boundaries, diverse engineering teams, training underserved groups, etc.); 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract.

We fear complexity. However, the panellists suggest that understanding and appreciating complexity is key to societal well-being and vitality. It stimulates creativity, innovation, and sustainability. Exploring complexity from different perspectives, each panel participant will present a position statement to start the conversation. We will then transition to an open forum discussion and Q&A format to bring in additional perspectives and approaches towards expanding our collective understanding of complexity as an enabler for the betterment of society.

Biography

Jawahar Bhalla (JB Engineering Systems / Shoal Group) - jb@engineeringsystems.com.au
JB is a passionate Systems professional with over 30 years experience across multi-national organisations in technical and strategic leadership roles. He contributes to the advancement of Systems Thinking, Systems Engineering and Modelling & Simulation locally and globally as foundational enablers to understanding complexity for a better, safer world. He is the Technical Director of INCOSEs' Australian Chapter, SESA, an SME Industry Co-Chair of the ADF Synthetic Environment Working Group, a past member of the SimAust Board and a founding member and past Chair of the SimAust Professional Development Committee. He was recognised by Simulation Australasia at the ASC 2021 as the recipient of the "Ray Page Lifetime Achievement Award" for significant and consistent contributions to M&S in the Australasia region. He has a BE in Aerospace Engineering and a BSc in Computer Science from UNSW, a Masters in Systems Engineering from UNSW@ADFA and is a current iPhD candidate on an Australian Government Research Training Program scholarship, with industry partner Shoal Group, at the University of Adelaide, Australia. He has 24 technical papers published and has delivered numerous presentations, tutorials, workshops and sessions on systems concepts, systems engineering and Modelling & Simulation.

Position Paper

Everything we know and believe to be true is a mental model, an abstraction of reality, created for a particular purpose, considered from a particular perspective. Consequently, our (individual) understanding of reality (what we believe to be true), is both limited and biased. These differences in abstractions of our mental models result in varying levels of success in our interactions. Our ability to communicate effectively (explain and be understood) is best achieved using a common protocol (Eg. symbols, sounds, syntax), with a measure of effectiveness being directly related to the extent to which our mental model abstractions "correlate" with regards to their fidelity following a specific interaction. A lack of correlation of content leads to misunderstood intent, and usually in unintended emergent outcomes (or consequences). This variance across model abstractions and the resulting unintended emergent outcomes is typically observed/termed complexity and is always a double-edged sword. Emergent outcomes may be negative, or positive. Systems Thinking, Modelling and Simulation are foundational competencies that help us understand, recognise and deal with complexity to minimise unintended negative outcomes while capitalising on the opportunity and innovation that result from unintended positive outcomes.

Gary Smith (ISSS VP System Practice) - grs0036@gmail.com
Gary is an INCOSE ESEP and senior expert in systems engineering at Airbus Defence and Space. He has been a lead architect for system of systems solutions and is currently working on transformation programmes. In 2004, “just for fun”, he undertook the Open University course S807 Molecules in Medicine and as a direct result of the course published “Cancer, Inflammation and the AT1 and AT2 receptors in the BMC Journal of Inflammation. This was featured in the UK national press, “Open University Student publishes new theory of inflammation”. The paper has over 100 citations, including one in Nature Review Oncology. His paper “Angiotensin and Systems Thinking: Wrapping your mind around the big picture” describes a conceptual model for understanding complex diseases. He is an active contributor to the INCOSE systems science and healthcare working groups where he participates as the outreach leader for the EMEA region and is an INCOSE Healthcare Ambassador. He is the VP for System Practice at the International Society for System Science and is the relationship manager with INCOSE as well as the senior editor for section 2 of the SEBOK – Foundation for Systems Engineering. Currently, in the context of system science, he is leading an effort towards an integrative framework for system knowledge.

Position Paper

The word complex lives up to its name, as it contains multiple parts of speech and senses. ... The verb use is the oldest of the three, with an original meaning of “to join or unite.” Complex comes from the Latin complecti, which means “to entwine around, to embrace,” a word that is based in part on plectere (“to braid”). https://www.merriam-webster.com/dictionary/complex. The observable universe is a system that contains systems. Complexity is an emergent feature of the universe that results when things combine into new things. We can see the evidence in this from the progression of quanta to the sub atomics (nucleons and electrons), nuclei, atoms, molecules, cells, organisms, and social systems. With each new level, there are affordances for new relationships and new possibilities, some of which in the human experience of engineering might not be predicted – for good or ill, from our perspective. Nevertheless, without complexity the world, indeed our universe would be a formless void without matter or life. Let us not forget this lesson in our systems engineering. Regarding complexity, let us appreciate it, let us do our best to anticipate outcomes to optimise the positive for ourselves and for Life on this planet, but please we must not seek to remove it or beat it up, for without uncertainty there can be only stagnation and ultimately decline.

Charlotte Dunford (Rolls Royce) - charlotte.dunford@rolls-royce.com
Charlotte Natalie Dunford graduated with an Engineering Doctorate in Systems from the University of Bristol in 2016 and received a Bachelor of Applied Science in Mechanical Engineering from the University of British Columbia in 2003. Her doctorate was funded by the Engineering and Physical Research Council and Rolls-Royce plc. She works as an Engineering Lead in Systems Engineering and Project Management in Engineering for Rolls-Royce Defence ensuring the business has the capability it needs in these areas. Previously, she worked as a Research Engineer in the Space and Atmospheric Physics Group at Imperial College London. Her research focuses on the aspects of the social system relevant to systems engineering. She is a Chartered Engineer and Member of the Institution of Mechanical Engineers and the International Council on Systems Engineering.

Position Paper

My thesis is that complexity is an enabler of innovation. When teams innovate, I have found that flexible design approaches, risk-taking, and collaboration have helped. I am taking this panel presentation as an opportunity to review the published literature for and against this hypothesis and present my findings.

Suja Joseph-Malherbe (Letter27) - suja@letter27.co.za
Suja Joseph-Malherbe: Suja provides systems engineering training and consultancy services as well as leadership training and coaching to individuals and organisations through Letter27. She is also a sessional lecturer at the Faculty of Engineering and the Built Environment at the University of the Witwatersrand in South Africa delivering post-graduate courses on systems engineering. She is a Certified Systems Engineering Professional (CSEP) and a Solution-focused Brief Coach (ICF-ACSTHs training). Her involvement in INCOSE since 2010 reflects her passion for the industry. She was the President of the INCOSE South Africa Chapter (2017 - 2018) and served on the INCOSE board of directors as chair of the Policy Management Committee. She is one of five coaches at the INCOSE Institute for Technical Leadership and serves as a director on INCOSE Foundation’s board of directors. She has a bachelor's degree in engineering and a master's degree in engineering. She is a doctoral candidate. The research proposal title is, “A holistic leadership framework for

systems engineering practitioners”.

Position Paper

What is complexity? Why do we need to embrace it? What are some of the first steps we can take?

Patrick Godfrey (University of Bristol) - Patrick.Godfrey@systems-thinking.co.uk

Patrick Godfrey is a civil engineer, who retired as professor of systems engineering at the University of Bristol, and director of the Systems Centre and the EPSRC Industrial Doctorate Centre in Systems at the University of Bristol and the University of Bath. After graduating Godfrey worked for Halcrow, Consulting Engineers. He was part of the team that designed and constructed the Royal Sovereign Lighthouse, worked on various offshore projects and was a leading member of the group that designed and built an experimental offshore tower in Christchurch Bay. Godfrey led the team advising New Zealand's Petrocorp engineering the Maui field. He became Managing Director of Halcrow Offshore in the late 1980s and co-authored the Engineering Council Code of Practice and Guidelines on Risk Issues. In 1993, the Construction Industry Research and Information Association commissioned him to produce a client's guide to controlling risk. At Halcrow, he was asked to find ways of reducing costs and risks of ship collisions at the Second Severn Crossing. The success of this project led directly to his appointment as a consultant to the British Airports Authority on Heathrow Terminal 5 to manage project risks during the 4 years of the public enquiry. In the early 1990s, Godfrey was appointed Visiting Professor of Civil Engineering Systems at the University of Bristol. He co-authored with David Blockley ’Doing it Differently—Systems for Rethinking Construction’ which was awarded a Chartered Institute of Building (CIOB), Gold Medal and Author of the Year in 2000. In 2006 Godfrey was appointed Professor of Systems Engineering at the University of Bristol, and Director of the Systems Centre and the EPSRC Industrial Doctorate Centre in Systems at the University of Bristol and the University of Bath.

Position Paper

All complex systems are context dependent. This means that they will always be conditioned by uncertainty and our inadequate understanding of cause and effect. It follows that Systems Engineers recognise that the more we know - the more we know we do not know it all. So, the more we know we need to 'learn together' as human beings.

All complex systems are context dependent. This means that they will always be conditioned by uncertainty and our inadequate understanding of cause and effect. It follows that Systems Engineers recognise that the more we know - the more we know we do not know it all. So, the more we know we need to 'learn together' as human beings.

It is becoming apparent that there are tantalising benefits to be had from understanding natural systems like, for example, our own brains. Professor Evan Eichler, professor of genome sciences at the University of Washington, has mapped the part of the genome that was originally thought to be rubbish but turned out to be that which defines the uniquely human part of the brain function and immune system. “Some of the genes we have now mapped are very important for determining the high number of neurons in our frontal lobes and for the synaptic connections between our neurons being more robust and complicated,” Eichler explains. “…These determine how our bigger brains are wired for greater connectivity.” For example, our ability to cognitively collaborate and learn together.

To those who ask how we accelerate our learning to enable us to live with complexity. Let us learn from the evolution that has made us human and collaborate by listening together, learning from our joint experience, all the time measuring the outcomes against our intended purpose.

Panel#8

How to apply a criticality framework to your communications' networks

Susan Ronning (ADCOMM Engineering LLC) - s.ronning@adcomm911.com
William Schieble (MITRE) - wscheible@mitre.org
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Keith Rothschild (Cox Communications) - kar@cox.com

Keywords. IT;OT;IOT;communications systems;public safety;defense;tranport;telecommunications;rail;ICT

Topics. 11. Information Technology/Telecommunication; 16. Rail; 2.4. System Architecture/Design Definition; 4.4. Resilience; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 7. Emergency Management Systems;

Abstract.

Our society is reliant on information sharing, in the form of data or voice, between people and things. Without it, work stops. Even short duration network outages can result in chaos within public transport systems (air traffic control of commercial flights, traffic signaling of rail networks); disrupt financial systems (electronic payments, stock market transactions); and reduce business productivity (phone and email). It can also have the potential for loss of life: field utility workers communicating remotely with dispatch controllers to de-energize and re-energize lines for repair; law enforcement field personnel communicating needs for crowd control during riots; and alerting the public about dam breaches through emergency notification systems. Learn how a communications network (CN) criticality framework (CF) can help you evaluate your own networks to improve network resilience as well as network security.

Biography

Susan Ronning (ADCOMM Engineering LLC) - s.ronning@adcomm911.com
Ms. Susan Ronning is Owner and Principal Engineer of ADCOMM Engineering LLC (Rhododendron, Oregon, USA), a critical communications consultancy. She has over 20 years' experience in the telecommunications industry in the public safety, emergency management, utility, and transportation markets. She was a project engineer for Motorola and Tait Communications, led the operations and maintenance for City of Glendale, California, and consulted on multiple large-scale implementation projects across the United States. Ms. Ronning is a registered professional engineer in multiple states, a longtime member of IEEE, and Co-Chair of the INCOSE Telecommunications working group.

Position Paper

public safety personnel are reliant on voice and data comms with their dispatch center and each other. Municipal networks should be evaluated, especially those that touch emergency services.

Panel#3

Institutional Change and the Evolution of Systems Engineering

Richard Hodge (DrRichardHodge.com Pty Ltd) - richard@drrichardhodge.com
Joseph Bradley (Leading Change, LLC) - josephbradley@leading-change.org
Barclay Brown (INCOSE) - Barclay.Brown@incose.net
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Keywords. Transformation;Institutional Change;Good Regulator Theorem;MBSE;Organisational Learning;Systems Thinking;Systems Engineering;Leadership;FuSE

Topics. 1.5. Systems Science; 17. Sustainment (legacy systems, re-engineering, etc.); 22. Social/Sociotechnical and Economic Systems; 4.4. Resilience; 5.3. MBSE & Digital Engineering; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract.

Technologically, the digital future is here. Socially, digital connectivity impacts our everyday lives. Institutionally, the digital future is grossly inconvenient. It’s changing fast. Faster than organisations think, and faster than institutional connections and processes change.

Old ways of thinking and old ways of working cannot contend with the scope, scale, and pace of digital technologies as they seed through all strata and elements of society. At best, people are left behind. At worst, they’re dying waiting for the transformational change in our institutions.

At a time when institutions struggle to keep pace, the opportunity arises for systems engineers and systems engineering to shift the institutional approaches to change. More than agility, institutions require an integration of diverse ways of knowing, thinking, deciding and learning geared to the institutional context and the social value they add.

Panelists from Australia, US and Great Britain have varied backgrounds to explore the practicality and challenge of integrating systems engineering into institutional change and transformation programs, considering how systems engineering itself must continue to evolve to contribute leadership and guidance for sustainable development.

To this end, the panel will:

• Consider the institutional challenges in staying relevant in a fast-changing ecosystem of technological, social and political change

• Explore the capacity for MBSE to develop, maintain and evolve a model of enterprise worthy of satisfying

the Conant-Ashby “Good Regulator Theorem” – Every good regulator (and leader) of a system must be a model of that system, despite the combinatorial-explosion of systemic risk factors.

• Explore ways of decision making in turbulent times that assure relevance, timeliness, and action

• Explore ways to institutionalise learning within the living fibre of the enterprise to evolve the model of enterprise by connecting the agency of individuals with the social agency of the enterprise in ways that manage systemic risk.

Biography

Richard Hodge (DrRichardHodge.com Pty Ltd) - richard@drrichardhodge.com
Richard Hodge is an expert in organizational design with a focus on performance improvement and long-term sustainability. He has extensive experience across public, private and academic sectors as a consultant, general manager and company director. Richard brings specialist expertise in strategic and systems thinking for complex enterprises and what keeps them viable. He works at the enterprise, portfolio and program levels to design and deliver systemic interventions to improve outcome delivery, collaboration and interdependence across projects and their related work domains. After a long career with executive roles in Defence, Booz Allen Hamilton, and CAE, Richard now runs his own thought leaders' practice in leadership of change, especially in designing and implementing systemic intervention and large-scale transformation. Richard is a Doctor of Philosophy (Systems Approaches to Strategy & Execution) at the University of South Australia and holds a Graduate Diploma in Strategic Studies and a Bachelor of Arts (Mathematics & Linguistics). He is also a member of the Australian Institute of Company Directors.

Position Paper

Are systems engineers and systems engineering up for the integration challenge to prepare and support leaders of change to see those leaders become (as well as have) a model of the system their leading?

A critique of systems engineering (or hard systems thinking) is that “hard systems thinkers recognize the systems with which they deal exhibit aspects of complexity but still believe they are simple enough to be represented in mathematical models. When highly complex systems are involved, however, the building of a quantitative model is inevitably a highly selective process and will reflect the limitations of vision and biases of its creators. Far from recognizing this, hard systems thinkers tend to treat the model too readily as synonymous with the reality.” (Jackson, Critical Systems Thinking and the Management of Complexity – Responsible Leadership for a Complex World, Wylie, 2019)

Advances in contemporary psychology shed light on on the making of meaning (Vervaeke, Toronto University), to break through the constraints of the dominant reductionist approaches of the last 300 years. Vervaeke’s work opens four ways of knowing – propositional (which has been dominant), procedural, perspectival, and participatory. These last three are not new but lost ways of knowing that combine to achieve a recursive process of relevance realization we need to make meaning in a complex world.

Richard will explore Vervaeke’s work and its relevance to the profession of systems engineering, by focussing it on the question: How do we know if our approach is sufficiently thorough in concept and in what our people do and how they operate?

Boulding (1956) guided us not to accept as final a level of (short term) analysis below the level of complexity we’re addressing and seem surprised with the consequences. Perhaps with Vervaeke’s contribution we can take another step closer to that goal.

Richard will attempt to integrate these ideas into an ‘infinity loop’ considering how the interplay of these ideas must work artfully together and thus create opportunities for systems engineers and systems engineering to take a leadership role. How ready are we to amplify systems engineering support to leaders as models of the institutional systems they regulate?

Joseph Bradley (Leading Change, LLC) - josephbradley@leading-change.org
Dr. Bradley, received the Ph.D. degree in Engineering Management from Old Dominion University, received the Degree of Mechanical Engineer and a Master of Science in Mechanical Engineering from Naval Postgraduate School, and a BE from The Cooper Union. Prior to joining Old Dominion University, he was Deputy Director for Force Maintenance at Commander, Submarine Force, Atlantic Fleet. Prior to that, he served in various consulting roles, including Program Manager’s Representative for the conversion of the USS OHIO and USS MICHIGAN to SSGNs. He is a retired Engineering Duty Officer and submariner, having served over 26 years in the United States Navy. He is a member of the American Society of Naval Engineers, INCOSE

and IISE. His research interests include complex system governance, action research, project management, system dynamics, and decision making using modeling and simulation.

Position Paper

Einstein is frequently quoted for saying, “solutions to the problems we face require a higher-level of thinking to that we were at when we created them.” Interestingly, no one says what that “higher-level of thinking” is. Or, indeed, whether it will be adequate given the speed and volatility of change in the environment.

The interesting challenge for the future of systems engineering is to assure higher levels of thinking evolve and influence the model(s) of the systems of interest; that in turn, not only represent the nature of regulation and leadership that is present but guide their evolution. How can systems engineering better influence the speed and efficacy of institutional transformation and change.

The moderator aims to provoke diverse perspectives on the future of systems engineering, exploring the constraints and opportunities to improve the profession’s capacity to shape decision making, governance, learning and leadership.

There’s more to FuSE than MBSE. What ways of knowing, thinking, deciding and learning do we need to keep explicit to assure they are not at risk of becoming subsumed or lost in process?

Barclay Brown (INCOSE) - Barclay.Brown@incose.net

Dr Brown is the Engineering Fellow in MBSE and AI at Raytheon Technologies and CIO, International Council on Systems Engineering (INCOSE). At Raytheon he leads the implementation of Model Based Systems Engineering in business unit; incorporating, developing and delivering training courses in MBE, MBSE and SysML; leading multiple projects developing MBSE enabling technologies; implementation of AI/ML in Systems Engineering and Training domains; and leading a team of MBSE Mentor Instructors, providing training and mentoring across the organization. Dr Brown regularly speaks at internal Raytheon and external industry conferences on MBE, MBSE and Intelligent Systems. He has a long association with INCOSE, where he currently fulfils the part-time role of CIO.

Position Paper

Dr Brown will explore the capacity for MBSE to develop, maintain and evolve a model of enterprise worthy of satisfying the Conant-Ashby “Good Regulator Theorem” – Every good regulator (and leader) of a system must be a model of that system, despite the combinatorial-explosion of systemic risk factors.

Initially it appears the deep neural network style of AI systems, completely fail at the Conant-Ashby goal. A neural network is a model of sorts, but it does not represent the system in any kind of complete or even literal way, or in anything like a mental model, or visual model in MBSE. In reinforcement learning, the model is completely different but similar in that it is nothing like a full representation of the system but consists of only a few simple variables and a reward function. In Ashby’s swordsman example, the AI swordsman trained using reinforcement learning has no model at all of the possible moves, style or methods of the opponent, unless we simply infer that it does on the basis that it can learn to win the match after training in thousands or millions of practice matches. But to make such an inference seems to nullify any insight from Conant-Ashby since we thus conclude that all successful regulators have matching models of the systems they regulate.

On the other hand, systems thinking would seem to follow exactly the guidance implied by Conant-Ashby, with its models and patterns approach, though these seem mainly geared toward helping a human create a mental model of the system, from which the regulation comes.

With Barclay's presentation we will get a sense of the state of the art in MBSE and explore questions on its potential to shape and contribute to developing institutional models / systems of models for successful change.

Duncan Kemp (Defence Equipment and Support UK MOD) - duncan@17media.co.uk

Professor Duncan Kemp is the Senior Fellow for Systems Engineering in Defence Equipment and Support (DE&S) within the UK Ministry of Defence. He is both the discipline lead for Systems Engineering and the team leader of the DE&S internal SE consultancy, which he has grown from scratch to a team of over 60 systems engineers over the last six years. Duncan has over thirty-years’ experience of developing safe and effective systems, in: air defence, submarine combat systems, strategic command and control systems, operational and business information services, railways and land systems. Previous roles have included Chief Systems Engineer for rail in the UK Department for Transport, Chief Architect for MODs Command, Control, Computing and Communication systems and MOD acquisition reform team leader. Duncan is a chartered engineer, Fellow of the Institution of Engineering and Technology and INCOSE Fellow. He was one of the authors of the SE Vision 2025, the lead author for the INCOSE UK Capability SE Guide and an author of the INCOSE UK Agile SE guide. He has presented over 20 peer reviewed papers (4 best papers) at INCOSE international symposia and INCOSE UK conferences. Duncan has held a range of formal positions within INCOSE and is currently the co-chair of the INCOSE System Safety Working Group. Duncan is the Visiting Professor for Systems Thinking at the Wolfson School of Mechanical, Electrical, and Manufacturing Engineering at Loughborough University.

Position Paper

Effective Systems Engineering is the product of good quality systems engineering activity with how well that activity influences the real-world decisions.

For Systems Engineers working to more senior engineers this normally goes smoothly. Their work will be judged by:

• The quality of analysis and supporting modelling and simulation
• The assumptions and boundary conditions they assumed
• The experience and qualifications of the people involved in the work

In this case good quality advice will be followed and poor-quality advice ignored. The regulator will effectively oversee project delivery because they have a clear mental model of how to develop highly Complicated Systems.

However, not all decision makers / regulators are engineers or think like engineers. Depending on the regulators background they may view the engineering advice in a very different light:

• For those used to simple situations, they will judge quality by how well procedures have been followed.
• For those used to Complex situations, they will look for a diversity of opinion, and seek to follow multiple approaches simultaneously
• For those used to Chaotic situations they will seek advice that is simple, clear and presented with confidence.

Duncan will describe approaches used within UK MOD to help influence these less traditional regulators to make the right decisions when presented with the information that they have been presented with.

From Duncan's experience with the UKMOD, we have opportunity to explore questions of systems practice in developing and utilising models /systems of models to support leaders with their change initiatives.

Meaghan O'Neil (System Design and Strategy) - meaghan.oneil@gmail.com

Meaghan O’Neil has over 18 years of experience in designing and improving mission critical and safety critical systems. She currently provides consulting in innovation, transformation and systems engineering as the founder of System Design and Strategy LLC. She provides technical leadership for the design of connected safety critical systems, as well as C-suite support for technical due diligence and transformational change. She has aided the formation of new startups in healthcare delivery and the medical devices industry. She previously led projects as a technical authority and chief engineer at Cambridge Consultants for safety critical applications. As Director of Systems Engineering at Bigfoot Biomedical, she led the development of a closed loop control insulin pump. As a Product Manager at Mathworks, Meaghan led the development and global launch of model-based development testing software. Meaghan has also led: software implementation projects at Accenture, design projects at GE Energy, and manufacturing process design and improvement efforts at Cordis Johnson & Johnson. Meaghan has a masters degree in System Design and Management from the Massachusetts Institute of Technology and a bachelors degree in Chemical Engineering from Cornell University. Meaghan is a founding co-chair of the INCOSE System Safety Working Group. She previously served on the board of INCOSE as treasurer and as the co-chair of the Biomedical Working group.

Position Paper

Effective leadership and regulation require an understanding of the system under control, the potential actions, and the related feedback loops. This requires applying key concepts of controls theory.

Meaghan will provide a review of key areas of control theory and examples of how leaders can apply these concepts in practice. This will include a demonstration of employing elements of Nancy Leveson's STPA (System Theoretic Process Analysis) such as the hierarchical control structure as well as user centered design concepts.

Meaghan will provide an approach for identifying areas of concern and opportunities such as:

• How hierarchical controls structure changes over the lifecycle of design, build, test, and deployment.
• Identifying changes in the control structure over time during operational use.
• Recognizing changes in operators’ mental models as well as variation in mental models between human operators.
• Limitations of control actions
• Common areas of concern related to feedback

Meaghan will describe how STPA and effective use of user centered design can aid the design and regulation of digitally connected systems.

Meaghan's presentation will enable exploration of the perennial issues of understanding control in organisational settings that impact the theory and practice of leaders becoming (as well as having) models for institutional change.

Michael Henshaw (Loughborough University) - M.J.d.Henshaw@lboro.ac.uk
Michael Henshaw is Professor of Systems Engineering; he is head of the Systems Division and leads the Engineering Systems of Systems (EsoS) Research Group. His research focuses on integration and management of complex socio-technical systems, with a particular emphasis on the challenges of through-life management of systems and capabilities. The main research topics studied include modelling of Systems of Systems (SoS), Systems Lifecycles, Network Enabled Capability (NEC), management of knowledge for through-life management (TLM), cyber-security, pilot training, C2, and autonomous robotic systems. Within all these areas there is a strong emphasis on the challenges of interoperability between systems and the importance of including humans and organisations as part of the systems. After graduating in applied physics, he joined British Aerospace (later BAE Systems) as an aerodynamicist and worked for seventeen years in aeronautical engineering tackling problems associated with unsteady aerodynamics (computational and experimental) and, later, multi-disciplinary integration. He was appointed to a chair in Systems Engineering at Loughborough in 2006 to direct the large (£4M) multi-university, multi-disciplinary programme sponsored by EPSRC and BAE Systems, NECTISE, that ran from Nov 2005 – April 2009. He has an international reputation for his work in systems of systems.

Position Paper

In 1970, Professors Roger C. Conant and W. Ross Ashby produced a seminal paper "Every good regulator of a system must be a model of that system." Every leader is a (small-r) regulator whose language, character, behaviours and actions exercise direct control over the success (or otherwise) of change in their institution/enterprise. A syllogism can be formed: Every leader is a regulator; every regulator must be a model of that system. Thus, every leader of a system of institutional change must be a model of that system.

We expect few to know of Conant-Ashby's "good regulator theorem" - thus we invite Michael to give us an introduction to the seminal paper.

Insights from their paper provide a cornerstone for the panel's conversation, as they state, "The design of a complex regulator often includes the making of a model of the system to be regulated. The making of such a model has hitherto been regarded as optional, as merely one of many possible ways. In the paper a theorem is presented which shows, under very broad conditions, that any regulator that is maximally both successful and simple must be isomorphic with the system being regulated. (The exact assumptions are given.) Making a model is thus necessary. The theorem has the interesting corollary that the living brain, so far as it is to be successful and efficient as a regulator for survival, must proceed, in learning, by the formation of a model (or models) of its environment."

Michael will provide a good introduction to the Conant-Ashby paper – its context, strengths and flaws and current challenges for use. (Michael has been using the paper to teach masters students ‘how to read a technical paper’ – Professor Kemp doubts anyone knows more about the paper than him).

Panel#6

SE Leadership Through Influence and Persuasion - An Art We Should All Master!

Brian Collins (University College London) - brian.collins@ucl.ac.uk
Kerry Lunney (Thales Australia) - kjlunney@tpg.com.au
Anne O'Neil (Anne O'Neil Consultants) - systems.oneil@gmail.com
Melissa Jovic (Engineers Australia) - Melissa.jovic@gmail.com

Keywords. Leadership;Influence;Persuasion;Organizational Attributes;Diversity;Teams

Topics. 20. Industry 4.0 & Society 5.0; 3.3. Decision Analysis and/or Decision Management; 3.5. Technical Leadership; 5.10. Diversity (cultural boundaries, diverse engineering teams, training underserved groups, etc.); 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract.

Rarely the ultimate decision-maker or policymaker, Systems Engineering (SE) leaders undertake a role to enable informed decision-making and guide outcomes to align with overarching strategic objectives. Therefore, influence and persuasion skills are a fundamental necessity for SE leaders to acquire and hone.

Our world is becoming increasingly interconnected at all levels of society across all demographics. Effective systems require a team effort across multiple disciplines that may not in the past have been as pivotal to the success of the solution. Recognizing the cruciality of interoperability, interdependencies, vulnerability, ownership, deployability, safety, obsolescence, technology rate of change, and other architectural and realization considerations, requires SE leaders to be highly informed, flexible, and adaptable. With the arrival of technologies such as Artificial Intelligence (AI) and Autonomy, coupled with the rising prominence of sociotechnical challenges, compels SE leaders to direct outcomes through team collaborations.

The panel explores the various factors that shape the influence and persuasion strategies SE leaders adopt and adapt to their varied circumstances including, preserving the ‘strategic thread’; organizational attributes; diverse audiences, roles, and culturally diverse teams; industry and domain characteristics; and new technologies – with considerations for temporal constraints and the perceived value of the SE leader. Possible metrics for measuring success will also be discussed.

Biography

Brian Collins (University College London) - brian.collins@ucl.ac.uk
Professor Brian Collins took up the role of Professor of Engineering Policy at UCL on 1st August 2011 retiring as Emeritus in 2020. He led the creation of a £278M capital investment programme in 14 Universities in the UK, UKCRIC, which he launched in 2017 which enables the UK to have a robust and innovative research and analysis base for informing the £600B estimated spend in Infrastructure in the UK in the next few decades. He is currently vice chair of the National Preparedness Commission, whose mission is to help the UK be better prepared for an uncertain future. https://nationalpreparednesscommission.uk/ He has held senior leadership and advisory positions in UK Government, City Finance, a Medical Charity and Defence and Intelligence agencies. He continues to advise Governments on a global scale.

Position Paper

Leadership by Influence and Persuasion (I and P) combined with Command and Control is in my experience the best way of achieving outcomes where all actors are enabled to give of their best. The approach must be tailored to the issue and to the experience and attitude of the individuals concerned, but using I and P enriches the culture of leading and enables collaboration as the norm.

Kerry Lunney (Thales Australia) - kjlunney@tpg.com.au
Kerry has extensive experience developing and delivering large system solutions. She has worked in various industries including ICT, Gaming, Transport, Aerospace and Defense. The systems delivered include combat systems, communication systems, road, and rail ITSs, vehicle electronic systems, and gaming systems. Kerry's career has taken her throughout the Asia-Oceania region and beyond including engineering leadership roles in India, Sri Lanka, Thailand, USA, and NZ. Her career has spanned over 30 years in which she has held roles such as Lead Systems Architect, Engineering Manager, Principal Systems Engineer, Technical and Engineering Director, and Design Authority in the international organizations of Rockwell, Boeing, GTECH, and Thales. Currently, she is the Country Engineering Director and Chief Engineer in Thales Australia. Kerry is a Fellow of Engineers Australia, an Engineering Executive and Chartered Professional Engineer, and holds the ESEP qualification from INCOSE. Kerry contributes extensively to SE, increasing the awareness and competencies of SE, and the benefits of applying a systems approach. She has held many volunteer roles in her career including past National President of the Systems Engineering Society of Australia (SESA), INCOSE Director for Asia-Oceania, INCOSE President-Elect, and INCOSE President.

Position Paper

Member 3 will present the challenges and uniqueness of different industries and domains that can impact SE leaders’ approach to carrying out their means of influencing and persuading. To illustrate this, thirteen industries compared across three sets of characteristics will be presented. The characteristics are –

• Asset driven to service driven: where the industry is oriented, from an asset driven perspective to a service driven perspective;
• Client focused to community focused: where the industry is strongly focused on specific client needs versus a more general and broader community need; and
• Low criticality of failure to high criticality of failure: where the impact of the system failing in such an

industry has a negative effect and unfortunate consequences, on a scale of low to high criticality.
Likewise, the practice and maturity of SE in different industries will be taken into consideration and explained through the lenses of influence and persuasion.
Member 3 will also present new and/or disruptive technologies and what this means to the approach taken to influence and persuade decision makers. To illustrate different influence and persuasion strategies, four technologies will be presented – Artificial Intelligence (AI), Autonomy, Data Analytics, and Augmented or Virtual (A/V) Reality.

Anne O'Neil (Anne O'Neil Consultants) - systems.oneil@gmail.com
Founding principal of Anne O'Neil Consultants, Anne counsels industry executives to adopt Systems practices and apply SE capability to achieve and improve business outcomes. This spans an increasingly diverse range of infrastructure industries, ranging from mobility to water, smart buildings, telecommunications, and healthcare. As founding Chief Systems Engineer for MTA New York City Transit (2005-2013), Anne established an SE capability to improve the agency's capital project delivery. This required developing SE expertise and modifying the agency's business process and program development approach. It also necessitated effecting change and building Systems awareness, cultivating executive sponsors internal to the agency as well as at an industry level. A registered professional engineer and qualified INCOSE CSEP, Anne has served in corporate strategy, program leadership, engineering design, technical management, and construction management capacities – in both private and public sectors. A former INCOSE Board member, Anne currently serves as INCOSE Industry Outreach Ambassador. A recognized Systems champion for mobility, she evolved INCOSE's Transportation Working Group (2006-2012) into an international forum for industry exchange. Concurrently, she founded and chaired the Systems Engineering Committee for APTA, [North]. Anne also advises SAE International on SE adoption and adaption for automotive and future mobility executive forums and industry events.

Position Paper

Member 1 will introduce the concept of Systems Engineering and the preservation of the "strategic thread" that links the policy and strategy drivers with operational needs to guide the design for an optimum solution. This will be followed by emphasising the criticality of influence and persuasion.
Next, member 1 will present the art of applying influence and persuasion to roles. How influence and persuasion are applied varies on the situation, largely affected by the audience to engage. When interfacing and socializing with varied audiences, from executives and policymakers to project managers, peers and supply chain partners, an adept SE leader adopts a different influence or persuasion strategy tailored to the role of the audience.
Member 1 will discuss the concept of calibrating to the audience, adaptive leadership roles adopted over the project life, and holding "cultural intelligence".
Lastly the concept of the engineer's own perceived value will be woven through this presentation.

Melissa Jovic (Engineers Australia) - Melissa.jovic@gmail.com
Melissa is a chartered professional civil engineer, Fellow, Engineer Executive, Certified Associate in Asset Management, and Graduate Company Director with more than 30 years' experience in transportation strategic planning, governance, design, and program/ project management of railway and infrastructure projects. Her experience includes high-speed, heavy, and light rail systems within Australia, New Zealand, and Europe. Since 2009, after an extensive career in the corporate sector, Melissa has worked for the NSW government in rail transport strategy, and more recently with Engineers Australia in their internationally recognized Chartered Engineering program. Her work included the application of SE to ensure benefit realization and justify integrity and operational consistency within the rail strategy portfolio. She was also responsible for development and implementation of System Thinking/Systems Engineering approach in the early stages of Transport for New South Wales (TfNSW) investment lifecycle. In 2017, Melissa was awarded the company honor of Champion of Diversity and Inclusion by TfNSW. Melissa is also an experienced Non-Executive Director, Chair & Committee member with over twenty years of board and committee level experience in Australia. Melissa is an active member and volunteer of Engineers Australia/ Women in Engineering (WIE) since 2002, especially in mentoring.

Position Paper

Member 2 will discuss the attributes of an organization in relation to influence and persuasion. This will be illustrated through 3 dimensions – organizational structure, organizational type, and organizational culture. Organizational structures characterize the strategy, values, implementation policy and risk appetite of the organization. How influence and persuasion is applied across this landscape will be illustrated through three different organization classes – corporate, public, and not-for-profit organizations.
SE leaders must also consider organizational type. Different organizational types include Research and Development (R&D), product/system delivery, and service delivery. The influence or persuasion premise used by SE leaders can vary greatly under these three organizational ecosystems, and likewise the technique employed. To illustrate this point, Member 2 will discuss the four qualities of goal, business drivers, targeted audience, and risk tolerance for each of the organizational types, and what this means to influence and

persuade.
An organization’s culture cannot be ignored but in turn is leveraged by impactful SE leaders influencing and persuading decision-makers. As such Member 2 will discuss different cultural drivers to be considered.

Panel#2

Systems of Systems and Complexity Roundtable

Judith Dahmann (The MITRE Corporation) - jdahmann@mitre.org
Ali Raz (George Mason University) - araz@gmu.edu
Dan DeLaurentis (Purdue University) - ddelaure@purdue.edu
Stephen Cook (The University of Adelaide and The Shoal Group) - stephen.cook@shoalgroup.com
Jakob Axelsson (Mälardalen University and RISE Research Institutes of Sweden) - jakob.axelsson@mdh.se

Keywords. Complexity;Systems of systems;SE practice

Topics. 1.1. Complexity; 2. Aerospace; 21. Urban Transportation Systems; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 7. Emergency Management Systems;

Abstract.

As part of INCOSE Systems of Systems (SoS) Working Group efforts to work towards development of practical approaches to address SoS challenges, there is an ongoing collaboration between the INCOSE Systems of Systems and Complexity Working Groups to identify ways to leverage work coming from the complexity community to address this SE practice area.

In particular, the INCOSE Complexity Primer and the recent paper on ‘appreciative methods’ provide approaches to characterize and address complexity. In this initiative, these have been viewed through the lens of systems of systems to assess how and why systems of systems exhibit complexity, as the basis for identifying approaches from the complexity community that can guide the application of systems principles to systems of systems.

This roundtable will share the results of this working group effort to date and provide a set of perspectives on the nature of SoS complexity, an understanding of the drivers and dimensions, and approaches to address these from both the complexity and SoSE principles and practices.

Biography

Judith Dahmann (The MITRE Corporation) - jdahmann@mitre.org
DR. JUDITH DAHMANN is a Technical Fellow at the MITRE Corporation and the Systems of Systems Engineering lead in the MITRE Systems Engineering Innovation Center. Dr. Dahmann is currently the MITRE project leader for Systems Engineering Technical Support activities in the US DOD Office of the Under Secretary of Defense for Research and Engineering supporting mission engineering activities for selected priority Defense missions and the application of digital engineering to mission engineering. She was the technical lead for development of the DoD guide for systems engineering of systems of systems (SoS) and

was the project lead for International Standards Organization (ISO) 21839, the first ISO international standard on ‘SoS Considerations for Systems Throughout their Life Cycle’. Dr. Dahmann is the cochair of the INCOSE SoS Working Group and the NDIA SoS Committee.

Position Paper

As an SoSE practitioner, Dr. Dahmann has focused initially on identifying challenges for systems engineering for systems of systems and is now exploring ways to address these challenges using digital engineering and approaches drawn from other disciplines. The concepts from the complexity community appear to be very helpful in understanding SoS challenges in new ways and open the opinions for practically leveraging the complexity community perspective in creating methods to addressing challenges in ways that could materially improve SE practice.

Ali Raz (George Mason University) - araz@gmu.edu

Dr. Ali Raz is an Assistant Professor at George Mason University Systems Engineering and Operations Research department and an Assistant Director of Intelligent Systems and Integration at the C4I and Cyber Center. Dr. Raz research and teaching interests are in understanding collaborative 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. He holds a BSc. and MSc. in Electrical Engineering from Iowa State University, and a Ph.D. in Aeronautics and Astronautics from Purdue University. He is a co-chair of International Council of Systems Engineering (INCOSE) Complex Systems Working Group, Artificial Intelligence Working Group, and a Certified Systems Engineering Professional (CSEP). He is also a senior member of the American Institute for Aeronautics and Astronautics (AIAA) and Institute of Electrical and Electronics Engineers (IEEE).

Position Paper

Pursuit of greater functionality that results from collaboration of distributed system of systems that are both present and yet to be developed is a challenge filled with great reward and risk. As systems move away from centralized and tightly controlled monolithic processes, there is complexity that is introduced not only in the technical domain but other-than-technical aspects of functionality. I will present a family of “lenses” on complexity that provide insight on striking the risk/reward balance in evolving and designing future distributed systems of systems. A key finding is that, while complexity is most often thought to pertain to technical aspects and technicality of functions, the reality is that the other dimensions of complexity (e.g., organizational complexity, process complexity, data complexity, and people complexity) are as important, if not more, for understanding distributed operations.

Dan DeLaurentis (Purdue University) - ddelaure@purdue.edu

Dr. Daniel DeLaurentis is professor in Purdue University's School of Aeronautics and Astronautics, where he also directs the Center for Integrated Systems in Aerospace (CISA). His primary research and teaching interests include problem formulation, modelling, design and system engineering methods for aerospace systems and systems-of-systems, all from a model-based perspective. Dr. DeLaurentis also provides leadership in his role as Director of Purdue’s Institute for Global Security and Defense Innovation (i-GSDI) in Discovery Park and also as Chief Scientist for the DoD’s Systems Engineering Research Center (SERC). He is a Fellow of the International Council on Systems Engineering (INCOSE) and Associate Fellow of the American Institute of Aeronautics and Astronautics (AIAA).

Position Paper

As an academic researcher and educator who has worked for years in both the SoS and complexity domains, I remain both excited at the interesting scientific and engineering ideas raised by the view of SoS via a complexity lens but also (increasingly) sober about the difficulty in realizing benefits from the confluence. Complex Systems, in general, and SoS in particular are hierarchic and thus exhibit integration at multiple levels of hierarchy and must be studied as such, marrying structural and functional representations of the system, addressing cross-domain interactions and seeking appropriate allocations of autonomy. While there is merit in using quantitative complexity metrics to reason about alternatives in SoS architecting, I believe that the “lowest hanging fruit” lies in borrowing conceptual models and fundamental behaviors from complexity science as a means to generate a common understanding of the nature of SoSs.

Stephen Cook (The University of Adelaide and The Shoal Group) - stephen.cook@shoalgroup.com

Dr. Stephen Cook has had a varied career that commenced with ten years in the telecommunications and aerospace industries in the UK and Australia, working as a design engineer, systems engineer, and technical manager. He subsequently joined the Defence Science and Technology Organisation rising to Research Leader Military Information Networks responsible for the management and scientific leadership of a substantial branch of research staff. In 1997 he was seconded to the University of South Australia as Professor of Systems Engineering and became the founding director of the Defence and Systems Institute where he developed an interest in the theoretical underpinnings of SE and SoSE. Since 2014, he has been sharing his time between contract research work for Shoal Group Pty Ltd and his part-time duties as Professor of Defence Systems at the University of Adelaide where he teaches postgraduate courses in complex systems and systems engineering and supervises research students. He is an INCOSE Fellow, a Fellow of Engineers Australia, Past President of the Systems Engineering Society of Australia, a Member of the Omega Alpha Association SE honor society, a Chartered Professional Engineer, and an active member of several INCOSE working groups, in particular, the SoSWG.

Position Paper

In broad terms, SoSE is seen by the INCOSE community as a practice area of SE that is employed where the differentiating characteristics of SoS are apparent: managerial and operational independence of the constituent systems. In contrast, complex systems approaches have arisen from the broad systems movement and have attracted significant interest in the domains of business, in particular, enterprise improvement, and project management. Many of the systems of interest of the latter community are not the sort of systems traditionally addressed by the INCOSE community. The recent Fellows work on the definitions of SE and system takes a broad approach to the term engineering: “the action of working artfully to bring something about”. In, say, a public transport example, if the aim is to bring about a widely accepted public transport solution for the community of a city, this will require looking after a range of matters such as: the systems engineering and asset management of the transportation fleet, coordinating interchanges between transportation modes, timetable coordination, dealing with ticketing and distribution of fare revenue, and marketing, to name just a few. Thus, when starting on such an endeavour, it is vital to identify, characterise, and classify the SoS of interest and hence the various aspects of the problem space and corresponding ways to address each. Complexity theory together with the contributions from the business and systems engineering communities are starting to produce useful methods, processes, tools, and techniques for a variety of sub-problems. Frameworks that can capture all of these and guide practitioners have been proposed and continue to develop; these can usefully synergise the work of the various contributors and improve SoSE practice.

Jakob Axelsson (Mälardalen University and RISE Research Institutes of Sweden) - jakob.axelsson@mdh.se

Dr. Jakob Axelsson received a PhD in computer systems in 1997, from Linköping University, Sweden. He then spent about 15 years in the automotive industry within the Volvo Group and at Volvo Cars. Currently, he is a full professor in computer science at Mälardalen University and is also a senior research leader in systems-of-systems at RISE Research Institutes of Sweden. His research interests cover all aspects of system-of-systems engineering as well as system architecture for cyber-physical systems. He is the author of over 100 research publications and has received best paper awards at international conferences on four occasions. He was the general chair of the 16th IEEE System of Systems Engineering Conference in 2021. He has been president and board member of the INCOSE Sweden Chapter.

Panel#4

The Social Dimension of Human Systems Integration

Guy Andre Boy (CentraleSupélec (Paris Saclay University) & ESTIA Institute of Technology) - guy-andre.boy@centralesupelec.fr
Shamsnaz Bhada (Worcester Polytechnic Institute) - ssvirani@wpi.edu
Charlotte Dunford (Rolls-Royce plc) - charlotte.dunford@rolls-royce.com
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Keywords. Human Systems Integration;Social issues;Socioergonomics;Sociotechnical systems;Human-centered design;Industry 4.0;Digital engineering;Modeling & Simulation;Human-in-the-loop simulation;Collaboration & trust;Human Autonomy teaming

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

Abstract.

20th century engineering was mainly based on mechanical engineering, physics, and mathematics. During the last three decades of the 20th century, electronics and computer science considerably increased their influence on engineering by providing greater and greater automation. Work shifted from physical to cognitive. Human operator's job shifted from doing to thinking. People who were used to manipulate hardware-based machines had to adapt to software-based systems. The shift was from hardware to software. Cognitive engineering was born in the beginning of 1980s. It led to interaction design, user interface design techniques and tools, and usability engineering (UX).

Since the beginning of the 21st century, we are experiencing an opposite approach where the shift is not only from software to hardware, but also from single agent facing a machine to multi-agent sociotechnical systems. This is the reason why social aspects have become so important today. At the same time, digital modeling and simulation techniques and tools never stop to develop and are more effective and realistic. Human factors and ergonomics can be considered seriously during the early stages of the design process, as well as during the whole life cycle of a sociotechnical system. This is currently done using virtual prototypes, digital twins, human-in-the-loop simulations, formative evaluations, agile developments and so on. Participatory design and development have become extremely effective. Human-centered design (HCD) is now a reality (i.e., considering people and organizations at design time effectively).

The association of HCD and systems engineering led to human systems integration (HSI). Performing HSI in industrial settings requires appropriate knowledge representations, which are relevant representations of what a system is about. This leads to a systemic approach of human-machine systems that turns out to be social, or socio-cognitive (i.e., multi-agent). This panel will discuss the social dimension of HSI toward improving the tryptic technology-organizations-people during the whole life cycle of a sociotechnical system.

Biography

Guy Andre Boy (CentraleSupélec (Paris Saclay University) & ESTIA Institute of Technology) - guy-andre.boy@centralesupelec.fr
Guy A. Boy, Ph.D., is University Professor, FlexTech Chair Holder at Paris Saclay University (CentraleSupélec) and ESTIA Institute of Technology. He is Fellow of INCOSE and the Air & Space Academy. Former Chief Scientist for Human-Centered Design (HCD) at NASA Kennedy Space Center, and former Dean of the HCD Institute of Florida Institute of Technology. Former President and Chief Scientist of the European Institute of Cognitive Sciences and Engineering (EURISCO), he taught in several engineering schools in France, including

ISAE-SUPAERO, ENAC and Ecole Polytechnique. He is currently the Chair of the Human Systems Integration Working Group of INCOSE and the founder of HSI Conference Series organized in cooperation with ACM and IEA. He has more than 40 years of experience in aerospace, mainly with Airbus and NASA. He was Executive Vice Chair of ACM-SIGCHI worldwide from 1995 to 1999, and is Chair of IEA Aerospace Technical Committee.

Position Paper

Revisiting the concept of system. There is clearly a contemporary need for an appropriate socio-technical framework to support human systems integration (HSI) in research, development (including manufacturing, training, and maintenance) and operations. The very notion of system should be understood as a representation of Technology, Organizations and People (the TOP Model) involved during the whole life cycle of a socio-technical system. In our growing digital society, the concept of tangibility should an important topic of research, more specifically in the context of increasingly autonomous systems. It entails complexity analysis, organization design and management, and maturity management at three reediness levels: technology (TRLs); organizations (ORLs); and humans (HRLs). I will introduce the socioergonomics approach that support the investigation of systemic properties such as flexibility, separability, and emergent social facts.

Shamsnaz Bhada (Worcester Polytechnic Institute) - ssvirani@wpi.edu

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

Position Paper

The INCOSE social systems working group addresses the role of social sciences, policy modeling and systems dynamics in systems engineering. In this panel discussion I will layout the goals of the INCOSE social systems working group and the interface points with the system of systems group. Along with that I will also introduce the challenges I face in my research in addressing policy issues in rural broadband, health care and public transportation all of which are social systems but are also multiple independent systems coming together for achieving common goals

Charlotte Dunford (Rolls-Royce plc) - charlotte.dunford@rolls-royce.com

Charlotte Natalie Dunford graduated with an Engineering Doctorate in Systems from the University of Bristol in 2016 and received a Bachelor of Applied Science in Mechanical Engineering from the University of British Columbia in 2003. Her doctorate was funded by the Engineering and Physical Research Council and Rolls-Royce plc. She works as an Engineering Lead in Systems Engineering and Project Management in Engineering for Rolls-Royce Defence ensuring the business has the capability it needs in these areas. Previously, she worked as a Research Engineer in the Space and Atmospheric Physics Group at Imperial College London. Her research focuses on the social systems aspects relevant to systems engineering. She is a Chartered Engineer and Member of the Institution of Mechanical Engineers and INCOSE.

Position Paper

Engineering is a social system. I described systems engineering to a retired electrical engineering professor once, he listened and then suddenly his eyes lit up and he said, 'you are doing meta-engineering!' I think this is apt. Systems engineering processes and techniques look not at the systems we engineer but the generic activities and techniques engineers use to engineer them. It engineers the engineering. It helps us plan our work and inform the engineering judgements we need to make from initial requirements capture to solution retirement. I think this makes it important for systems engineers to have an appreciation of social systems that is often not part of our formal training. This will help us from better understanding the human factors of the systems we are creating, to improving our study of systems engineering and ultimately help us to create better solutions more effectively.

John Gill (SSCI, Woburn) - johnjgillphd2@gmail.com

John Gill, Ph.D., INCOSE ESEP. John has worked in defense technology acquisition for his entire career having served in the United States Air Force as a Chief Scientist at the Kirtland AFB Advanced Weapons Lab and as a project manager for global sensor and communications systems. Subsequently, he was a Systems Engineering Director at BAE Systems, North America. He currently develops autonomous systems and is co-owner of a Veterinary Emergency hospital. John restores and tours in classic cars.

Position Paper

"What is the System behind the System?" Sociotechnical Systems Engineering has many facets that extend well beyond what has evolved to become the Systems Engineering process. Over the course of the preceding Industrial Revolutions, we have progressed from tools to complex systems and into the realm of highly integrated technical ecosystems with embedded cognitive and autonomous capabilities. Many such systems already exist that possess characteristics of primitive life forms. And a significant amount of effort and investment is being applied to the development of humanoid systems. While these systems may look and operate as humans can (walk, run, dance, and perform gymnastics), their cognitive abilities are relatively limited. I assert that cognition is a powerful influence over the ongoing evolution of systems and may also have an imperceptible yet overwhelming influence on the trajectory of our ongoing system development. In prior collaborative works, we have presented a framework for Sociotechnical Systems as a balancing complement to what we referred to as the “Traditional” SE process. In a subsequent paper, we introduced an underlying mechanism allowing us to balance the social cost and impact of a given system against the ease and affordability with which the system is developed and may be used. In this panel/paper, we delve further into the motivations that guide us during development. We do so to expose what may be a deeply subliminal influence on what we choose to develop, why and how it (the system) may be used. While Sociotechnical System Engineering may topically be viewed as building systems that we humans interact with (in the form of a complex relationship – each influencing the other), we may be stagnating in our (system) development process owing to a fundamental attribute of human nature – our innate drive to survive.

Grace Kennedy (University of Wollongong) - gracek@uow.edu.au
Grace Kennedy is a Research Fellow at the SMART Infrastructure Facility at the University of Wollongong (UOW). She has 15 years’ experience as a Systems Engineer; first at BAE Systems, then at the SEIC (Loughborough University), and now in academia at UOW. She is the lead of the SE team within SMART who apply systems modelling to various infrastructure challenges in Australia. She lectures in SE, Innovation & Design and Human Factors topics. Grace is a Chartered Engineer (CPEng) in the Systems Engineering area of practice and a Certified Systems Engineering Professional (CSEP). Grace is co-chair of the INCOSE Human Systems Integration Working Group and a member of Cohort 7 of the INCOSE Technical Leadership Institute. She is currently undertaking a part-time PhD investigating the application of MBSE and Digital Engineering for organizational change through the lens of organizations as systems.

Position Paper

Organizations as Systems – a Neglected Perspective in SE? Traditionally Human Systems Integration efforts revolve around the consideration of the users of the system from as early in the conceptual design phases through the entire lifecycle of the system and how these considerations are integrated into the wider Systems Engineering efforts. Whilst we can design for a given set of characteristics of an intended type of user(s), we should not fall into the trap of only thinking about users as a static set of characteristics (i.e., at the point when the technical system is mature, we cannot assume the individuals who become the users will be automatically able nor willing to use the new technology). Put simply, people have ‘baggage’; they have both technical experiences (to build knowledge, skills, ability), but are also shaped by the history of the organizations that they have been part of (e.g., culture, processes, team working, role models, organizational structures, policies, etc.).

As systems engineers we look to create and develop systems that provide new capabilities, and at a socio-technical system level we consider the organizational issues around that system being developed. What if we however broaden the scope and flip our perspective, to considering the organization as the system, parts of which exist in one or more socio-technical systems? This talk will discuss organizational systems change through the lens of the Viable Systems Model (Beer) and asks what we can learn from organizational behavior and design to better inform the way we view socio-technical systems.

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

Position Paper

HSI towards the sociotechnical systems engineering approach in the context of Industry 4.0. Human Systems Integration concept is evolving through the years from Human Factors & Ergonomics (HFE) to Human Centered Design (HCD), to HSI as an integral part of the systems engineering. The Fourth Industrial Revolution-INDUSTRY 4.0 poses new challenges and opportunities for the HSI discipline and practical processes. The automation and the autonomous of the systems, the digital communication of people through IoT, AI, AR with different types of systems in their environment, create socio-technological systems in an advanced ecosystem. For designing, building, and operating these systems in this ecosystem, we are offering socio-technological systems engineering, which is the next stage of HSI. Overlapping domains of these building blocks reflect the cooperative interfaces of human and AI, in human-system integration. This vision is only in its preliminary steps, further investigation and development is needed, to fulfill the potential of such a relationship.

Panel#5

Transdisciplinary Systems Engineering: What is it, why do we need it, and how do we get there from here?

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David Rousseau (Centre for Systems Philosophy) - david.rousseau@systemsphilosophy.org
Azad Madni (University of Southern California, Viterbi School of Engineering.) - azad.madni@usc.edu
Peter Brook (Dashwood Systems Engineering) - peterbrook47@gmail.com
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Keywords. Transdisciplinarity;Elegant solutions to complex challenges;Future of SE;General Systems Theory;Complexity Science;Sustainability;Resilience

Topics. 1. Academia (curricula, course life cycle, etc.); 1.1. Complexity; 1.5. Systems Science; 1.6. Systems Thinking; 10. Environmental Systems & Sustainability; 2.1. Business or Mission Analysis; 2.3. Needs and Requirements Definition; 2.4. System Architecture/Design Definition; 20. Industry 4.0 & Society 5.0; 3.1. Acquisition and/or Supply; 3.3. Decision Analysis and/or Decision Management; 3.5. Technical Leadership; 4.3. Reliability, Availability, and/or Maintainability; 4.4. Resilience; 4.5. Competency/Resource Management; 5.10. Diversity (cultural boundaries, diverse engineering teams, training underserved groups, etc.); 5.4. Modeling/Simulation/Analysis; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.);

Abstract.

Transdisciplinarity has been advanced as an important goal for SE as it rises to the challenge of accelerating growth in complexity of required systems, expansion of the scope of SE to address social and sustainability concerns, and the emergence of new solution-frameworks based on the integration of knowledge, techniques, and expertise from multiple fields. However, many are uncertain about what transdisciplinarity is, how it empowers SE, what its principles are, and what we have to do to achieve the transition to fully-fledged transdisciplinarity. In this discussion leading researchers will present various views on these important questions, to be followed by an extended audience discussion to share further views and explore opportunities for supporting this transformation in the capability of SE.

Biography

David Rousseau (Centre for Systems Philosophy) - david.rousseau@systemsphilosophy.org
David is the Director of the Centre for Systems Philosophy (UK). He has an academic background in engineering and philosophy, and professional experience in the areas of military systems acquisition, semiconductor manufacturing, and academic research. He currently serves on the Scientific Council of the Bertalanffy Centre for the Study of Systems Science (Austria), and is a past Editor-in-Chief of their journal Systema (2013-2016). He is a member of the Editorial Board of the International Federation for Systems Research's book series on Systems Science and Systems Engineering (Springer). He is a Past President (2018) and the current Chair of the Board of Trustees of the International Society for the Systems Sciences, a Fellow of the Royal Society for the Arts, Commerce and Manufactures, and a full member of the Omega Alpha Association (SE Honor Society) and a Fellow of INCOSE. He has published more than 40 articles in peer-reviewed journals and edited books. His current research is focused on expanding the scientific foundations of systems thinking by refining and extending the concepts, principles and methods of Systemology, and contributing to the emerging paradigms of elegant design and transdisciplinarity in systems engineering and frontier research.
Position Paper
An extensive discussion of transdisciplinarity's theoretical foundations and future potential is presented in my co-authored book "General Systemology: Transdisciplinarity for Discovery, Insight and Innovation" (Springer,

2018).
The approach we recognize today as “transdisciplinarity” originated as a theoretical position in the 1930s, although the term was only coined in the 1970s. Many definitions of the term have been offered, but the professed aims of transdisciplinarity are remarkably consistent across advocates and disciplines, namely to overcome the barriers between traditional disciplines, to focus on “real-world” problems, to support ethical and sustainability goals, and to challenge the constraints that maintain the status quo.
The theoretical basis of this arose in the 1930s, when von Bertalanffy realized that all real systems interdepend, and consequently that complex situations could not be properly analysed by any specialized discipline or even any set of specialized disciplines, but would require what he called a “meta-science”, a science that recognized the holistic but complex embeddedness of systems, and that understands the principles that govern the balancing of the causal relationships between things of different kinds forming a complex whole. An important consequential insight is that a system’s capability and sustainability depends not only on its inherent functionality and robustness but also on the balance it achieves with its environment/context (and hence the possibility for unintended consequences of systemic interventions). From these considerations evolved the insight that we need a science that is not value neutral, but overtly aims to help achieve a future in which humanity not only survives but that would be worth living in. In this, values such as equality, equal opportunity, justice, sustainability and ecological responsibility take center stage. The key to achieving this vision, as von Bertalanffy identified, is to embrace the systems perspective, and thus to take a systemic approach to analysis, synthesis and practice. This approach transcends the traditional boundaries of specialized disciplines and connects them without devaluing their individual significance.
Engineering employs our experiential and scientific insights to meet human challenges and aspirations, and in the modern era these increasingly involve complex systems, both in their origin and in their resolution. Due to the interdependence of systems in the complex nexus that constitutes the real world, a form of engineering that recognizes, leverages and delivers on this holistic responsibility will be increasingly important in the face of “Industry 4.0” and “Society 5.0” (as these are called in the INCOSE Vision 2035). SE is naturally positioned to do this. INCOSE’s motto, “a better world through a systems approach”, perfectly encapsulates the acceptance of this holistic responsibility for a vision and a practice that is not value neutral but cares about its impact on human thrivability and planetary resilience.
SE’s transdisciplinary approach sets it aside a distinct discipline with a unique value to society and the planet, and the need for this transdiscipline has never been greater or more urgent. Its theoretical foundations in General Systems Theory and Complexity Science will be a key enabler of that future value.

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Azad is the holder of the Northrop Grumman Fred O’Green Endowed Chair in Engineering in University of Southern California’s Viterbi School of Engineering. A member of the U.S. National Academy of Engineering, he is a Professor of Astronautical Engineering and the Executive Director of USC’s flagship Systems Architecting and Engineering Program. Under his leadership, the program has graduated more than a thousand systems engineers and is currently a top-ranked program in the country. He also founded the Ph.D. Program in Systems Engineering within the Astronautical Engineering Department. He is the founder and CEO of Intelligent Systems Technology, Inc., a high-tech R&D company specializing in transdisciplinary approaches to addressing scientific and societal problems of national and global significance. Previously, he was the EVP and CTO of Perceptronics and lead Simulation Engineer in the GN&C Group at Rockwell International on NASA’s Space Shuttle Program. He is a member of Research Councils of DoD’s Systems Engineering Research Center and DoD’s Acquisition Innovation Research Center. He is the co-founder and chair of IEEE SMC Systems Science and Engineering award-winning Technical Committee for Model Based Systems Engineering. He is the Chief Systems Engineering Advisor to The Aerospace Corporation. He received his Ph.D., M.S., and B.S. degrees in Engineering from University of California, Los Angeles. He is a graduate of AEA/Stanford Institute for Senior Executives. His research interests include advancing and exploiting the convergence of systems engineering with other disciplines to address complex societal problems. He is the author of Transdisciplinary Systems Engineering: Exploiting Convergence in a Hyper-Connected World (foreword by Norm Augustine), Springer 2018, and co-author of Tradeoff Decisions in Systems Design, Springer, 2016. He has received the Pioneer Award from both INCOSE (2011) and IEEE Aerospace and Electronic Systems Society (2019). His recent awards include INCOSE Benefactor Award (2021), INCOSE/ASEE Outstanding Systems Engineering Educator Award (2021), IEEE AESS Judith A. Resnik Award for Excellence in Space Engineering (2021), IEEE SMC Norbert Wiener Award for Outstanding Research (2020), AIAA/ASEE John Leland Atwood Award for Excellence in Engineering Education and Research, INCOSE Founder’s Award (2019), NDIA’s Ferguson Award for Excellence in Systems Engineering Research, Education, and Practice (2019), ASME CIE Leadership Award for advancing use of computers in engineering (2019), Society of Modeling and Simulation International Presidential Award (2019), Boeing’s Lifetime Achievement Award (2016) for “sustained excellence and fundamental contributions to Boeing, aerospace industry and the nation,” and Boeing’s Visionary Systems Engineering Leadership Award (2016). He is a Life Fellow/Fellow of INCOSE, IEEE, AAAS, AIAA, WAS, SDPS, IETE, and AAIA. He is an elected member of the Omega Alpha SE Honor Society.
Position Paper
The eminent Swiss psychologist, Jean Piaget, is generally credited with coining the term “transdisciplinarity” in 1970 at a seminar on interdisciplinarity held at the University of Nice and jointly sponsored by the

Organization of Economic Cooperation and Development, and the French Ministry of Education. In 2007, I wrote a journal article on transdisciplinarity [1], in which I stated that what sets transdisciplinarity apart from traditional approaches is its acceptance of the inherent complexity of reality that is revealed when one examines a problem or phenomena from multiple perspectives with a view toward discovering hidden connections among the contributing disciplines. Today transdisciplinarity represents a dramatic shift in thinking about research and education by encouraging a re-imagination of disciplines to uncover new synergies among disciplines and new ways of combining them. This recognition has spurred interest in the SE community to incorporate transdisciplinary thinking into SE.

Systems engineering today is in the midst of a transformation fueled by ever-increasing system complexity, technological advances in AI, ML and digital twinning, and a desire to introduce more rigor into SE while exploiting the growing convergence of SE with other disciplines. I have addressed these topics in my book, Transdisciplinary Systems Engineering: Exploiting Convergence in a Hyperconnected World [2]. In this book, I define transdisciplinary systems engineering as “a meta-discipline that exploits the convergence of SE with other disciplines to solve problems that appear intractable when viewed solely through an engineering lens.” Today we are beginning to see evidence of this advance in both education and research as boundaries between disciplines are becoming increasingly more porous. In my book, I state that disciplinary convergence is a key enabler of transdisciplinary systems engineering and that disciplinary convergence can take different forms based on how SE combines with other disciplines to produce a new concept or capability [2]. For example, exploiting the convergence of SE with Digital Engineering (and specifically digital twinning) can potentially enhance real world system performance, increase system availability, and extend system lifespan. Similarly, the convergence of SE with AI and machine learning can enhance the system’s ability to cope with uncertainty and deal with disruptions through learning and adaptation.

This shift is most palpable in systems engineering education. For example, in my Model Based Systems Engineering (MBSE) course, I have updated the course content to address this convergence by extending system modeling to represent partially observable systems using probabilistic methods (from mathematics and statistics) and machine learning methods (from AI and computer science). The result today is that system modeling is now a closed-loop process that starts with partial knowledge of the system and the environment and incrementally updates them with incoming evidence during system test and operation. In a similar vein, systems architecting is being informed and enhanced by biological models while cybersecurity is being enhanced by leveraging artificial immune system methods. I am hopeful that this trend will continue resulting in a gradual elimination of disciplinary siloes [3].

[1] Madni, A.M. “Transdisciplinarity: Reaching Beyond Disciplines to Find Connections,” Journal of Integrated Design and Process Science, Vol. 11, No. 1, March 2007, pp. 1-11.
[2] Madni, A.M., Transdisciplinary Systems Engineering: Exploiting Convergence in a Hyper-connected World, (foreword by Norm Augustine), Springer, September 2018.
[3] Madni, A.M., Boehm, B. et al. (eds.) Disciplinary Convergence: Implications for Systems Engineering Research, Springer, 2018.

Peter Brook (Dashwood Systems Engineering) - peterbrook47@gmail.com
Peter is an independent consultant, who has worked since retirement for a range of clients across government. He is widely recognised for his contributions to systems engineering, both as practitioner and thought-leader, having lectured and published extensively in the field and co-authored a standard textbook. He has contributed to many complex programmes and capability improvement initiatives, centred on IT and C3I systems in the Defence and Security domains, acting mainly for the client side. His career was originally based in the defence R&D establishments with secondments to MOD, most recently as Head of the Integration Authority in the Defence Procurement Agency and previously as Chief Scientist for the Army. His current research interests lie in Enterprise Systems and Systems of Systems, in which he has given NATO-sponsored lectures in a number of countries. He was awarded a visiting professorship at the Cranfield University/Defence Academy and retains an active presence in the academic and professional communities, including a 4 years on main board of INCOSE, which awarded him a Fellowship in 2015. He was elected to the UK's Royal Academy of Engineering in 1999.

Position Paper

Complexity is on the rise everywhere: systems are connecting in unprecedented ways to impinge on all areas of society, making our enterprises increasingly co-dependent; global challenges are growing, some as a result of our actions; radical uncertainty is on the rise, eroding our ability to predict systems performance; and engineering itself is being revolutionized by Digital Engineering and AI. Taken together, these trends provide fresh imperatives for the discipline of SE, and new opportunities for it to grow its capability and value to society. As a result, SE is at a critical juncture (some say crisis) just when it is needed most, and others are looking to it for guidance. So it must embark on its own transformative journey to equip it to transform others. In so doing it must share its principles and practices with those of other disciplines and undertake a journey towards becoming Transdisciplinary.

This proposition will be examined from a number of perspectives, each presented by a leading thinker in the field. Mike Pennotti will lead off by putting SE's Transdisciplinarity in its historical context, arguing that our recent adoption of the term is in fact a rediscovery of older principles. Hillary Sillitto will talk about

Transdisciplinay SE and how it was recognized inthe work done by the INCOSE Fellows Team which he led on Definitions of SE. Azad Madni will present his perspective on the subject and its relation to disciplinary convergence, based on his recent book on the subject. Lastly, David Rousseau will talk about the theoretical underpinnings for Transdisciplinarity in General Systems Theory and Complexity Science.

Michael Pennotti (Stevens Institute of Technology) - mpennott@stevens.edu
Michael Pennotti is a Distinguished Service Professor at Stevens Institute of Technology and a founding member of the School of Systems and Enterprises. In that role, he was instrumental in developing, implementing, and evolving Stevens' innovative graduate program in systems engineering. During the early years of the school, he served as Associate Dean for Academics and later, Director of Systems and Software Programs. Prior to joining Stevens in 2001, Dr. Pennotti spent 20 years as a systems engineering practitioner and leader at Bell Laboratories, designing and improving the operational performance of four generations of undersea surveillance systems for the U.S. Navy, and another 10 years applying systems principles to enterprise systems in executive positions with AT&T, Lucent Technologies and Avaya. Dr. Pennotti is a Fellow of the International Council on Systems Engineering, a senior member of the IEEE and co-founder and coach of the INCOSE Institute for Technical Leadership. He holds Ph.D. and M.S. degrees in electrical engineering from the Polytechnic Institute of New York, a B.E.E. from Manhattan College and is a graduate of the AEA/Stanford Executive Institute for Technology Executives.

Position Paper

Since first being recognized as a distinct engineering discipline in the 1940s, systems engineering has continually evolved to meet increasingly complex challenges. In its early decades, systems engineering was informal in nature, essentially the application of systems thinking to engineering. Its success depended on first, determining the objective that is to be reached and second, thoroughly considering all the factors that bear upon the possibility of reaching the objective, and the relationships among those factors. Systems engineers did whatever was necessary to accomplish these goals. Their approach was holistic, focused on the success of the whole more than that of the individual parts. It transcended not only other engineering disciplines, but disciplines farther afield, like economics, psychology, and marketing. Systems engineering was, from its inception, transdisciplinary.

Despite the lack of formal structure, systems engineering played an essential role in the success of what was probably the greatest technical achievement of that era, landing a man on the moon and returning him safely to earth in July 1969. Coincidentally, that same month, July 1969, the first formal systems engineering process was introduced. Published by the US Air Force, MIL-STD-499 defined systems engineering as a "closed-loop, iterative process," comprising four interrelated activities. From this modest beginning, formal systems engineering processes have continued to grow, both in number and in detail. Each seeks to standardize some aspect of the discipline, reducing it to a set of well-defined tasks and specified deliverables. In doing so, something essential is lost, however. Simply completing the tasks and producing the deliverables does not guarantee the system will accomplish its goals.

In 1991, concerned that the evolving processes were proving inadequate for addressing the most complex systems challenges, Rechtin introduced the notion of systems engineering heuristics. Suggested as an alternative to process approaches, Rechtin defined heuristics as lessons learned expressed as guidelines for the conduct of systems engineering. He identified more than 100 such guidelines in his first book, a number that has grown to at least several hundred over the ensuing years. While each might be useful individually, taken as a set, they would overwhelm even the most competent practitioner. And attempts to reduce them to an essential minimum set do not offer much promise.

In recent years, the continuing increase in systems complexity has sparked renewed interest in how systems engineering might not only execute formal processes and satisfy specified requirements, but more importantly produce more elegant designs. This concept was first suggested by Frosch in March 1969, and apparently was then lost to the systems engineering community until it was resurfaced by Griffin in 2010. Griffin proposed four attributes for design elegance: that a system produces the intended result, is both robust and efficient, and generates a minimum of unintended consequences. Pursuing these attributes, rather than following systematic processes, appears to have has the potential to restore systems engineering to its transdisciplinary roots.

Hillary Sillitto (Sillitto Enterprises) - hsillitto@googlemail.com
Hillary was born and grew up in Scotland. He has lived there for most of his life, travelling widely in connection with his work. He has a degree in Physics from St Andrews University and an MSc in Applied Optics from Imperial College, and had a successful engineering career with Ferranti and Thales. He holds eight patents. His appointments included Chief Engineer for Thales Optronics Glasgow, Head of the UK MOD's Integration Authority, and Systems Engineering Director for Thales UK. He is a Chartered Engineer, Fellow of the Institute of Physics and an internationally recognised expert in Systems Engineering and Systems Science. He is one of only 50 or so living Fellows of the International Council on Systems Engineering, and a member of the Omega Alpha Association (https://omegalpha.org). He held visiting professorships at the universities of Bristol and Strathclyde. His book Architecting Systems - Concepts, Principles and Practice was published in 2014, and he co-authored another book published in 2020: Scotland 2070 - Healthy Wealthy and

Wise, an ambitious vision for Scotland's (net-zero) future without the politics (see https://scotland2070.org).

Position Paper

In 2018 I coauthored a paper (Sillitto et al, Envisioning Systems Engineering as a Transdisciplinary Venture (July 2018, INCOSE International Symposium 28(1):995-1011, DOI:10.1002/j.2334-5837.2018.00529.x), which said:

"We envision that Systems Engineering (SE) can be transformed into a truly transdisciplinary discipline - a foundational meta-discipline that supports and enables collaboration between all the disciplines that should be involved in conceiving, building, using and evolving a system so that it will continue to be successful and fit for purpose as time passes. SE can be applied in different ways depending on the situation and how well current SE process patterns are matched to the problem in hand. We identify four elements of this new transdisciplinary framework: SE Tenets; SE Approach; SE Process; and SE Toolbox. We suggest that the use of SE then needs to be considered in three domains: problem space, solution space, and transformation space that helps us along the development-delivery-evolution trajectory. We propose twelve SE tenets and show how they should be applied in these three domains. We perceive that even though all elements of the current SE Process can be justified in terms of the twelve tenets applied to these three domains, the current commonly used, standardized SE Process is not suitable for all situations requiring an SE Approach or an application of the SE Tenets. We claim that the framework presented in this paper can act as a unifying structure that facilitates the evolution of Systems Engineering from the current focus on a "standardized" process model suited to a particular class of problem, to a more agile and capable "transdiscipline" that will provide an enabling construct for more successful collaborations that can better deal with a wider range of complicated, complex and chaotic problem situations."

This paper was one of the outputs of the INCOSE Fellows' Project on definitions of System and SE, which resulted in the change in the INCOSE definition of SE from 'interdisciplinary' to 'transdisciplinary'. I will briefly outline the work of the Fellows' Project and discuss how this reframed definition was enormously helpful when presenting Systems Engineering in the context of the climate emergency in a fringe meeting at CoP26.

Tutorial

Tutorial#26

Artificial Intelligence for Systems Engineers: Going Deep With Machine Learning and Deep Neural Networks

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

Abstract.

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

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

Biography

Barclay Brown (Raytheon Technologies) - Barclay.Brown@incose.net
Barclay R. Brown is Associate Director for Foundational Artificial Intelligence in Collins Aerospace, a unit of Raytheon Technologies, focusing on AI research and expanding the use of AI technologies in Collins. Before joining Raytheon in 2018, he was with IBM for 14 years, serving in the Public Sector practice of IBM Global Business Services, where he was the lead systems engineer for some of IBM’s largest development projects. He also served as the worldwide lead for the IBM systems engineering software business in the aerospace and defense industry. He received a bachelor’s degree in Electrical Engineering followed by master’s degrees in Psychology and Business and a PhD in Industrial and Systems Engineering. He is a certified Expert Systems Engineering Professional (ESEP), Certified Systems Engineering Quality Manager, CIO of INCOSE for

2021-2023, and the former INCOSE Director for the Americas.

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Dr. Ramakrishnan Raman has rich and diverse experience in design & development of complex systems spanning aerospace, industrial/ building automation and process control domains. He is currently Fellow at Honeywell Aerospace. In his current role, he is driving key technology focus areas across multiple COEs in Aerospace and enabling systems engineering excellence. He has to his credit several publications in refereed international conferences & journals, pertaining to Machine Learning, complex systems, system-of-systems, system architecture design and verification. Dr Ramakrishnan Raman has B.Tech and MS(by Research) degrees from IIT Madras, and PhD from IIIT Bangalore. He is a INCOSE certified Expert Systems Engineering Professional (ESEP), and certified Six Sigma Black Belt. His areas of interest include complex systems and system-of-systems, software architecture and design, lean product development and machine learning. He is a Recipient of “Outstanding Service Award” from INCOSE for sustained outstanding and significant contributions towards the growth of systems engineering awareness, adoption, and practice in INCOSE and in India. He is currently serving as Assistant Director for INCOSE Asia Oceania Sector.

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Dr. Ali Raz is an Assistant Professor at George Mason University Systems Engineering and Operations Research department where is research and teaching interests are in understanding the nature of collaborative 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. Prior to joining Mason, he was a Visiting Assistant Professor at Purdue University School of Aeronautics and Astronautics where he taught courses in aerospace systems design and led research projects for introducing machine learning techniques in high-speed aerospace systems. He holds a temporary faculty appointment with the U.S. Navy Naval Surface Warfare Center at Crane, Indiana and has worked with John Hopkins University Applied Physics Laboratory (JHU-APL), the United States Missile Defense Agency, and Honeywell Aerospace. He holds a BSc. and MSc. in Electrical Engineering from Iowa State University, and a Ph.D. in Aeronautics and Astronautics from Purdue University. He is a co-chair of INCOSE’s Complex Systems Working Group and a Certified Systems Engineering Professional (CSEP). He is also a senior member of the American Institute for Aeronautics and Astronautics (AIAA) and Institute of Electrical and Electronics Engineers (IEEE).

Tutorial#23

Back to Basics: Fundamentals for Systems Engineering Success

David Long - david.long@incose.net

Keywords. #SEFundamentals;Fundamentals;Requirements analysis;Systems architecture;MBSE

Abstract.

“I know the processes”, “we’re managing requirements”, “I have a tool”, “it’s all checklists and documents”. 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 half-day tutorial provides a primer to the foundational concepts of systems engineering within a framework for overall project success. We will focus on the classic systems engineering domains of requirements, behavior, architecture, and V&V. Rather than treating these in isolation, the fundamentals are positioned within a flexible systems engineering process suitable for system development tasks across the complexity spectrum. While there is a place for process and documentation standards, our focus will be on eliciting the proper requirements, understanding the problem and solution domain, enhancing communication amongst the design team and the stakeholders, and satisfying the system need. 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.

Biography

David Long - david.long@incose.net
For over 25 years, David Long has focused on helping organizations increase their systems engineering proficiency while simultaneously working to advance the state of the art. David is the founder and president of Vitech where he leads the team in delivering innovative, industry-leading methods and software to help organizations engineer next-generation systems. Throughout his career, David has played a key technical and leadership role in advancing and expanding the practice of systems engineering. He has worked with government and commercial organizations around the world as they assess, adopt, and deploy new methods and tools to enhance their engineering enterprise. David is a frequent presenter at industry events worldwide delivering keynotes and tutorials spanning introductory systems engineering, the advanced application of model-based systems engineering, digital engineering, and the future of engineering systems. His experiences and efforts led him to co-author the book A Primer for Model-Based Systems Engineering to help spread the fundamental concepts of this key approach to modern challenges. An INCOSE Fellow and Expert Systems Engineering Professional, David was the 2014/2015 president of INCOSE.

Tutorial#21

Behavior control: methodology and framework for integrating socio-technical systems

Avi Harel (Ergolight) - ergolight@gmail.com

Keywords. System integration;operation control;Operational complexity;operational reliability;Failure prevention;Model-based integration;Structured server design

Abstract.

Operation failure is often due to crossing the performance boundaries. According to the first principle of cybernetics, realized in the System Theoretic Analysis Method and Process (STAMP) methodology, the system should enforce its own operation according to rules.

Rule-based models enforce mitigating the risk of operational complexity. This principle is difficult to follow when the rules are implicit or vague, as is typical of socio-technical systems (STS). This results in unexpected incidences. Unexpected incidences are often due to improper system integration. When the results are costly, they are often attributed to operator errors. It is a design goal to protect the system from insane unexpected activity.

The framework proposed comprises a model and an architecture of rule-based client-server integration, a software-oriented hyper-model of the server, and a server controller obtained by customizing a digital twin of the server. The server hyper-model extends a model of a universal operation controller proposed for the special case of human-system integration (HSI). This architecture supports critical client-server control challenges, such as providing previews of upcoming situations, evaluation of decision options, and assisting in the server troubleshooting.

The coordination between the client and the server is based on the concepts of system scenarios and the server operational modes. These concepts enable direct mapping from the client tasks to the server activity. Utility-critical systems should incorporate means, including sensors and data analytics, for informing the operators and the developers about integration flaws.

In addition, the framework comprises a waterfall model of transdisciplinary cooperation in the STS integration.

The instructor invites students to bring their own case studies and experiences to the tutorial.

Students who would like that their case studies will be integrated into the tutorial are invited to send their case studies to ergolight@gmail.com

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Tutorial#24

Building Really Big Systems with Lean-Agile Practices

Harry Koehnemann (Scaled Agile) - harry.koehnemann@scaledagile.com
Robin Yeman (Project & Team) - Robin@projectandteam.com
Jeff Shupack (Project & Team) - jeff@projectandteam.com

Keywords. Lean;Agile;System-of-systems

Abstract.

Gone are the days when companies had the luxury of long delivery cycles. To compete in today's market, engineers must specify, build, and deliver products quickly to learn and evolve them based on customer feedback. And do so in increasingly complex, connected, and unpredictable environments. As systems engineers today face these significant challenges, many look to Lean-Agile principles and practices for solutions. While these practices have worked well for small, software systems, many organizations in automotive, aerospace, defense, and other industries apply them to their large system development. This tutorial discusses how Lean-Agile principles and practices help organizations build and evolve some of the world's most significant and critical systems.

In this workshop, you will learn how an enterprise can move from stage-gated development approaches to a flow-based, value-delivery-focused model. This model requires a more continuous approach to define and refine system specifications. Agile teams are cross-functional, so we will also learn how to organize around value and perform Agile planning at a large scale. Finally, since systems continuously evolve, the workshop will show the importance of architecting systems for change (including hardware) and building a continuous delivery pipeline along with the system.

Biography

Harry Koehnemann (Scaled Agile) - harry.koehnemann@scaledagile.com
Harry Koehnemann is a SAFe Fellow and Principal Consultant at Scaled Agile Inc., where he helps organizations build and deliver solutions faster, more predictably, and with high quality. He has spent the past two decades consulting with organizations in aerospace, defense, automotive, and others to adopt better engineering practices, including Lean, Agile, MBSE, requirements management, quality management, and the related activities necessary to support compliance. He has delivered 100s of presentations at many conferences at both conferences (INCOSE Symposium and Chapters, Agile Alliance, Systems and Software Technology - SSTC, Embedded Systems - ECS, Agile Alliance) and commercial ones (Scaled Agile, IBM Interconnect)

Robin Yeman (Project & Team) - Robin@projectandteam.com
Robin Yeman is the Director of Cyber-Physical Advisory Practice at Project & Team bringing over 25 years of experience and proven ability to identify and evaluate market needs, build opportunities, and provide solutions leveraging best practices from Lean, Agile, and DevSecOps. Before joining Project & Team, Yeman spent almost three decades at Lockheed Martin as a Technical Fellow advising entire product lifecycles and driving multi-billion dollar revenues by focusing on speed and agility. Yeman is also the Chief Technical Officer for Catalyst Campus, Technology & Innovation.

Jeff Shupack (Project & Team) - jeff@projectandteam.com
Jeff Shupack helps organizations deliver some of the world's most complex virtual and physical products at scale. As a SAFe Fellow & SPCT, he is a sought-after transformation expert focusing on digital enterprise, cyber-physical delivery, and change leadership. Jeff is President of Advisory Practice at Project & Team, specializing in digital transformations within highly regulated and complex environments for the Fortune 100 and government agencies. Results are faster time-to-market, improved productivity, and exceptional focus on the customer.

Complex System Governance: Practical Implications for Improving Complex System Performance

Joseph Bradley (Old Dominion University) - josephbradley@leading-change.org
Richard Hodge (DrRichardHodge.com) - richard@drrichardhodge.com

Keywords. Systems Thinking;Causal Analysis;Complex System Governance;System Theory

Abstract.

This tutorial introduces Systems Engineering practitioners to Complex System Governance (CSG) as a new and novel advanced systems-science based approach to improve complex system performance. CSG is explored and applied as the design, execution, and development of essential systems functions that provide system control, communications, coordination, and integration – ultimately driving sustainable system performance. Practical application of CSG is emphasized to encourage a different level of thinking, decision, action, and interpretation in response to ‘wicked’ and ‘systemically deep’ sociotechnical system problems. Five tutorial objectives include: (1) explore the complex system problem domain and its apparent immunity to traditional approaches, (2) examine the conceptual basis of CSG found in Systems Theory (principles governing the behavior/performance of all complex systems), Management Cybernetics (the science of effective system structural organization), and System Governance (design for direction, oversight, and accountability), (3) introduce a reference model to help with assessment of nine essential CSG functions, and (4) conduct a CSG assessment to identify, classify, and develop strategies to ‘deep system’ issues. The tutorial introduces concepts through guided discussion, hands-on practical application exercises, and an application case. This approach prepares participants to immediately apply what has been learned to their specific complex systems of interest. As a result of the tutorial, participants will be better prepared and equipped to identify, assess, and more effectively deal with complex systems and their inherent design, execution, and development issues.

Biography

Joseph Bradley (Old Dominion University) - josephbradley@leading-change.org
Dr. Bradley, received the Ph.D. degree in Engineering Management from Old Dominion University, received the Degree of Mechanical Engineer and a Master of Science in Mechanical Engineering from Naval Postgraduate School, and a BE from The Cooper Union. Prior to joining Old Dominion University, he was Deputy Director for Force Maintenance at Commander, Submarine Force, Atlantic Fleet. Prior to that, he served in various consulting roles, including Program Manager’s Representative for the conversion of the USS OHIO and USS MICHIGAN to SSGNs. He is a retired Engineering Duty Officer and submariner, having served over 26 years in the United States Navy. He is a member of the American Society of Naval Engineers, Association for Computing Machinery and ASQ. His research interests include complex system governance, action research, project management, system dynamics, and decision making using modeling and simulation.University, and a Ph.D. in Engineering Management from Old Dominion University. His memberships include the American Society for Engineering Management, the International Council on Systems Engineering, the Institute for Industrial Engineers, and the International Society for System Sciences.

Richard Hodge (DrRichardHodge.com) - richard@drrichardhodge.com
Dr. Hodge brings over 40 years of experience, with strong foundations in defence science where he fulfilled representative and advisory posts including Defence Science counsellor in Washington DC and Scientific Adviser, Strategic Policy and Planning in Canberra. He was a ‘founding father’ of Booz Allen Hamilton’s defence office in Canberra. Then General Manager for CAE Professional Services in Australia, before returning to consulting to help people address their toughest problems. A consultant, educator and expert in "living enterprises" at individual, group and organisation levels, creating capabilities in people to solve problems in ways that don't create further problems. He is engaged in building new knowledge from the science of life and living, using that to help people layer complexity, find simple patterns of thinking and examine the relationships among them. These patterns help explain, manage and govern the complexity we find in our world. While he learnt the ropes from working extensively in national security enterprises, the absolute beauty is finding those patterns influencing individual and group behaviours as well as complex enterprises -

and then transporting the thinking easily across other equally complex enterprises like health, transport, education and energy

Tutorial#22

Modelling Systems of Systems Without Drowning: Using ISO 24641-Compliant ARCADIA Methodology

Anthony Komar (Siemens Digital Industries Software) - tony.komar@siemens.com

Keywords. MBSE;methodology;Systems of Systems;modelling;ARCADIA;recursive

Abstract.

In today's world, few systems remain cleanly within their scoped boundaries; most interact with other systems as a communication network, GPS, or an external power supply. Current methods of modeling Systems of Systems (SoS) struggle with limitations of language and diagram-based representations on top of the challenges of scale and scope. ARCADIA provides an alternative approach with a robust way to capture known and to-be-defined interfaces/integrations while using representations that facilitate cross-discipline collaboration, systems models that can be differentially decomposed based on the domain, and bidirectional sharing subsets of models with suppliers, partners, and even customers.

The ARCADIA methodology offers a way to avoid the "language barrier" because it emerged from work by a top-ten aerospace company who was looking for a systematic approach to support a diversity of product and system types, facilitate cross-domain collaboration, and be effective for projects that start at different points in the system/product lifecycle. Since its release as open-source, over 400 organizations have or are using it, and that community helped inspire the creation of an ISO standard, 24641 (in-work).

We will discuss the challenges of SoS modeling, explore doing recursive modeling (addressed in INCOSE SEBOK), and show several practical examples of its application. Demonstration via ARCADIA-supporting tool as well as interactive activity and discussion will provide insights into issues of composing new systems from pre-existing constituents and of extending an existing product with new system interactions and capabilities.

Note: ARCADIA is an open-source methodology managed under the Eclipse Foundation (www.eclipse.org/capella/arcadia.html).

Biography

Anthony Komar (Siemens Digital Industries Software) - tony.komar@siemens.com
Anthony Komar has a master's in systems Engineering and has been practicing and/or supporting systems engineering practitioners for over 35 years. Tony began his career as a System Engineer on development of engine and flight controls in the early 1980s. He led his team supporting FADEC I for CF6 engine control through FAA software certification. His research and development of flight control system based on COTS platforms led Tony to work as a consultant helping auto and other companies establish architectures focused on increasingly complex and powerful software-based control systems. Tony joined Siemens 17 years ago and has helped customers establish requirement management and systems engineering solutions in variety of industries including those subject to significant certification requirements.

Tutorial#14

Negotiation, Persuasion and Conflict Management for the Systems Engineer

Zane Scott (Vitech Corporation) - zscott@vitechcorp.com

Keywords. Conflict management;Negotiation;Persuasion;Communication

Abstract.

Did you know:

. . . conflict is the engine that drives innovation and that it should be managed rather than resolved?

. . . INCOSE's Competency Model lists "negotiation" as a competency essential to requirements management, verification and validation, and acquisition and supply?

. . . problems with conflict, persuasion, and negotiation can be handled using skills and techniques that can be easily learned and, with practice, applied in many aspects of your professional and private life?

This tutorial will offer you not only an awareness of the issues around negotiation, persuasion, and conflict management but will introduce you to practical knowledge and skills that can make you a better, more persuasive, negotiator and equip you to better manage conflict from the position of a participant or mediator/facilitator whether at work or in your private life. It will cover the foundation and use of communication, influence, interest-based problem-solving in personal and professional settings.

Biography

Zane Scott (Vitech Corporation) - zscott@vitechcorp.com
Zane Scott is a veteran of 18 years in the courtroom where he tried over 100 jury trials. He has presented live and virtually in a variety of settings, ranging from the courtroom to the classroom. Trained as a hostage/crisis negotiator, mediator, and labor-management facilitator, he has taught communication, negotiation, and facilitation skills in a variety of government and commercial venues. As VP for Professional Services for Vitech and an Associate Systems Engineering Professional (ASEP), Zane understands the world of systems engineering and the role of these soft skills in it. He has served as the Chair of the INCOSE Corporate Advisory Board and as a member of the INCOSE Board of Directors. A member of INCOSE’s Chesapeake Chapter, he is a frequent teacher, speaker, and blogger on a wide variety of systems engineering and soft skills topics.

Tutorial#28

Systems 101 - An Introductory Tutorial on Systems Thinking and Systems Engineering

Jawahar Bhalla (JB Engineering Systems) - jb@engineeringsystems.com.au
Andrew Madry - ndrew@madry.com.au

Keywords. #SEFundamentals;Systems Thinking;Systemic Thinking;Complexity;Emergence;Abstraction;Modelling and Simulation;MBSE;Systems Engineering Life-Cycle;Efficiency and Effectiveness;Verification and Validation;Conceptual Design

Abstract.

Systems Engineering is a “transdisciplinary and integrative approach” that uses “systems principles and concepts”, to enable the definition and realisation of complex capabilities (INCOSE). This introductory tutorial will focus on some of these “systems principles and concepts” that underpin the efficient and effective engineering of systems. It is broadly structured to be delivered in six parts, sandwiched between a motivational introduction and a concluding session summary.

Part 1 focuses on the "Why, What and How" of systems thinking. Part 2 introduces key M&S concepts of abstraction and fidelity and the associated systems concepts of interoperability and emergence. Part 3 then applies these concepts to outline a mental-models framework and introduces two key concepts - efficiency and effectiveness - that underpin the engineering of systems and the foundational role of systems engineers in the creation of complex, safe, secure and sustainable capabilities. Part 4 builds on the concepts from previous parts to introduce "systems models" and a first-principles perspective to systems engineering life-cycles, while part 5 focuses in on contextualising and defining verification and validation as a core activity spanning the systems engineering life-cycle. Part 6 is an introduction to complexity - building on the concepts from previous parts and introduces the Cynefin framework as one means of understanding and dealing with complexity.

Breakout sessions, discussion sessions and breaks are embedded through the tutorial, to allow for interaction, discussion, engagement and networking. The last breakout session focuses inward to review and draft an “elevator pitch” to communicate the central and critical role systems engineers play in the transformation of complex concepts into tangible critical capabilities in an ever evolving and interconnected technological context for a safer, secure and sustainable future.

Biography

Jawahar Bhalla (JB Engineering Systems) - jb@engineeringsystems.com.au
JB is a passionate Systems professional with over 30 years’ experience across multi-national organisations in technical and strategic leadership roles. He contributes to the advancement of Systems Thinking, Systems Engineering and Modelling & Simulation locally and globally as foundational enablers to understanding complexity for a better, safer world. He is the Technical Director of INCOSEs’ Australian Chapter, SESA, an SME Industry Co-Chair of the ADF Synthetic Environment Working Group, a past member of the SimAust Board and a founding member and past Chair of the SimAust Professional Development Committee. He was recognised by Simulation Australasia at the ASC 2021 as the recipient of the "Ray Page Lifetime Achievement Award" for significant and consistent contributions to M&S in the Australasia region. He has a BE in Aerospace Engineering and a BSc in Computer Science from UNSW, a Masters’ in Systems Engineering from UNSW@ADFA and is a current iPhD candidate on an Australian Government Research Training Program scholarship, with industry partner Shoal Group, at the University of Adelaide, Australia. He has 24 technical papers published and has delivered numerous presentations, tutorials, workshops and sessions on systems concepts, systems engineering and Modelling & Simulation.

Tutorial#6

Systems Engineering an Off-Grid Utility System – A MBSE Tutorial

Steve Cash - steve.cash@sbcglobal.net

Keywords. Model-Based Systems Engineering;Hands-on;Practical Application

Abstract.

The tutorial provides the opportunity to create a systems engineering model using a systems engineering tool. The tutorial starts with an overview of the systems engineering principles of system thinking, system processes, and model-based systems engineer. This is followed by an instructor led activity to establish a high-level problem definition in the model. The journey continues with a sequence of hands-on team-based exercises to build use cases and elicit requirements, develop behavior representation, simulate behavior, develop physical architecture, and parameterize the model. The activities will utilize SysML diagrams (Block Definition, Internal Block, Activity, and Use Case diagrams) along with text data entry to capture the data in the model. In addition, traditional systems engineering diagrams (Hierarchy, Physical Block, Enhanced Functional Flow, N2) and additional SysML diagrams (Sequence, Requirements, Parametric) will be used to demonstrate how the coherency and consistency of the model can be preserved. Attendees will come away with an understanding of how to perform systems engineering utilizing a fully functional model-based system engineering tool.

For use in the tutorial, you will be provided Vitech's GENESYS University Edition to be installed and licensed on your machine. Software, Licenses, preparation, and training materials will all be provided in advance.

Biography

Steve Cash - steve.cash@sbcglobal.net
I am a Certified Systems Engineering Professional (CSEP) through the International Council on Systems Engineering (INCOSE). I have held the position of Academia Chair on the board of the Chicagoland Chapter of INCOSE and graduated from the INCOSE Institute for Technical Leadership. As a Principal Systems Engineer at Vitech, I provide consulting and training support for Vitech customers. I have spent 25+ years developing my systems engineering skills through experiential learning. While my experience is broad, I have spent the majority of that time in the automotive sector supporting the development of engine controls, transmission controls, suspension controls, and lithium-ion batteries. My roles over the years have ranged from electrical engineer to project lead to subject matter expert to manager.

Tutorial#3

Systems Engineering by the Book

Paul Martin (SE Scholar, LLC) - paul.martin@se-scholar.com

Keywords. INCOSE SE Handbook;SE Processes;Systems Engineering Fundamentals

Abstract.

The INCOSE SE Handbook is a key product for the SE Community. Not only does it provide a foundation for our profession but it also is the basis for the INCOSE SEP exam. This tutorial will provide an overview of the SE Handbook by taking it apart from the inside out. By using a comprehensive, context informing Process Flow diagram, the instructor will cover all the Processes from the SE Handbook from the Life Cycle Model Management Process to the Disposal Process. Thus making this tutorial a compressed SE Fundamentals Course. Although this tutorial will not go into depth, it does provide an effective way to study the handbook in a more logical manner.

Biography

Paul Martin (SE Scholar, LLC) - paul.martin@se-scholar.com
Paul Martin is a practising Systems Engineer with over 35 years of experience. He’s been everything from a Product Engineer for General Electric Products Division to a Software Systems Engineer for a multi-million dollar Navy program. He started SE Scholar, LLC several years ago in order to help other Systems Engineers go through the INCOSE SEP Certification process because he didn’t have any help back in 2007 when he got his CSEP. On the Certification side of things, Paul has two: (1) INCOSE’s “Expert Systems Engineering Professional” (ESEP) since 2012 and (2) CompTIA’s Certified Technical Trainer (CTT+). Paul has a side job as an Adjunct Professor in the UMBC College of Engineering and Information Technology, Systems Engineering Graduate Programs where he developed and teaches the SYST 660 Systems Engineering Principles course which is part of the INCOSE Academic Equivalency program.

Tutorial#13

Systems Security Engineering: A Loss-Driven Focus

Mark Winstead (The MITRE Corporation) - mwinstead@mitre.org
Michael Mcevilley (The MITRE Corporation) - mcevilley@mitre.org
Daryl Hild (The MITRE Corporation) - d.hild@ieee.org

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

Abstract.

Systems security engineering (SSE), as an integral part of systems engineering, applies scientific, mathematical, engineering, and measurement principles, concepts, and methods to coordinate, orchestrate,

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

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

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

Biography

Mark Winstead (The MITRE Corporation) - mwinstead@mitre.org
The MITRE Corporation’s Systems Security Engineering Department Chief Engineer, had over twenty-five years’ STEM experience before joining MITRE in 2014, including stints as a crypto-mathematician, software engineer, systems engineer, systems architect and systems engineer as well as systems security engineer. He has worked for several defense contractors, an Environmental Protection Agency contractor, a Facebook-like start up, a fabless semi-conductor manufacturer of commercial security protocol acceleration solutions, and a network performance management solutions company. Additional to serving as a chief engineer, Mark works with various MITRE sponsors, helping programs with security engineering as well as teaming with others on integrating SSE into the acquisition systems engineering process. He has also worked with the MITRE Institute on developing materials for training in SSE. Additionally, Mark is co-author of NIST SP 800-160 Volume 1, Revision 1 Engineering Trustworthy Secure Systems. Mark is a graduate of the University of Virginia (PhD, Mathematics) and Florida State University (BS & MS, Mathematics). He resides in Colorado Springs, CO.

Michael Mcevilley (The MITRE Corporation) - mcevilley@mitre.org
Michael has over 35 years’ experience in high confidence software-intensive systems and requirements engineering. He has been employed at The MITRE Corporation for over 20 years where he has supported several DoD programs with focus on requirements analysis, and system design assurance for safety- and security critical ground, surface, subsurface, and air weapons platforms. Michael is currently a System Assurance Lead in the MITRE Systems Engineering Innovation Center and supports DoD systems engineering efforts for program protection planning and for achieving confidence in weapon systems engineered to operate in contested cyberspace environments. Prior to joining MITRE he served as an officer in the USAF, worked in industry developing software for the Aegis Weapons System and for Command and Control (C2) of worldwide military airlift operations. Michael is a co-author of NIST SP 800-160 Volume 1 Systems Security Engineering: Considerations for a Multidisciplinary Approach in the Engineering of Trustworthy Secure Systems and the forthcoming Revision 1.

Daryl Hild (The MITRE Corporation) - d.hild@ieee.org
Daryl's career spans 3 decades consulting on systems engineering solutions that span US Army tactical communications networks, IT networks and systems management solutions; NORAD / NORTHCOM air warning and missile warning systems, the US Air Force global positioning system, space systems, and cyberspace security. He is currently the Department Head for the Systems Security Engineering department within the MITRE Labs. Prior to MITRE, Daryl was an Army Signal Officer. He received his BS in Electrical Engineering from Washington University, St. Louis, MO; and his MS and PhD in Electrical and Computer Engineering from the University of Arizona, Tucson.

Tutorial#12

Trustworthy Secure Design

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Michael Mcevilley (The MITRE Corporation) - mcevilley@mitre.org

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

Topics. 2.3. Needs and Requirements Definition; 2.4. System Architecture/Design Definition; 4.4. Resilience; 4.7. System Security (cyber-attack, anti-tamper, etc.);

Abstract.

A system with an inherently more secure design 1) avoids security hazards, rather than controlling them, 2) provides a design structure enhancing the ability for active controls to succeed with assurance, and 3) is intrinsically easier to analyze for vulnerabilities and hazards.

Common practice with cybersecurity engineering is a tactical risk based approach of identifying vulnerability, prioritizing around likelihood and consequences, and mitigating through countermeasures. A principled, strategic engineering approach to produce an inherently more secure system not only aids in prioritizations, but also reduced the workload and mitigates concerns of “unknowns”.

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

Biography

Mark Winstead (The MITRE Corporation) - mwinstead@mitre.org
The MITRE Corporation’s Systems Security Engineering Department Chief Engineer, had over twenty-five years’ STEM experience before joining MITRE in 2014, including stints as a crypto-mathematician, software engineer, systems engineer, systems architect and systems engineer as well as systems security engineer. He has worked for several defense contractors, an Environmental Protection Agency contractor, a Facebook-like start up, a fabless semi-conductor manufacturer of commercial security protocol acceleration solutions, and a network performance management solutions company. Additional to serving as a chief engineer, Mark works with various MITRE sponsors, helping programs with security engineering as well as teaming with others on integrating SSE into the acquisition systems engineering process. He has also worked with the MITRE Institute on developing materials for training in SSE. Additionally, Mark is co-author of NIST SP 800-160 Volume 1, Revision 1 Engineering Trustworthy Secure Systems. Mark is a graduate of the University of Virginia (PhD, Mathematics) and Florida State University (BS & MS, Mathematics). He resides in Colorado Springs, CO.

Michael Mcevilley (The MITRE Corporation) - mcevilley@mitre.org
Michael has over 35 years’ experience in high confidence software-intensive systems and requirements engineering. He has been employed at The MITRE Corporation for over 20 years where he has supported several DoD programs with focus on requirements analysis, and system design assurance for safety- and security critical ground, surface, subsurface, and air weapons platforms. Michael is currently a System Assurance Lead in the MITRE Systems Engineering Innovation Center and supports DoD systems engineering efforts for program protection planning and for achieving confidence in weapon systems engineered to operate in contested cyberspace environments. Prior to joining MITRE he served as an officer in the USAF, worked in industry developing software for the Aegis Weapons System and for Command and Control (C2) of worldwide military airlift operations. Michael is a co-author of NIST SP 800-160 Volume 1 Systems Security Engineering: Considerations for a Multidisciplinary Approach in the Engineering of Trustworthy Secure Systems and its Revision 1, retitled Engineering Trustworthy Secure Systems

Presentation

Presentation#72

10 years of Creation and Evolution of INCOSE BRASIL, the first INCOSE Chapter in Latin America.

George Sousa (Engeflux) - george.sousa@engeflux.com
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Fabio Silva (Oceaneering International) - f.gsilva@live.com

Keywords. Chapter development;Brazil;Collaboration;Latin America;Teamwork

Topics. 2.1. Business or Mission Analysis; 22. Social/Sociotechnical and Economic Systems; 3.5. Technical Leadership; 3.7. Project Planning, Project Assessment, and/or Project Control; 5.10. Diversity (cultural boundaries, diverse engineering teams, training underserved groups, etc.); 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract.

This presentation provides a brief history of the origins of the Brazilian Chapter of the International Council on Systems Engineering (INCOSE BRASIL). The rationale that led to the creation of an official organization is described, as well as some of the challenges it faced, key successes achieved, and lessons learnt. In addition to a historical review, the audience will take away a rationale that might be helpful in establishing other INCOSE Chapter around the world.

By the late 1990s, a select community of engineers with a systemic mindset initiated involvement with the International Council on Systems Engineering (INCOSE) through various venues, particularly through graduate-level academic work involving international collaboration. These efforts contributed to growing awareness of systems engineering in the country and nurtured a group of people willing to embrace and evolve a more advanced and integrated systems approach. In the years that followed, many meetings, seminars, trainings, and other gatherings occurred over the country with the help and engagement of many; especially in the city of São José dos Campos area – which has evolved as an aerospace technology center.

A conscious attempt towards establishing an INCOSE Chapter had been born and was quite active despite various difficulties and an initial low adoption rate. Nevertheless, by 2010, a few INCOSE ambassadorships had been issued to residents in Brazil which then established a direct communication channel with INCOSE´s international board of directors. This shared communication enabled a few communities in geographically distant regions of this large country to become aware of each other and connect. The movement towards establishing a chapter strengthened, and people felt more confident and motivated.

A core group of organized leaders emerged. A more advanced plan was traced. Decisions on desired emergent behaviors, functional, and formal elements were made. Legal aspects and administration were addressed, and by 2012 a group of people came together in the premises of the National Institute for Space Research in São José dos Campos to have a public say in the creation of a professional organization with established principles and bylaws aligned and recognized by INCOSE. This gathering led to a successful outcome. INCOSE BRASIL was then officially established and became the first INCOSE chapter in Latin America.

INCOSE BRASIL was consciously conceived as a national entity, to serve simultaneously as the Brazilian section of INCOSE as well as the Brazilian National Association of Systems Engineers. The idea was to create a single, designated point of contact and a mechanism for coordinating the systems engineering community. The overall concept has been well accepted and is working effectively.

The operational concept was carefully established to be as much as possible an emulation of the international INCOSE organization with the intent to ensure cohesiveness of purpose. The idea was to remove unnecessary administrative barriers that could create incompatibility of procedures or prevent the flow of value in the chapter operations. For instance, its mission statement was purposefully set as the same as INCOSE´s, and the same classification of member types and overall policies regarding membership management was adopted. Considerations regarding a narrower geographical context and collaboration with the remainder INCOSE international community were incorporated.

In terms of governance, the chapter was designed to function with a Board of Directors charged with making the executive decisions; a Deliberative Council responsible for nurturing guiding principles, policies and a code of ethics, providing strategic direction and legal infrastructure; a Fiscal Council acting as an internal auditing agent; and a Corporate Advisory Board to organize the participation of institutional members, their voice and expectations.

The first three years of operation tested and refined this structure and saw a membership pool increase from 25 members to 40 members and then stabilizing at this level. By the fourth year of operation the Board of Directors decided it was time to put in place the efforts to establish its Regional Directorates. Regional Directorates are extensions of the National Board of Directors in charge of INCOSE BRASIL´s operations in specific geographical regions of interest. They are a governance component capable of providing a sense of identity and a professional home for communities of individuals.

Regional Directorates were conceived as part of the original bylaws and at that time a decision was made to have cities as the identifying geographical scope, rather than states or other larger geographical regions. The rationale driving this decision was the understanding that although modern remote communication technology is quite advanced and very welcome, there is an essential social component related to camaraderie, stewardship, and pride that emerges through face-to-face interaction. INCOSE BRASIL wanted to promote just that face-to-face based learning and growth while maintaining an overall sense of unity and national and international identity.

With that in mind, at the end of 2016, an effort to implement Regional Directorates was initiated. In little over a year, the membership level doubled to approximately 75 members. Products created at one Regional Directorate become part of the INCOSE BRASIL ecosystem, enriching the chapter portfolio and serving as references to be adopted by other Regional Directorates. Such collaboration is already taking place, as intended and is showing good results when it comes to putting Systems Engineers together to share their knowledge and experiences.

Even though the face to face effort helped INCOSE BRASIL to spread systems engineering across different cities. It became clear that, in a continental sized country like Brazil, the Regional Directories wouldn't be enough to reach all the potential members. So, since 2017, a huge collaboration effort was made to create products that would be a click away from Brazilian members, Webinars, Live Sessions, Systems Talks and conferences took place, increasing significantly the importance of the chapter when the topic was “Systems Engineering”.

Although the chapter is still quite young and relatively small, the difficulties surpassed thus far have led to the evolution of an aggressive growth strategy that is now in progress. Stakeholder expectations are high and so is the potential for expansion nationwide with additional impact for the presence of INCOSE in South America.

Presentation#61

A Platform for MBSE-Enabled, Digitally Threaded, Electronics Design and Verification

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Keywords. MBSE;Architecture;Microelectronics;Electronics;EDA;Digital Thread;Digital Twin;Verification

Topics. 1.1. Complexity; 14. Autonomous Systems; 2.4. System Architecture/Design Definition; 2.6. Verification/Validation; 3. Automotive; 3.5. Technical Leadership; 3.7. Project Planning, Project Assessment, and/or Project Control; 4.2. Life-Cycle Costing and/or Economic Evaluation; 4.6. System Safety; 4.7. System Security (cyber-attack, anti-tamper, etc.); 5.11 Artificial Intelligence, Machine Learning; 5.3. MBSE & Digital Engineering; 5.4. Modeling/Simulation/Analysis; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 6. Defense;

Abstract.

Problem and Motivation

The challenges of the complexity explosion are driving a transformation to digital engineering, requiring an enterprise level commitment to engineering workflows that formalize digital

twinning and digital threading. The foundation of the digital thread is verification, without which the digital thread becomes ambiguous and un-reliable. Micro-electronics execution of

real-time control software becomes the focal point for many of the highest risk corner case issues. Industry cannot advance without robust & trusted digitally threaded verification of electronics that informs system behavior. This paper describes the implementation of a platform that conceives realizing this goal. The status of the platform is described with example work products.

State of Practice

Current practices are not able to digitally thread electronics verification. A primary limitation is that system architecture modeling methods are inadequate in decomposition and explicitness. Diagram-centric models confound requirement allocation and the expression of architecture behavior and structure adequate to drive electronics design flows. There needs to be an breakthrough in architecture modeling methods and tools. Siemens is solving this problem by applying the ARCADIA methodology and Capella-derived tooling which is tightly integrated within an Authoritative Source of Truth (ASoT). This capability is believed to be an industry first. With this capability realized, a diverse array of design and simulation tools can now interoperate with the architecture model; constraining and specifying design efforts and enabling the verification through simulation that the design’s performance will meet requirements.

Platform Description and Examples

At INCOSE IS 2021, a solutions pattern for such a platform was introduced, as well as several technology components that contribute to implementing the platform. In this presentation, we will provide an update by describing the platform currently being deployed in pilot projects. Users are brought onto the platform to perform work in 3 phases:

Phase 1 – Developing verifiable requirements

Phase 2 – Architecture, functional allocation, and analysis

Phase 3 – Design and verification of electronic elements

The presentation will include examples of the work products from each phase based on an aircraft landing gear system. Progress towards standards conformance will include SysML V2 representations. The audience will take away an understanding of the steps to implement and future proof MBSE for Electronics in their organizations and ecosystems.

Presentation#77

An integrative approach proposal for System Engineering, Design Science and Configuration Management

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Keywords. C-K theory;MBSE;Configuration Management

Topics. 1.5. Systems Science; 2. Aerospace; 3. Automotive; 3.2. Configuration Management; 3.3. Decision Analysis and/or Decision Management; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract.

The purpose of our presentation is to explain how configuration management discipline can be seen as a connection between existing global approaches that focus on different aspects of Complex System Engineering: the design theories and methods, based on the design science that Herbert Simon widely contributed to develop, and the complex system engineering methodologies and frameworks. Indeed, Configuration Management is frequently seen as a subset of System Engineering Methodologies, while we consider it as the keystone that maintain both fluidity and reliability of the overall product generation process.

First, we will introduce how the two fields are mapped using one instance of each: the Concept - Knowledge Theory developed by A. Hatchuel and B. Weil, and the Model Based System Engineering framework. Example of this mapping exist in the literature. For instance, Jin, Yili & al. (Semantic Modeling Supports the Integration of Concept-Decision-Knowledge) present RFLP models that are output of MBSE methodology as ways to structure both Concept Space (the space of alternative solutions) and Knowledge Space. As such, this mapping is interesting. Indeed, CK theory is as theory for innovation, that overcomes simple decisions paradigms and optimization approaches. We consider it interesting, as a 1st outcome, to restate that System Engineering frameworks, although they are meant to ensure complicated artefacts design in a structured and industrialized way, are not antinomic with Innovation.

Second, we will try to expose how Configuration Management is way to ensure a safe conjunct exploration of both spaces, as described in C-K Theory. Indeed, as a discipline that ensure the reliability of data shared by teams and communities, Configuration Management can be seen as the infrastructure that allow collective actions to take place all along the Design Process. Based on a proposed extension of CK Theory to CDK Theory (Concept-Decision-Knowledge), proposed by Jin Yill and al. (supra), we will present how Configuration Management components (identification, baselining, change control processes) are enabling the process described in this formal framework, introducing a data behavior and processing approach that span through Concept, Knowledge and Decision Support, and complement the semantic modelling Jin Yill and al. present.

For the last part, we will present the implementation of this approach in examples from automotive and aerospace industries, and how it can be used to specify Computer Aided Design Systems and related Processes (such as Product Lifecycle Management capabilities). We will also discuss some limitations of this approach

Presentation#79

An Overview of the upcoming Communications Systems Primer: A Systems Engineer's Guide to Communications Networks: Modeling Networks as Systems

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Keywords. Communications;Systems Engineering;System of Systems;Modeling;INCOSE;Network Services;Telecommunications

Topics. 11. Information Technology/Telecommunication; 2.4. System Architecture/Design Definition; 4.4. Resilience; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 7. Emergency Management Systems; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract.

The Communications Systems Primer provides guidance on how to identify the many constituent systems that might collectively provide the communications services used by an organization.

Most modern IT and technology based systems rely heavily on networking to obtain and disperse the information they were designed for. And most Systems Engineers know little about the world of modern networking services and capabilities. In fact, many modern solutions rely upon components communicating through networks that are shared between multiple applications and/or are managed by third parties. The nature of those network services requires them to be treated differently than dedicated communications links.

The primer identifies the communication networks that a Systems Engineer may encounter; the unique considerations that should be contemplated with designing a Systems of Systems that rely upon one or more shared communication networks; and define the basic modeling requirements and techniques for including network services and resources into a systems model.

Presentation#35

Augmenting Agile Software Development to Improve Systems Thinking

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Keywords. Resilience engineering;Agile Software Development;Technical Debt

Topics. 1.6. Systems Thinking; 22. Social/Sociotechnical and Economic Systems; 4.4. Resilience; 5.1. Agile Systems Engineering;

Abstract.

With the world of software and technology changing constantly, the need for fast, adaptable deliverables has emerged. For this reason, adoption of Agile software development is rapidly increasing in the world of software development and project management. The Agile methodology focuses on releasing functioning technology as fast as possible by breaking the process down into quick iterations known as sprints. Each sprint is a complete loop in a continuous process that promotes user feedback, constant team coordination, and customer input. At the end of each sprint, the team has a deliverable piece of the project to share with stakeholders. The speed at which this software is released is clearly beneficial to business practices in a world reliant on the latest technology.

The problem is that the focus on velocity and continuous delivery can lead to issues later in the project. One of the issues that Agile critics frequently bring up is an idea known as technical debt (Behutiye et al., 2017; Cunningham, 1992). Technical debt is the term used to describe the increase in future costs associated with short term design adjustments made to keep up with Agile's continuous delivery concept. Technical debt also stems from investing inadequate time and effort in ensuring a technology is designed to integrate into high demand work system operations. It is easy to focus on meeting functional requirements and verifying functionality in routine conditions. When development teams do so, there is high risk that the technology will interfere with work system resilience during high-demand and nonroutine events, something Woods (2017) has termed “dark debt”.

To combat the technical debt problem, we developed a resilience engineering framework to introduce into the Agile methodology. This framework is called the Transform with Resilience during Upgrades to Socio-Technical Systems (TRUSTS) Framework (Neville et al., 2021). It specifies characteristics of complex work systems that enable them to respond to threats and high demands adaptively and resiliently. We posit that technical debt can be reduced during Agile software development by augmenting the Agile methodology with TRUSTS, i.e., with considerations, additions, and adjustments that help development teams attend to a technology's alignment with the resilience requirements of work system's real-world operations.

We are conducting an interview-based study of Agile engineering as practiced. We will use the results of our interview-based research to guide our augmentation of Agile methodology, its artifacts, and its activities. Semi-structured interviews are being conducted with Agile subject matter experts (SMEs) who have worked on at least three software development projects using Agile. The interviewees represent three categories: Agile coach or instructor, project manager, or software developer. Interviewees are asked to recount personal experiences using Agile development, what aspects of Agile were easier to practice than others, and where the limitations of Agile lie. Interview data are being translated into representations of Agile development-as-practiced. The representations are being assessed to identify leverage points in Agile-as-practiced, where work system resilience factors could be introduced into the development process.

The accumulation of technical debt, particularly debt that develops from misalignment with real-world

operations, is a factor that has contributed to failed software development projects and transitions across a wide variety of industries (Behutiye et al., 2017; Cunningham, 1992). We expect our additions to Agile methodology will lead to the improved rate of successful transition of artificial intelligence, machine learning and assistive automation technologies, especially into high-consequence systems that cannot afford periods of disruption and heightened risk caused by the revelation and resolution of technology misalignments with work operations.

This presentation will benefit an INCOSE audience in multiple ways. These include:

- Describing the TRUSTS framework of factors that give work systems their ability to be responsive, adaptive, and resilient

- Contributing to the system engineering community's work on reducing the risk of technical debt accumulation during Agile development.

- Providing an empirical view of Agile-as-practiced as opposed to the textbook definition of Agile

- Share initial ideas of how to imbed the TRUSTS framework into Agile-as-practiced to reduce technical debt associated with a disconnect between design and real-world operations

- Contributing to system engineering community efforts to improve systems thinking during software development.

This presentation also will benefit the quality of our contributions to the systems engineering community by enabling community members to provide inputs and share relevant experience and expertise.

BIOGRAPHY

Emily Barrett has a BS in Data Analytics and an MS in Cognitive Systems Engineering from The Ohio State University. Her personal research during graduate school included modeling distributed work systems to analyze decision making and coordination costs during contingency management operations. She is currently leading the work described above as well as working on projects involving resilience engineering, decision analysis, and human-machine teaming.

References

Behutiye, W. N., Rodríguez, P., Oivo, M., & Tosun, A. (2017). Analyzing the concept of technical debt in the context of agile software development: A systematic literature review. Information and Software Technology, 82, 139–158. https://doi.org/10.1016/j.infsof.2016.10.004

Cunningham W. (1992). The WyCash Portfolio Management System. OOPSLA'92 Object Oriented Programming Systems, Languages and Applications, Vancouver, B.C., Canada, October 18-22. NY: ACM, 29-30. doi: 10.1145/157710.157715.

Neville, K.J., Rosso, H., Pires, B. (2021). A systems-resilience approach to technology transition in high-consequence work systems. Proceedings of the 9th Symposium on Resilience Engineering, June 21-24, Toulouse, France

Woods, D.D. (2017). STELLA: Report from the SNAFUcatchers Workshop on Coping With Complexity. Columbus, OH: The Ohio State University. https://snafucatchers.github.io/

Presentation#50

Case Study: Using Digital Threads in a large System of Systems (SoS) for System Certification

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Keywords. Digital Threads;System of Systems;System Certification;Requirements;Verification and Validation;Systems Development Life Cycle

Topics. 12. Infrastructure (construction, maintenance, etc.); 16. Rail; 2.3. Needs and Requirements Definition; 2.5. System Integration; 2.6. Verification/Validation; 3.6. Measurement and Metrics; 3.7. Project Planning, Project Assessment, and/or Project Control; 4.6. System Safety; 4.7. System Security (cyber-attack, anti-tamper, etc.); 5.3. MBSE & Digital Engineering; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.);

Abstract.

This presentation will provide a case study on how the California High-Speed Rail System (CHSRS) is preparing for system certification throughout the systems development life cycle, demonstrating to the Federal Railroad Administration (FRA) that the system will be safe, secure, and ready to operate.

As established in prior INCOSE papers and presentations, CHSRS is multi-billion-dollar program delivered in several independently designed and constructed civil works, track and systems, trainsets, train operator and other projects, exhibiting the typical system of systems (SoS) challenges. Currently, CHSRS is under construction along approximately 119 miles with three active civil works contracts designing and building over 225 structures along the future CHSRS guideway, with more contracts planned to be released soon.

The presentation will address from an SoS perspective the system certification challenges faced, and the SoS engineering activities performed, and summarizes the achieved outcomes and conclusions as of today. Insights will be provided into the tracking of CHSRS program (SoS) requirements throughout the individual project life cycles (constituent systems), and by providing safety and security requirement examples, will describe how digital threads are used to the hundreds and thousands of the design, construction, and inspection and testing artifacts to make the successful case that the CHSRS can be certified for safe and secure passenger operation.

Presentation#65

Connecting the Systems Lifecycle through Architecture-Driven Engineering

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Keywords. architecture;complexity;lifecycle

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

Abstract.

INCOSE Vision 2025 “A World in Motion” identifies classic challenges that organizations face as they seek to deliver capabilities and systems in today’s world. We see accelerating growth in the complexity of the problems we address as well as the implementation technologies upon which we rely. As information transitions from team to team throughout the systems lifecycle, knowledge and investment are lost at lifecycle phase boundaries introducing inefficiencies and errors. Looking across projects, knowledge and investment are lost across the greater engineering portfolio. Put simply, what got us here won’t get us there as we deliver the vision of Industry 4.0, Society 5.0, and the next-generation systems our customers demand.

To successfully address these challenges, we must address both the part and the whole. We must address both the part complexity as the number of parts increases and the interaction complexity as the number and nature of the connections between those pieces explodes. Fortunately, the tool to manage interactions and complexity is well known to us. Architecture enables us to define the fundamental organization of a system as embodied in its components as well as their relationships to each other and the environment. Refocusing the systems lifecycle around architecture honors that interactions within the system (and within the organizations developing the system) that drive emergence enabling organizations to manage both part and interaction complexity through life.

Architecture-Driven Engineering recognizes the critical role architecture plays in managing system complexity, enabling knowledge retention, and establishing the design envelope. It is a pragmatic approach to effectively defining and capturing architectures which can easily transition to detailed design, implementation, and verification. It enables us to embed health, resilience, and security in the systems we develop and to maintain continuity from first concept through implementation, operations, and retirement.

Architecture-Driven Engineering is complementary to agile development, providing a framework for continuous expansion and improvement as our capability evolves. It establishes a foundation for model-based systems engineering, aligning and retaining information across the enterprise delivering the right data, right place, right time, right presentation to unlock the collective intelligence of the transdisciplinary team. It is scalable and tailorable to the specific problem and context enabling fit-for-purpose implementation. Architecture-Driven Engineering moves us from a manufacturing-centric view of the lifecycle to a systems-centric view necessary to define and manage the interactions, delivering the characteristics we want while avoiding the unintended consequences we cannot afford.

This presentation will address:

- The critical role of architecture in addressing complexity

- Developing better architectures through MBSE

- Connecting the engineering lifecycle and greater enterprise through architecture

- The benefits of Architecture-Driven Engineering.

As products become more complex and our environment becomes more dynamic, successfully delivering the right product is more challenging than ever. As we unleash the power of architecture, we better translate customer needs into product success.

Presentation#62

Cultural Influences on Systems Engineering

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Keywords. Culture;Systems Thinking;Systems Science;Islamic

Topics. 1.5. Systems Science; 1.6. Systems Thinking; 17. Sustainment (legacy systems, re-engineering, etc.); 22. Social/Sociotechnical and Economic Systems; 5.10. Diversity (cultural boundaries, diverse engineering teams, training underserved groups, etc.); 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract.

Even though modern systems engineering (SE) practices came from the West, there are other countries with success stories in SE implementation. China is the best example of that. Since the 1960s, the Chinese scientists -mainly Qian Xuesen - were tailoring the Western SE to fit their case. They had the right combination between Qian's experience in US aerospace and defense industry, the Marxist theories, actual China needs at that time, and the ancient Chinese philosophies.

During the last INCOSE IS and IW, several papers and presentations were touching the cultural aspects of SE in one way or another. The United Nations Sustainable Development Goals (UN SDGs) are implemented in the future of SE (FUSE). The need of multi-cultural side of SE is visible there. The Japanese experience in Society 5.0 and in Quality Management shown in IS21 and IW22 showed an example of successful tailoring of SE approaches in the far East. The heuristics research (e.g., Chinese Heuristics) showed a chance for another perspective of heuristics to deal with complexity. Several presentations elaborated the challenges of “values”

in Western SE, and the suggested solutions includes unifying the world towards UN SDGs, building environment similar to Apollo program, improving the transdisciplinary approach with social views and personal views, and learning from Zero Defect Attitude.

This success story of SE implementation in China, and the emerging challenges and opportunities in SE raises a question, if looking to SE from an Islamic perspective would improve the practice of SE in Islamic countries and in all over the world.

The presentation would be related to the Systems Engineers participating/interesting in systems science, systems thinking, transdisciplinary SE, social SE, history of SE, UN SDGs, working in multi-cultural projects etc.

The audiences might takeaway a good collection of the latest literature about the cultural influences of SE, and a new ideas for better SE.

The presenter is Ahmad Alsudairi, from Saudi Arabia, CSEP since 2020, Obtained his BSc in Aerospace Engineering from King Fahd University for Petroleum and Minerals (KFUPM), Saudi Arabia, MSc in Aerospace Vehicle Design from Cranfield University, United Kingdom, and doing a PhD in Aerospace Engineering at University Putra Malaysia, the PhD topic is cultural influences on systems engineering. Also he is working in aerospace industry in Saudi Arabia.

Presentation#85

Culture of Inquiry: Forming the Systems Engineering Mind

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Keywords. Engineering Management;Systems Thinking;Culture of Inquiry;Inclusion;Culture;Technical Reviews;Peer Review

Topics. 1. Academia (curricula, course life cycle, etc.); 1.6. Systems Thinking; 22. Social/Sociotechnical and Economic Systems; 3.3. Decision Analysis and/or Decision Management; 3.5. Technical Leadership; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract.

Engineering leaders have a responsibility to create productive atmospheres for technological development and innovation. And at the core, all organizations yearn to be influential entities driving profitable results from stakeholders' social, financial, and technical standpoints. Maintaining social, economic, and technological dominance across a market and steadily growing stakeholder subscriptions requires a culture to position business processes and people for optimal performance and innovation. Performance and innovation are widely known as being synonymous with workforce culture and engagement. What type of workforce culture possesses the ability to invoke the performance necessary for innovation and industry prowess? Furthermore, what key attributes should organizations embody to nurture the 'right' culture for superior and sustainable innovation? Systems engineering leaders must cultivate a teaming dynamic or culture that can properly synthesize, interpret, and redistribute knowledge for follower consumption, independent generation, and correct action. This ‘right’ culture is a culture of inquiry that combats silence and cognitive dissonance through the systems engineering development process when engineering leaders intentionally interest teaming models that invite habits inquiry and inclusivity.

As an engineering leader and aspirant scholar-practitioner, the ability to foster a culture of inquiry that creates an engineering body capable of proactively generating, retaining, and transforming knowledge is essential to sustainable technical success. This culture of inquiry is solidified through Habits of mind that offer conditioning techniques with the propensity to drive the positive behaviors necessary for engineering outcomes and a high-functioning workforce

This presentation will cover how the culture of inquiry should impact the systems engineering competency to generate the teaming dynamic for sustainable and competitive organizational success. The author will highlight how and where the systems engineering lifecycle process can evolve to increase the culture of inquiry and subsequently engineering results. Special emphasis will be placed on case studies with tools invoking sensemaking and reflective practice throughout the systems engineering development process

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Presentation#69

Death Rays, databases, and double diamonds

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Keywords. Systems thinking;Systems engineering;problem analysis;consulting;design thinking

Topics. 1.6. Systems Thinking; 2.1. Business or Mission Analysis;

Abstract.

The use of trade studies to evaluate alternative solutions is well understood within Systems Engineering. Using a similar approach to make sure that we are solving the right problem is less common. This presentation will describe why problem understanding can be so difficult and how to work with clients and internal stakeholders to better understand the real problems that need to be solved.

The double diamond model is a useful way to explain this (See figure in the attached document). The first diamond is about problem understanding, the second about solution selection. As the problem is explored, the situation becomes more complex, before being simplified. Conventional solution development is undertaken in the second diamond.

Systems engineers are often engaged to solve a precisely defined problem. Assuming that this is actually the problem that the client, or senior management actually wants is, however, risky. The initial problem analysis may: never have been done, been done poorly or be out of date.

This presentation will provide an overview of a key skill systems engineers should develop and employ. The presentation will cover:

• The financial, programmatic and safety implications of solving the wrong problems.

• Why as systems engineers we need to stay focussed on uncovering, confirming, and focussing on what the real problems are.

• How to identify the quality of problem analysis and how to convince different stakeholders to review their problem scoping.

• How to undertake problem analysis – what are the key activities to do, how to bring people with you and how to know when you have done enough

• Why problem analysis is hard for people to do and what you can do to make it easier for you and your stakeholders

The presentation will include specific real world examples from history and from the presenters’ recent projects. This will include the historical Death Ray example, as well as recent projects.

Presentation#73

Defining a Measurement Framework for Digital Engineering

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Keywords. Digital Engineering;Model Based Engineering;Model Based System Engineering;Measurement Framework

Topics. 17. Sustainment (legacy systems, re-engineering, etc.); 2.1. Business or Mission Analysis; 20. Industry 4.0 & Society 5.0; 4.2. Life-Cycle Costing and/or Economic Evaluation; 5.3. MBSE & Digital Engineering; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract.

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

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

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

This presentation will provide an overview of the Digital Engineering Measurement working group, a summary of applicable studies from SERC and other researchers on digital engineering/MBSE measures and benefits, and an overview of the initial digital engineering measurement framework published spring of 2022. We will also discuss the way forward now that a baseline framework has been published.

Presentation#40

Delivering Systems Engineering in practice

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Keywords. Systems Engineering;Practice;Practical;Value;Benefits;Teamwork

Topics. 3.5. Technical Leadership; 6. Defense;

Abstract.

In 2016 the UK Ministry of Defence established an Internal Systems Engineering team to reduce the cost of external technical support to Defence Acquisition projects. After an agreement to proceed in June 2016, the team started operation in August 2016. Over the next 6 years the team:

• Grew from 3 to 60 SE consultants

• Delivered 460 discrete Systems Engineering tasks, using nearly 160 person years of effort

• Delivered £21M in direct cost savings and an estimated £5.5M in indirect costs

• Expanded the model to 4 other Internal Technical Support teams – covering Safety, Cyber security, Human Factors Integration and Quality.

Over the last 6 years the team has delivered a significant amount of high quality Systems Engineering, supporting some of the largest MOD acquisition projects. In completing this work we gathered a significant amount of lessons in undertaking Systems Engineering tasks. This presentation will provide an overview of these lessons.

The presentation will cover:

• The ITS SE team, its history, context, operating model and people. We will explain how we have evolved the operating model to improve SE delivery. We will also explain some of the limitations to the lessons identified.

• Planning the SE tasks using Systems Engineering – agree the deliverables, acceptance criteria, requirements and constraints. The importance of tailoring the generic SE process based upon the specific risks and opportunities faced in the task. How to develop a Golden Thread for each task – from client benefits, through deliverables, activities down to what the client has to deliver to enable success.

• Avoiding the typical problems associated with core SE processes. The presentation will cover specific issues to look out for in Developing Requirements, Architecting and Design, Verification and Validation, in-service Asset Management, Integrating Specialisms and System of Systems Engineering.

• Selecting the right Systems Engineers to deliver specific tasks. Understanding the strengths and weaknesses of individual engineers and how to select and manage the right blended team to meet clients' needs and expectations.

• Working with Stakeholders to deliver. Understanding the level of competence of customers, their decision making style and managing the issues that this raises. Setting and managing the delivery drumbeat. Agreeing the details of deliverables – including purpose, size, format and the approach to approval. Managing the emotional journey of clients, systems engineers and wider stakeholders.

The presentation will include specific real world examples, from recent and current projects.

Presentation#67

Digital Twins for Space Exploration

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Keywords. Digital Engineering;Digital Twin;Digital Engineering Ecosystem;MBSE;Internet of Things;IoT;Virtual Reality;Mixed Reality

Topics. 2. Aerospace; 2.5. System Integration; 5.3. MBSE & Digital Engineering; 5.4. Modeling/Simulation/Analysis; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract.

Digital Engineering changes the way organizations conceive, design, manufacture, deploy, sustain and retire products. This enables engineers across different domains to effectively and efficiently communicate design intent, identify emergent behaviors of complex systems, and perform advanced trade studies, multi-domain analyses and optimization that provides stakeholders with the right information at the right time in the right format.

One of the core capabilities of Digital Engineering is the concept of a Digital Twin. A Digital Twin serves as a digital replica of an as-built, physical system that includes realistic replication of structural, behavioral and performance characteristics through models that are correlated with and corrected by field data from the physical system and data backhaul. As part of SAIC’s investment as a leader in the development and implementation of Digital Engineering solutions, a demonstration of a Digital Twin application was completed for an example space exploration program. This presentation provides an overview of this program’s design and development as it was completed using the Digital Engineering Framework to create an exemplar Digital Twin.

Digital Engineering requires a cultural change to engineering practices, particularly for large aerospace and defense programs. Delivering performance at the speed of relevance requires fundamental changes to how organizations acquire and develop technology. These fundamental changes accelerate technical integration and progression by consolidating and connecting once isolated data, exposing it to the entire multi-disciplinary development team, and storing it for future reference. Enabling availability of the right data at the right time in a meaningful format leads to more efficient communications, automation of tasks as

updates occur, reduced defects, reduced rework, improved system integration and faster time to initial operating capability.

SAIC’s Digital Engineering capabilities consist of five core thrust areas: Model Based System Engineering (MBSE), Digital Thread Development, Digital Twin Frameworks, Tool Federation with a Semantic Data Broker, and Digital Engineering Ecosystems. A team within the SAIC Digital Engineering Innovation Factory recently undertook an internally funded project to demonstrate a Digital Twin based on a mock product, the Lunar Landscape Lighting unit, as an example complex space exploration project. The small team consisted of multi-disciplinary engineers and scientists that had access to off-the-shelf software packages and were assigned the primary objective to demonstrate the implementation of a digital engineering framework. This presentation will be a summary of SAIC’s program as-executed and demonstrate how the digital engineering framework was used to construct engineering artifacts across multiple domains connected by the digital thread thus enabling on-demand requirement change impacts, exploring design what-ifs, and inspiring collaboration across the team through implementing a Digital Twin.

For the Lunar Landscape Lighting program (also referred to as Tri-Ell), the multi-disciplinary team utilized tools from the SAIC digital engineering ecosystem to develop models and analyses needed to address the program requirements. Using an agile process, the team carried out design sprints to develop solutions and perform trade studies. As the program progressed, the team also created physical prototypes and utilized sensors and feedback mechanisms to the modeling environment to create and validate the Digital Twin. The team was able to exercise design changes and what-if scenario execution with the Digital Twin, as well as provide real time data displaying to an Internet of Things (IoT) dashboard. Additionally, the team made use of Virtual Reality (VR) and Mixed Reality environments together with the Digital Twin to explore the design space, monitor operations, and better understand constraints and user needs.

This summary presentation of the Tri-Ell program will demonstrate the use and value of a Digital Twin for complex systems.

Presentation#19

Exploring Explainable Artificial Intelligence to aid Systems Engineers in Design and Evaluation of Complex Systems

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Keywords. Artificial Intelligence (AI);Modeling and Simulation (M&S);C4I and Cyber;Explainable AI;Probabilistic Ontologies;Multi-Entity Bayesian Network (MEBN);Deep Neural Networks (DNNs)

Topics. 5.11 Artificial Intelligence, Machine Learning; 5.4. Modeling/Simulation/Analysis; 6. Defense;

Abstract.

It is undeniable that modern multi-domain operations facing sophisticated threats are pushing for an ever-growing list of complex mission capabilities and changing the nature of how systems are designed. Today's systems of systems must have highly interoperable components requiring sophisticated integration techniques and holistic analyses covering from the lowest component level to the highest enterprise level. From increasingly demanding C4ISR and Cyber applications, real-time assimilation and fusion of disparate information, or cost-effective mission planning/operation; innovative technologies — often driven by artificial intelligence (AI) and machine learning (ML) — are working their way into defense systems and challenging the traditional systems engineering practices usually associated with this domain. Incorporating and integrating AI/ML driven technologies to defense systems brings a new set of challenges to the designers, integrators, and evaluators due to the "black-box" nature of these technologies. For instance, Deep Neural Networks (DNNs) are at the foundation of recent innovations in AI/ML and the lack of explainability of their algorithms is well documented in computer science and systems engineering literature.

As engineers become increasingly involved in designing solutions to complex technological and societal needs with AI/ML techniques, modern engineering principles dictate the use of techniques like Modeling and Simulation (M&S) and Explainable Artificial Intelligence (XAI) to understand, analyze and validate the assumptions, theories, and operations of modern complex systems. Here, XAI techniques are combined with M&S to provide a window of opportunity to understand the decision-making constructs of DNNs that can directly aid systems engineers in their professional practice. Under this context, the C4I & Cyber Center at the George Mason University is aggressively pursuing novel methods for integrating theories and results across multiple disciplines including M&S, AI, and XAI. The center’s goal is to develop an understanding of the systems level behavior driven by complex technologies, align the state of theoretical knowledge to the state of practice in systems engineering, and bridge the cultural gaps between government, industry, and academia. The Center was created in the 80's as the nation’s first civilian university-based entity offering comprehensive academic and research programs in the national security domain and is actively working on projects funded by DARPA, AFRL, NATO, and Sandia National Labs, to name a few.

In this presentation, we will highlight the spectrum of ongoing research projects performed by the C4I and Cyber Center, focusing on the technical achievements of two different efforts that directly address systems engineering with the aid of M&S and XAI techniques. The first one combines Probabilistic Ontologies with Multi-entity Bayesian Networks to provide explainable AI insights into the design of adaptable system of systems architecture. The second one focuses on utilizing Shapely Additive Explanations (SHAP) — a state-of-the-art XAI technique — to understand decision making of Reinforcement Learning in dynamic environments. A synopsis of these efforts is provided in the following paragraph.

Anytime Reasoning and Analysis for Kill-Web Negotiation and Instantiation across Domains (ARAKNID): this project is part of the DARPA Adapting Cross-Domain Kill-Webs (ACK) Program (www.darpa.mil/program/adapting-cross-domain-kill-webs) and is being developed to manage data on various threats in real-time to help decisions involving weapons, sensors and military assets. The C4I & Cyber Center supports Raytheon-BBN technologies providing state-of-the-art research on Applied Explainable AI and Probabilistic Semantic Technologies (e.g., Probabilistic Ontologies and Multi-Entity Bayesian Network inference) for analysis and prediction of courses of actions. The goal of the ACK program is to provide decision aid for mission commanders to assist them with rapidly identifying and selecting options for tasking (and re-tasking) assets within and across organizational boundaries. Important decisions are ultimately made by a real person but automating machine-to-machine interactions is a significant tactical advantage when seconds and minutes matter.

The second segment of the presentation will focus on XAI techniques for Reinforcement Learning (RL). RL is becoming increasingly popular in AI communities and provides the ability to train an AI agent to operate in dynamic and uncertain environments. Recently RL has demonstrated promising performance in missile guidance, flight controls, motion planning for swarms of autonomous vehicles, and the list of potential application areas continues to grow. Despite the demonstrated performance outcomes of RL, characterizing performance boundaries, explaining the logic behind RL decisions, and quantifying resulting uncertainties in RL outputs are major challenges that need to addressed by System Engineering community. We have built a robustness testing framework for RL solutions and successfully applied Shapely Additive Explanations (SHAP) to uncover decision making construct of DNNs trained by RL algorithms.

We believe the capabilities addressed in our presentation are applicable not only in the field of defense but also for a broader sphere of applications including information technology and cybernetics. Our presentation directly addresses and advances the tools and techniques required for System Engineering for AI (SE4AI) — which is an identified area of need for the SE community under INCOSE’s FuSE efforts.

Presentation#84

From Systems Engineering to System Family Engineering

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Keywords. System Family Engineering;Product Line Engineering;PLE;Feature-based Product Line Engineering;Variation Management

Topics. 1.6. Systems Thinking; 5.3. MBSE & Digital Engineering; 5.6. Product Line Engineering;

Abstract.

Virtually all systems engineering is performed in the context of a product line – a family of similar systems with variations in features and functions. Hardly anyone builds just one edition, just one flavor, just one point solution of anything. When presented with this hypothesis, the initial reaction from systems engineers is often disagreement. However, when pressed for examples where organizations build a complex system without deriving from an existing similar system and without the intent of building other similar systems, examples are not readily forthcoming.

Because of the inherent assumption in the system engineering community that systems engineering is primarily a methodology for building a single system, systems engineering methods and tools have traditionally focused on how to build the individual point solutions within a family rather than how to engineer a system family as a whole. This mismatch comes with significant risks. A recent study by the analyst firm Tech-Clarity, involving surveys of nearly 200 company leaders engineering products and systems, the number of product and system configurations is largely viewed as the top and growing source of complexity, which results in one of their top two business challenges. Engineering complexity slows progress and leads to defects, errors, and omissions, which in turn leads to the business risks of delays, budget overruns, recalls, system failures, and opportunity losses.

When systems in a system family are engineered as individual point solutions, techniques such as clone-and-own, branch-and-merge, and reuse repositories result in ever-growing duplicate and divergent engineering effort. Trying to manage the system family commonality and variation among these individually engineered systems relies on tribal knowledge and high bandwidth, error-prone interpersonal and document-based communication among different subject matter experts. Furthermore, when each engineering discipline adopts a different ad hoc technique for managing variations among the members of the system family, the result is error prone dissonance when trying to translate and communicate across the lifecycle.

This is self-inflicted complexity, over and above the complexity inherent in the systems being engineered. It consumes engineering teams with low-value, mundane, replicative work that deprives them of time and energy that would be better spent on high-value innovative work that advances system and business objectives. As more and more of systems engineering moves to model-based systems engineering (MBSE) where documents and tribal knowledge are replaced with sophisticated webs of digital information, the complexity of managing system family variation using tribal knowledge and other non-digital engineering techniques becomes an intractable mismatch.

Engineering a product line, or system family, holistically is much more effective and efficient than engineering each of the systems individually. This requires engineering the product line as a single System of Interest (SOI), with variations formally defined and managed to support the individual system instances within the family. This shift requires INCOSE and the engineering industry at large to elevate our thinking from Systems Engineering to System Family Engineering.

Feature-based Product Line Engineering (PLE), as defined by the new ISO/IEC 26580 standard, is the modern digital engineering approach to System Family Engineering. This presentation will explore how Feature-based PLE enables organizations to elevate from Systems Engineering to System Family Engineering. It plays an essential role in the new digital engineering age, offering engineering economies in effort, cost, time, scale and quality in some of the industry's most challenging and complex system families.

For many organizations, Feature-based PLE represents a shift in engineering approach that requires organizational change along with commitment from engineering and business leadership to make that change. The return-on-investment (ROI) to justify the organizational change is in most cases compelling, based on the elimination of low-value, mundane, replicative work, with doubling, tripling and larger improvements in engineering metrics such as effort, cost, time, scale, and quality.

In consideration of this ROI, the question to leadership is, "What if your engineers could do their normal day's work before lunch; what would you have them do in the afternoon?" There are many answers to this question, all of them good.

Presentation#82

Functional Architectures using SysML

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Keywords. Function;Function Architecture;Architecture;SysML;Form follows function;Functional allocation

Topics. 2. Aerospace; 2.4. System Architecture/Design Definition; 3. Automotive; 4. Biomed/Healthcare/Social Services; 4.6. System Safety;

Abstract.

The presentation will describe the different types of Function definitions that can be done in SysML. How those functions are used/allocated to specify design and linkages throughout the Model.

I will go through the definition of Functional hierarchy, Functional allocation, and how Functions can be the center point of identification of a form failure understanding exactly what functions can not be performed.

Presentation#70

How to faithfully model systems composed of millions of parts?

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Samuel Boutin (Knowledge Inside) - sbo@k-inside.com

Keywords. complexity;system model;patterns in systems;viewpoints;diagramming complex systems

Topics. 1.1. Complexity; 1.3. Natural Systems; 1.6. Systems Thinking; 2.4. System Architecture/Design Definition; 3. Automotive; 3.3. Decision Analysis and/or Decision Management; 3.6. Measurement and Metrics; 5.3. MBSE & Digital Engineering; 5.4. Modeling/Simulation/Analysis; 8. Energy (renewable, nuclear, etc.);

Abstract.

Our presentation is about faithfully modeling complex systems, whether they are human made or not. In particular, we explain how to handle modeling of highly repetitive systems and try to specify what is a faithful model in this context. By highly repetitive, we mean systems that may include several hierarchical levels and millions to billions of parts organized according to a small number of patterns. Such a complexity raises the question of relevant intentional versus extensional modeling. The usual flaws are that the extensional representation can be too complex while the intentional representation can be too abstract: we think we found an elegant mix.

Many systems include a high number of parts or subsystems. This is the case for natural systems: if you want to model a lung with it’s bronchial system and all pulmonary alveoli, you will have to handle several hundreds of millions of similar objects. More generally, human body is made of about 10 000 billions of similar cells. It is the same for many human made systems around us: batteries can integrate several dozens of thousands of cells or even much more, a nuclear plant embeds several steam generators and thousands of pumps and pipes, a railway network is made of a very limited number of components and you may integrate hundreds of seats in a plane. Integrated circuits also embed a very repetitive and systematic design. Very often, we integrate redundant functions and components as a safety mechanism leading to parts replication. All systems made of thousands of parts (or much more) are usually made of a much smaller number of different parts.

In a case of systems containing many similar subsystems, similar does not mean equal, e.g. the “position” of “objects” may impact their interfaces and properties. When looking at a pack of cells, cells from “the border” will not have the same interface as cells from “the inside”. This is what we could call side effects. Managing such side effects is a important aspect to maintain modeling accuracy.

In face of high complexity, Lewis Carrol and Borges tell us that a map on a one-to-one scale is useless. Repetition seems a useful lever but side effects need to be taken into account. And despite the complexity we would like to get a faithful model.

What a faithful system model should be deserves an explanation. Here are the properties we would like to keep for our modeling:

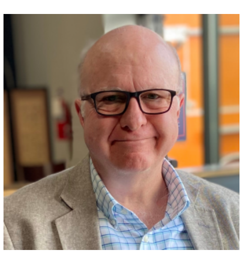
- Any parent-child relation between a system and its subsystems in the actual system shall be faithfully represented by a parent child relation between respective modelled subsystems in the modelled system.

- Any interface between a system and other systems in the actual system shall be represented faithfully by a relation between respective modelled systems.

- Any attribute of an item in the real system we wish to consider shall be represented faithfully by an attribute of that modelled item.

As an example, we will present a way of modeling a battery from cell level to battery pack level inside a single diagram. We also discuss how this system modeling approach fits with requirements management, functional architecture and behavior modeling. We estimate the complexity leverage of the presented approach by estimating the number of terms of the model w.r.t the number of parts of the real system.

Biography



David Hetherington (System Strategy, Inc) - david_hetherington@ieee.org
David Hetherington is a leading Model-Based Systems Engineering (MBSE) consultant serving multiple defense and commercial industry sectors. He has extensive personal experience in designing and leading design teams for both software and hardware covering an unusually broad range of system types. In addition to MBSE, he has a strong concentration of domain knowledge in safety, reliability, maintainability, and diagnostics.

Presentation#76

Industrial DevOps: From Value Streams to Lean-Agile Teams for sustainable delivery

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Keywords. Value stream;DevOps;Agile

Topics. 1.1. Complexity; 1.6. Systems Thinking; 14. Autonomous Systems; 2. Aerospace; 3. Automotive; 5.1. Agile Systems Engineering; 5.2. Lean Systems Engineering;

Abstract.

As Agile and DevOps practices continue to challenge the status quo and improve business outcomes, companies need to learn how to scale these practices across large, complex systems composed of hardware, firmware, and software. The ability to iterate and deploy faster requires companies to adapt to changing needs, reduce cycle time for delivery, increase value for money, and leverage innovations. An industry-wide misconception is that this form of rapid iteration is only for software or small applications and systems. For cyber-physical solutions, software is only one part of the value stream leading us to consider the implication and the application of DevOps principles across the entire end-to-end system. When adopting Agile and DevOps principles to developing systems it is important to capture the value stream and to identify how teams are organized to reduce handoffs and improve delivery of capabilities.

In this session, we will share the principles of Industrial DevOps that development organizations can use to harness the power of Agile and DevOps to the build and maintenance of large-scale, cyber-physical systems such as vehicles, robots, complex medical devices, defense weaponry, and others. We will also walk through the importance of systems thinking and value stream identification, and demonstrate how systems engineers can support their organization in identifying value streams and organizing teams for improved delivery. Using a scenario of an autonomous vehicle, we will discuss the challenges and opportunities for improving dynamic learning and feedback loops for both culture and technical architectures.

Participants will:

Become familiar with Industrial DevOps principles as applied to cyber-physical solutions.

Learn how systems engineers can support their organization by identifying value streams and organizing teams for improved delivery

Presentation#59

Insights from the First ‘State of Systems Engineering in India’ Survey

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Keywords. Systems Engineering Practice;Systems Engineering Challenges;Systems Engineering Trends;Survey;India;Government;Industry;Academia

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

Abstract.

The awareness and recognition of Systems Engineering (SE) as a formal discipline in India started around the year 2000, though it has been practiced informally since the 1960s. Over the past decade, there has been a rapid increase with multinational corporations (that already practice SE) opening off-shore design centers in India, enforcing SE practices in existing ones, or when outsourcing engineering work to Indian companies. Formation of the INCOSE India chapter in 2010 and its growth since then has both contributed to and benefited from these trends.

Systems Engineering focused events organized in India, including two instances of the Asia Oceania Systems Engineering Conference (AOSEC) in 2016 and 2019, provided some insights into SE related practice in India. However, a bigger picture of SE in India was largely missing; and any available information was informal, anecdotal, or concentrated. With this background, there was need to gain a better understanding of SE in India, so that the growth, development, and adoption of the discipline can be observed holistically and supported effectively. This led to the launching of the first “State of Systems Engineering in India” survey, with the following objectives:

To establish the current state of SE in India

To create a baseline to observe changes in this state over time (annually or biennially)

To gather SE related trends, expectations, challenges, and best practices of SE practitioners and stakeholders in India

To identify opportunities to support the growth of the SE discipline in India

To share findings with INCOSE at large and the global SE community

There were only two criteria for participation: the respondent must be aware of SE and must be based in India. The survey was designed with a set of common questions to capture general demographics of the respondents. These include their familiarity with SE, whether they considered themselves to be systems

engineers, where they first heard about SE, major SE events they have attended recently, and if they wish to become an INCOSE certified SE professional (if they are not already one).

Subsequently, questions were presented under four categories, and respondents got to choose one category that matches their current position and then answer questions under that category. The categories were identified to best represent the SE-aware population in India:

1. WORKING PROFESSIONALS

They were expected to form the majority of the respondents, who would be actively practicing SE or interacting with those who perform SE. They are expected to represent a wide variety of domains, industries, and organizations. Survey questions were designed to capture their responses on various aspects including their designations, educational qualifications, maturity of various SE areas that are being practiced in their organizational unit, SE activities they perform on a daily basis, SE topics they wish to know about, how SE can help in their current role, challenges they face while implementing SE, and what could be done to promote SE at their workplace and across India.

2. STUDENTS

Though there are no Bachelors or Masters programs in India that offer a major in SE, awareness within academia is on the rise. Hence, students pursuing undergraduate or graduate degrees were expected to participate in this survey. Survey questions were designed to capture their responses on various aspects including details about their education, years of work experience between their Bachelors and Masters degrees (if applicable), SE related courses they have taken, SE related talks/presentations/seminars at their institution, applying an SE approach to their thesis/project, their interest in establishing an INCOSE Student Division, target institutions for any Master or PhD degrees they wish to pursue, SE topics they wish to know more about, and how they would like to contribute to the promotion of SE in India.

3. FACULTY/RESEARCHER

Though formal programs in SE are yet to be offered in educational institutions, there are some SE related courses that are being offered, and a few faculty members are known to conduct SE related research or project activities. In an attempt to gather insights from them, survey questions were designed to capture their responses on various aspects including their educational background, courses they teach, their current research projects, SE related events at their institution, SE topics of interest for conducting research, establishing an INCOSE Student Division, and promotion of SE in India.

4. RETIRED PROFESSIONALS

This category forms a critical part of SE in India particularly in the aerospace / defense industry, since many of those who were instrumental in introducing and promoting SE in the early 2000s have now retired. In India, the retirement age is fixed by the organization. So, after retirement, only some remain engaged in an advisory role, and a few choose to teach. Survey questions were designed to capture their responses on various aspects including their last official designation, their educational background, SE efforts they have led/initiated/engaged in at their organization, ways to improve the level of SE awareness and adoption in their former organization, and how they would like to contribute to the promotion of SE in India at large.

Survey invitations were sent via email to all INCOSE India Chapter members, participants of recent SE events (conferences, webinars, etc.), leaders of SE-aware organizations, and professional contacts of the survey investigators. Including some overlaps, survey invitations were sent to about 750 individuals, and responses were received from 122 respondents at the time of closing the survey.

The survey was closed on 31-Jan-2022 and detailed analysis of the survey responses is ongoing. Insights based on responses the many survey questions will be included in the presentation during IS2022.

Biography

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Dr. Yogananda Jeppu is a BE in Electronics and Communication, from Mangalore University, a Postgraduate in Missile Guidance and Controls from Pune University. He has a PhD in Certification of Safety Critical Control Systems using Model Based Techniques from IIT Bombay. He has been working in the field of Control System Design and Implementation, Simulation of Aerospace Systems, Verification and Validation for aircrafts and missiles for the past 32 years. He has several publications on Formal Methods, Artificial Intelligence Systems, Randomized Testing, Orthogonal Array Testing and Missile Guidance and Control. He started his career in 1987, working on Missiles and the Indian LCA program with Defense R&D Organization. He is currently working in Honeywell Technology Solutions as a Principal System Engineer. He is also an adjunct faculty at MIT Manipal and NITK, Surathkal, in India.

Presentation#47

ISO/IEC/IEEE 24641 MBSSE standard

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Keywords. MBSE;Model-Based Systems Engineering;MBSSE;Digital Engineering;ISO/IEC/IEEE 24641

Topics. 5.3. MBSE & Digital Engineering;

Abstract.

As systems keep growing in scale and complexity, the Systems and Software Engineering commu-nities have turned to Model-Based Systems and Software Engineering (MBSSE) to manage com-plexity, maintain consistency, and ensure traceability during system development. It is different from “engineering with models”, which has been a common practice in the engineering profession for decades. MBSSE is a Systems and Software Engineering approach centered on evolving mod-els, which serve as the “main / major source of knowledge” about the system or software entity un-der consideration.

In addition; due to the diversity of approaches and terminologies such as MDD, MBE, MBSD, etc. used either

in the context of systems or software engineering; there is a lack of common under-standing of what MBSSE means.

Thus, there is a need for defining a reference model for MBSSE processes. Furthermore, support of tools and methods are required so that an organization can perform MBSSE or digital engineering under the systematic control of complexities.

The ISO/IEC/IEEE 24641 standard provides a MBSSE reference model comprising an abstract representation of the process areas of MBSSE and the relationships between these process areas. The process areas described are ‘Plan MBSSE’, ‘Build Models’, ‘Support Models’ and ‘Perform MBSSE’. These processes are related to the ISO/IEC/IEE 15288 System life cycle processes and describes the way to perform those processes based on models.

The MBSSE reference model concerns human-made systems composed of one or more of the fol-lowing system elements: hardware, software, data, humans, services to users, procedures, facilities, materials and naturally occurring entities. The processes can be applied at any level in the hierarchy of a system’s structure.

The MBSSE reference model can be used either independently or in conjunction with existing standards.

The scope of this International Standard is to provide the terms and definitions specific to MBSSE; define a MBSSE reference model for the overall structure and processes of MBSSE, describe how the components of the MBSSE reference model fit together; and define interrelationships between the components of the MBSSE reference model.

This presentation gives an overview of the progress status of this standard and presents the refer-ence model and summary of its content.

Presentation#28

Manufacturing industry in industry 4.0: As experienced by engineering managers.

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Keywords. interpretative phenomenological analysis;industry 4.0;manufacturing industry;engineering management

Topics. 2.2. Manufacturing Systems and Operational Aspects; 20. Industry 4.0 & Society 5.0; 3.7. Project Planning, Project Assessment, and/or Project Control; 5.5. Processes;

Abstract.

The study investigates the experiences of engineering managers in the manufacturing industry as they adopt the innovative technologies of the industry 4.0. The knowledge, competencies and attributes that would be required by engineering managers to effectively address the challenges faced by engineering managers in adapting to the industry 4.0 will be explored. The research study identified gaps in competencies and qualification strategies were suggested. The focus was on the competence gaps since those determine the skills and knowledge that engineering managers will require to be able to cope with the challenges brought by the evolution within the engineering manufacturing industry and to effectively develop a culture that supports innovation in the manufacturing industry.

Semi structured interviews were conducted with key participants identified in organisations. These took place using appropriate online platforms. The sample size was eleven engineering managers from various organizations within the manufacturing industry at different stages of implementation of industry 4.0. The composition of the participants included those from the food industry, construction industry, energy industry, electrical industry, chemical industry, automotive, textile and clothing industry and consumer goods industry. The selected research methodology was the interpretative phenomenological analysis (IPA) approach which allowed respondents to narrate the research findings through their experiences. The research questions were as follows: 1. How do engineering managers experience the changing requirements in manufacturing to meet the needs of industry 4.0? and 2. What are the skills, knowledge and competencies required by engineering managers in the manufacturing sector to meet the needs of engineering management in the industry 4.0?

The study recommends training and development that can be implemented to ensure that engineering managers have the required competencies for the industry 4.0. This was done in three vital steps, namely: identification of emerging challenges faced by engineering managers due to the changes in the manufacturing industry from the experiences of engineering managers in this industry, draw conclusions from the experiences of engineering to suggest the competencies necessary to face these challenges and the visualization of the required competencies.

Presentation#9

Negotiation: Playing the Infinite Game

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Keywords. Negotiation;Infinite game;Communication;Persuasion

Topics. 20. Industry 4.0 & Society 5.0; 22. Social/Sociotechnical and Economic Systems; 3.3. Decision Analysis and/or Decision Management; 3.5. Technical Leadership; 3.7. Project Planning, Project Assessment, and/or Project Control; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract.

Many people approach the subject of negotiation looking for tricks and stratagems with which they can gain the upper hand in negotiations. Their quest flows from a mental model of negotiation as a contest around persuasion where the “winner” is able to determine the outcome of the deliberations. The techniques sought are those that will “force” or “trick” the “other side” into capitulating to the will of the trickster.

This presentation casts negotiation into the more realistic workplace setting where the goal of the activity is to seek solutions that are best for the team and their stakeholders/customers. In this setting teams typically work together over periods of time that transcend particular negotiations. Intra-team and organizational relationships are important to success over time and should not be subjected to techniques that will damage them in order to achieve a “win” in a particular negotiation.

The work of Simon Sinek and James Carse serves to frame the contrast between the “play to win” mindset and the longer-range considerations as finite and infinite games. This presentation will show the wisdom of adopting the “infinite game” view of workplace negotiations and teach solution-seeking techniques designed to produce healthy and effective negotiations that will generate creative solutions while preserving and strengthening team relationships.

Presentation#53

NRO Application of a SOW Model

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Keywords. MBSE;DE Transition;SOW;Modeling;Profile Development;Acquisition

Topics. 2. Aerospace; 3.1. Acquisition and/or Supply; 3.3. Decision Analysis and/or Decision Management; 5.3. MBSE & Digital Engineering; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract.

The National Reconnaissance Office (NRO) is transitioning from a siloed approach of engineering to an integrated and cross-discipline Digital Engineering (DE) approach. The Systems Engineering Directorate (SED) is at the tip of the spear for that transition. As we look to acquire the next generation of a digital engineering workforce, SED government personal know that the best way to acquire a DE workforce is for us to 'practice what we preach' and approach it from a DE perspective. In support of that, SED government developed a model to aid in the traceability of requirements from current to future contracts across the new acquisition strategy responsibility lines. This allows for clarity as contract transitions occur and aids in developing a Statement of Work (SOW) for each new contract. It also allowed for both top-down and bottoms-up requirements decomposition and traceability to ensure gap closure across the portfolio while keeping interfaces and responsibilities clearly defined between contracts. The model went through multiple development interactions to meet the needs laid out by senior leadership. This presentation will provide an overview of the model, excerpts of the modeling profile developed, discussions on how it was used for gap analysis, lessons learned, and government path forward.

Presentation#5

Past, Present, and Future of the Unified Architecture Framework (UAF)

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Keywords. enterprise architecture;enterprise architecture framework;mbse;system of systems engineering;uaf

Topics. 2. Aerospace; 3. Automotive; 5.3. MBSE & Digital Engineering; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 6. Defense;

Abstract.

The fourth industrial evolution, Internet of Things, and large-scale machine-to-machine interactions are driving digital transformation in the industry. Model-based Systems engineering (MBSE), as a new paradigm of capturing and analyzing knowledge about the system, is one of the core factors to drive this transformation. MBSE practices are more and more widely applied to system-of-systems (SoS), including enterprise and mission engineering. It becomes a crucial part of the successful digital transformation. This presentation explores enterprise and SoS Engineering with Unified Architecture Framework (UAF) putting a specific focus on answering the following questions:

o How SoS engineering differs from systems engineering and where enterprise engineering fits?

o How is UAF related to model-based systems engineering (MBSE)?

o What kind of problems is UAF applicable for solving?

o What industries UAF is applicable for?

o Where one could find more information on UAF?,

o Whats new in a brand new UAF V1.2?, and

o How UAF will be affected by SysML V2

Questions above will be answered from the perspective of the co-chairman and leading architect of UAF standard development, giving the real-world examples of UAF application in various industries.

Presentation#7

Perceptions of Emerging Urban Air Mobility Systems: Differences Between Early to Laggard Adopters of Passenger Air Vehicles

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Keywords. Autonomous Transportation;Technology Adoption;Human Systems Integration;Urban Air Mobility Systems;Passenger Air Vehicles

Topics. 14. Autonomous Systems; 21. Urban Transportation Systems; 4.1. Human-Systems Integration; 5.12 Automation;

Abstract.

Urban Air Mobility Systems, which include on-demand Passenger Air Vehicles (PAVs), are the next frontier in aviation innovation. Passenger Air Vehicles are autonomously-piloted, electric aircraft that transport 1 to 4 passengers at low altitudes within densely populated metropolitan areas. These air taxis promise to offer an eco-friendly alternative to road traffic emissions and congestion. However, successful implementation of PAVs is largely dependent on acceptance and eventual use by the public. In this study we examine two research questions: (1) what are the initial perceptions of PAVs from the public; and (2) what are the differences in perceptions, behavior, and intent to ride between early, moderate, late, and laggard adopters of PAV technology. A quantitative survey was administered with 407 respondents across the United States, which provides insights and general perceptions of PAVs as an autonomous aircraft system concept. The technology acceptance model is applied as a framework to estimate acceptance and use of the PAV technology across user groups. The technology adoption lifecycle model is used to characterize technology adopter profiles and rates of adoption. Survey respondents are classified into one of four PAV adopter group levels based on their response to how soon after PAVs are available to the public they would be willing to ride. These adopter groups are labeled as early, moderate, late, and laggard. Statistical analyses were performed on the data, where chi-square tests and ordered logistic regression models are presented to quantify differences between PAV adopter groups (early vs moderate vs late vs laggard adopters). Key results indicate that respondents classified as early adopters of PAVs are more trusting of PAV technology, willing to pay more to ride, and exhibit higher risk tolerance in their overall general behaviors. Interestingly, these earlier adopters have shorter daily commutes. Later PAV adopters are less trusting of PAV technology and present as risk-adverse. These later adopters need more in-flight feedback and an on-board pilot to consider riding, as compared to earlier adopters. All respondents, regardless of adopter group, expect additional in-flight safety feedback (i.e., displays relating to current and projected flight operations) beyond the level of safety systems found in conventional aircraft (i.e., seatbelts, air quality). Respondents also do not perceive PAVs as an immediate replacement for daily trips. PAV noise, which is often cited as a concern with community acceptance of PAVs, is not found to be a crucial in-cabin deterrent to PAV ridership. These insights are beneficial to Urban Air Mobility stakeholders, ranging from community members to manufacturers to operators to policy makers, in achieving full-scale system integration and the envisioned value of PAVs, both in near- and long-term adoption.

In accordance with this year’s symposium theme, The Power of Connection, the audience may find inspiration in aviation innovation and the emerging technology of Passenger Air Vehicles (PAVs), which have the potential to connect people in a faster, more convenient and more eco-friendly way than ever before. This study provides insights about PAV adopters and what drives their human behavior and intention to adopt new technology. This research is built on human systems integration framework and can provide methodological support to other research. This research focuses on sustainable integration of technology to meet users’ needs and expectations. Findings from this study also highlight community acceptance and integration of emerging technology. Audience members with ties to aviation, transportation, automation, and/or community integration will find value in this talk.

Presentation#63

Rapid Application of Systems Engineering: Quantifying Airborne Dispersion & Solutions in Response to the COVID-19 Pandemic

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Keywords. COVID-19 Aerosols;Rapid Systems Engineering;Pandemic;Evidence-Based Systems Engineering;Systems Engineering Theoretical Foundations

Topics. 21. Urban Transportation Systems; 22. Social/Sociotechnical and Economic Systems; 4. Biomed/Healthcare/Social Services; 5. City Planning (smart cities, urban planning, etc.); 5.1. Agile Systems Engineering; 5.3. MBSE & Digital Engineering; 5.4. Modeling/Simulation/Analysis; 5.5. Processes; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 7. Emergency Management Systems;

Abstract.

During the SARS-CoV-2 (COVID-19) pandemic, many countries have struggled to provide definitive guidance on ways to reduce the highly infectious transmission of the virus within indoor and other environments where there are more people contained within a shared air volume. Yet the engineering of pandemic related mitigations required multiple domains and disciplines to rapidly execute on scientific discovery and evidence-based decisions balanced with supply availability and practicality – all of which have made this a challenging Systems Engineering problem. In this presentation, we discuss the concepts of using observable phenomena as a basis for theoretical foundations that enable evidence-based systems engineering and model-based systems engineering for reducing COVID-19 aerosol transmission risks. We will share our story of rapidly applying systems engineering to several real-life pandemic scenarios and field experiments on reducing the airborne dispersion of aerosolized particles from exhalation. We will also share our experiences on the emerging need to develop reusable models and practical system engineering frameworks for reducing aerosol risks and present a use-case of applying MBSE and evidence-based systems engineering to reduce COVID-19 aerosol transmission risks at the southern U.S. border and in schools.

Presentation#68

Realizing viewpoints in digital engineering

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Keywords. Digital engineering;Digital Viewpoint Model;Domain Models;Linked data;Lifecycle Graphs;OSLC;MBSE

Topics. 2. Aerospace; 3. Automotive; 3.2. Configuration Management; 5.3. MBSE & Digital Engineering; 5.4. Modeling/Simulation/Analysis; 6. Defense;

Abstract.

Topic Overview:

One of the key concepts defined by the INCOSE DEIXWG (Digital Engineering Exchange Working group) is the DVM (digital viewpoint Model). The DVM is a reference model of how engineering information is provided to various consumers (stakeholders) formalized as viewpoints and views. Such exchange viewpoints are the core value of the digital engineering process. Views are made by assembling digital information items from multiple authoritative sources, such as requirements data, MBSE architectures, V&V data, and implementation disciplines models, into meaningful digital renderings. Such views serve stakeholders to conduct activities such as gate reviews for example. DVM does not currently suggest on how it is implemented, and there are quite a few challenges in realizing such combined views in a systematic way, without resorting to a document centric process. In this presentation we discuss a framework and an implementation platform to represent digital items across domains and tools, establish the necessary relationships, and enable the systematic creation of digital views. We will show how standard ontologies, link data, and graph-based self serve queries can produce views in various presentations such as tables, KPI charts, and relationship graphs. The framework is based on the Open Services for Lifecycle (OSLC), which is an open specification that addresses common data representation, cross domain linking, data exchange, and tool collaboration. In addition to OSLC we will discuss specific tooling implementation that leverage the OSLC specification to support realization of DVM like concepts. We will use examples such as change impact considerations, safety related compliance and more.

Related industries: Digital engineering is essentially a cross industry topic. Nevertheless it becomes more beneficial and critical for industries that deal with large complex systems, such as Aerospace and Defense, and Automotive. It would also be highly relevant for adjacent industries such as Medical Devices, Electronics, Railways and Marine industries etc.

Benefits: Digital engineering is a topic which is highly discussed in the abovementioned industries, but the industry is still looking for implementation approaches. It is important to mention that Digital Engineering and the DEIXWG DVM is a much wider concept than MBSE (eg SysML tools). So while MBSE which is an important pillar, is getting more traction, realizing a DVM like model requires wider cross domain framework that can deal with multi-domain models. The proposed talk details a standards based approach for such a framework. The imminent takeaways is enriching systems engineers and MBSE practitioners with concepts that will help them solutioning DE frameworks.

The presenter: Eran Gery has over 25 years of experience in deploying MBSE and lifecycle processes into the Aerspace/Defence, Automotive, and other complex systems industries as a lead IBM ELM Solution Architect. Eran has been an active member of OMG SysML and UML submission and RTF teams since the inception of UML and SysML 1.0. Eran is also active in the OASIS OSLC community, working across industries on leveraging OSLC as a digital lifecycle framework. Eran is also active member of the INCOSE DEIXWG. As part of his daily work Eran engages with implementation of various industry practices such as the Aviation ARP4754a and DO178 practices, and the Automotive ASPICE and ISO26262 practices. In short the speaker has a very wide perspective that combines industry challenges with engineering lifecycle solutioning.

Presentation#38

Requirements Management framework for program RFQ phase

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Keywords. Requirements Management;Requirements Engineering;Request for Quotation (RFQ);Non-recurring engineering (NRE);Project Management;Negotiation;Automotive SPICE (ASPICE)

Topics. 19. Very Small Enterprises; 2. Aerospace; 2.3. Needs and Requirements Definition; 3. Automotive; 3.7. Project Planning, Project Assessment, and/or Project Control; 3.9. Risk and Opportunity Management;

Abstract.

Many project management headaches, including resources, budget, timing, and scope, originate prior to the project even starting. During the Request for Quotation (RFQ) phase for a development program, solution providers focus on the financials of the potential program – submitting a competitive quote while maintaining an acceptable profit margin. Yet they leave one of their most powerful tools, a robust Requirements Management process, sitting in their toolbox until after the project has kicked off – when it’s often too late.

This presentation will describe a specific Requirements Management framework to be used during RFQ phase to allow suppliers to be more effective in quoting a program. A streamlined setup leads to more efficient tool use and reduces resource intensity during this phase. Crucially, it minimizes the time required of subject matter experts (SMEs), freeing them from expending excessive effort on a proposal that may not be accepted. Attributes such as Maturity, Complexity, and Allocation are used to categorize requirements and focus on to the most resource-intensive aspects of development, resulting in accurate projections for non-recurring engineering costs (NRE), test and lab resources, hiring needs, and development time. Negotiations with the customer can include specific requirements, helping define a realistic scope that all parties are comfortable with and will actually be achieved on-time and on-budget. Equally important, the supplier will be establishing the groundwork for the entire product development process to demonstrate Automotive SPICE (ASPICE) capability.

Presentation#71

Risky Business – Developing an Approach to Managing Technical Systemic Risks

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Keywords. Systemic Risk;Technical Risk;Enterprise Risk Management;Viable System Model;Cynefin;Opportunity Management

Topics. 1.2. Cybernetics; 3.9. Risk and Opportunity Management; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract.

Systemic Risk Management is a discipline familiar to the financial world, having been born out of the systemic failures which resulted in the 2008 financial crisis. Since November 2019, a small team has been working within the UK Ministry of Defence (MOD) to develop a pragmatic interpretation of Systemic Risk Management which can be applied to technical risks. The approach is complementary to both traditional programme/project risk management (which tends towards bottom-up escalation), and contemporary Enterprise Risk Management (ERM) which tends to look top-down for risks to objectives. Systemic Risk Management provides a means to identify and manage cross-cutting and transverse risks which could be impacting multiple areas of the organisation, and risks within one area of the business that could have a disproportionate effect elsewhere. Currently these could slip though unnoticed and potentially recur across the enterprise. The team took inspiration from a variety of sources, including ERM, Viable Systems Model and Cynefin, before settling on an indicator-based approach that could be readily understood by risk management practitioners without needing to bombard them with seemingly abstract theoretical constructs. The result has been the production of guidance material for identifying and managing Technical Systemic Risks which has been tested through significant stakeholder engagement, and is being piloted within the UK MOD. Whilst this approach has been developed for use within UK MOD to manage Technical Systemic Risks, it can extend to Systemic Risks in general, and has utility for any large organisation grappling with complex interdependencies between disparate technical and organisational activities.

The following conclusions have been drawn from the transformation initiative described in this presentation:

• Traditional risk management practice tends to overlook Systemic Risks, often due to lack of vision beyond project and programme focus or organisational and functional boundaries.

• Technical Systemic Risk management allows risks that may be common to, or impacting upon, several areas of the business to be identified, and managed. This will allow common and consistent risk mitigation to be applied in a “best for the business” way.

• Technical Systemic Risk management is complementary to existing P3M and ERM approaches, providing an almost orthogonal view on the same problem-spaces and solution-spaces.

• Technical Systemic Risk management is equally applicable to business-as-usual activities as it is to projects and programmes. LFE reviews are a rich source of potential Systemic Risks.

• The approach outlined above is an accessible and useful approach which risk practitioners should find easy to adopt and can be readily adapted for non-technical Systemic Risks.

• This approach should be readily applicable in any enterprise which is grappling with the issues outlined in this paper.

This presentation is based upon material previously presented at the INCOSE UK Annual Systems Engineering Conference 2021, but will be updated where appropriate to reflect the current situation.

Presentation#23

SMART Traceability

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Keywords. Traceability;MBSE;Natural Language Processing;Artificial Intelligence;Aerospace domain

Topics. 2. Aerospace; 2.3. Needs and Requirements Definition; 2.6. Verification/Validation; 5.11 Artificial Intelligence, Machine Learning; 5.12 Automation; 5.3. MBSE & Digital Engineering; 6. Defense;

Abstract.

The need for traceability

Traceability is a time-consuming activity, and yet mandatory in any aeronautic domain project, as requested by numerous international standards such as ISO/IEC/IEEE 29148 and 15288, or ARP4754A. Therefore, at Safran Aircraft Engines (SAE), we are studying how to optimize the task by applying semantic technologies to suggest automatically to engineers relevant links between requirements based on the use of ontologies.

In the present paper, we extend the use of basic semantic similarity algorithms [3], with help based on models to solve cases of “complex” traces when the requirements are not sharing the same meaning.

NLP to help this tedious task

The application of Natural Language Processing techniques (NLP), together with Artificial Intelligence, and also the possibility of retrieving relevant information from models (i.e. SysML models) makes that traceability tools could better “understand” the actual meaning of the requirements (among other types of textual artifacts), and this opens a wide range of automatization possibilities. Among these possibilities, and together with the idea of automatizing the process of requirements quality assessment (based on the INCOSE Guide for Writing Requirements or other similar guidelines), traceability management can be massively impacted through the automatic identification of missing traces or the consistency checking of the existing ones.

For the understanding of textual engineering items, ontologies play a vital role. Ontologies are multi-layer artifacts. The structure of a typical ontology, based on the evolution of controlled vocabularies, taxonomies, and thesaurus, starts with the definition of the controlled vocabulary, i.e. concepts relevant to a specific domain (layer 1). Furthermore, both humans and computers hate “isolated” items, which is why layer 2 focuses on connecting elements of layer 1 together. Elements from the controlled vocabulary can be connected either by means of semantic relationships (hierarchical/taxonomical, associations, compositions, synonyms, functional flows, state transitions, PBSs…), or by means of clustering or classifying them together into semantic classes (aka upper ontologies) such as System Elements, Actors, Signals, States, or even using those clusters to group together different verbs with similar meanings…

On top of this “typical” ontology, a system aimed at understanding requirements shall include the concept of grammar (aka template, pattern, or boilerplate [1][2]). This defines the structure for a well-formed requirement. Furthermore, these patterns also enable the means to transform natural text into a semantic graph formalization. This represents layers 3 and 4 of the ontology and is depicted in this figure (first a natural text requirement, then the pattern whose structure is matching with the text, and finally the formal representation obtained as the result of the semantic indexing process).

The use of patterns facilitates the identification of the meaningful blocks of the requirements. That is:

- The element performing the main action described by the requirement (i.e. the subject of the main sentence)

- The condition: based on an event in this pattern, but similarly based on a state or a complex condition

- The other entities involved in the requirement

The fifth and final layer of the ontology proposed in this paper represents the inference, a typical layer in every ontology. We could think of inference to check the consistency of a model, inference to automatically assess the quality of requirements, or inference to suggest missing traces or to detect inconsistent traces. These last two goals represent the core of the remaining of the presentation.

Previous works on the application of a semantic search engine to automatically generate missing traces have been already proposed by the authors of this presentation [3]. However, this presentation shows a deeper research case where other methods have been implemented and analyzed. All these new cases will be taking advantage, not only of the information stored in the ontology but also of information from MBSE such as PBSs, FBSs…

Implementation

Therefore, the following traceability methods have been studied and implemented into a traceability management tool (the ENGINEERING Studio [4], by The REUSE Company) to automatically suggest different types of traces:

- Flow-down: using “basic” semantic retrieval to find similar requirements into the specification of a SOI (level N) and the one of its subsystems (level N+1). For example, if a system shall comply with a given environmental regulation, this compliancy shall also be applied to every subsystem.

- Property allocation: considering information from a PBS, detection of requirements assigning values for the same physical property for 2 elements connected in the PBS (in 2 different documents).

- Functional allocation: linking requirements of level N invoking a given function with requirements of level N+1 invoking any of the sub-functions in an FBS.

- State-based derivation: to connect two state-driven requirements of levels N and N+1 whose state name in the condition is the same.

- Action-based derivation: suggesting traces for 2 requirements where:

1. the subjects are at two consecutive levels in the PBS,

2. the main verb (the one after the “shall”) is the same, and

3. the object of the action is also the same.

- Realization: suggesting traces between requirements and model elements where the text of the requirement mentions the name of any of the model elements.

Results

For the evaluation of the previous methods, we have created a simple MBSE (with IBM Rhapsody) including a PBS, and a FBS.

The results (traces suggested automatically) obtained with the ENGINEERING Studio that was used to implement the methods will be shown in the presentation.

Future work

All the previous methods aim at the identification of mission traces. But what about checking whether the ones provided by the engineer are consistent? Similar methods might also help here.

References

[1]. https://www.researchgate.net/publication/313599554_Using_statement-level_templates_to_improve_the_quality_of_r

[2]. https://alistairmavin.com/ears/

[3]. https://www.researchgate.net/publication/347423726_Automatic_Traceability_with_Semantic_Technologies_Used_in_

[4] https://www.reusecompany.com/traceability-management

Presentation#46

Space Policy Insights: A System Dynamics Model-based Assessment of the growing NewSpace Ecosystem

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Keywords. System Dynamics;NewSpace;Forecasting;Space Policy;Small Satellites

Topics. 1.4. Systems Dynamics; 1.6. Systems Thinking; 2. Aerospace; 22. Social/Sociotechnical and Economic Systems; 4.2. Life-Cycle Costing and/or Economic Evaluation; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract.

The past two decades have seen a paradigm shift in the space industry with the proliferation of distributed satellite systems, Consumer-Off-The-Shelf (COTS) components, and above all: small satellites, constellations composed of these architectures and a growing number of ventures focused on commercializing them, bringing in vast amounts of private capital. The increased interest of both public and private entities in small satellites and satellite constellations has created a positive feedback loop fueling further technology development and eventually an exponential growth of objects in space. The growth of the satellite industry is not simply a matter of private investment and technology innovation; indeed, public policy plays a role in the progress for both upstream and downstream participants in the New Space industry as it should, given the common pool resource-nature of space and particularly the low Earth orbits. However, to create strong and effective policies simultaneously regulating the space industry for public benefit but also enabling its further growth, it is paramount to understand the direction in which the industry is heading, ultimately rooted in the dynamic behavior of the satellite ecosystem. Building off previous research in systems of systems, technology road mapping and risk management, this paper proposes a system dynamics model augmented by time series forecasting methods to conceptualize the complex interactions amongst participants in the NewSpace economy in an attempt to assist the creation of informed public policy. Therefore, in addition to creating a system dynamics model of the industry and various constituents of it, it also posits a forecasting model for industry growth based on historical data from among other sources the International Telecommunications Union (ITU), applying a Machine Learning/time-series forecasting methods that—along with with the system dynamics model—could help forecast potential risks and failures in the industry and direct the focus of policy makers to the right domains.

Presentation#25

Systems Engineering Challenge of a Solar Powered High Altitude Aircraft

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Keywords. Solar Powered High Altitude Aircraft;Complex Aircraft Systems Design;Coping with Technical and Organzational Complexity

Topics. 1.1. Complexity; 2.4. System Architecture/Design Definition; 5.3. MBSE & Digital Engineering;

Abstract.

The German Aerospace Center (DLR) aims to develop an solar powered aircraft able to persistently fly in the stratosphere. The current design has a wingspan of 27 m and a weight of approximately 130 kg. The aircraft shall carry a payload with a maximum weight of 5 kg.

Within the project, the aircraft and two innovative payload systems are developed concurrently. This approach enables the overall design optimization, but increases technical complexity at same time. Besides the technical complexity, organizational complexity is a major issue as well. The development team is spread over 18 different organizational entities at 5 different locations in Germany.

The presentation will introduce the project and it’s challenging goals at the beginning. Example missions for the air system to be built will be explained and the derivation of the top level aircraft requirements discussed.

The second part of the presentation provides a brief overview of historical and current designs and highlights the rationale behind the decision to focus on a heavier than air vehicle for our project. A constraint diagram for solar powered high altitude aircraft will be derived and the most significant challenges for the design will be explained based on this diagram.

The third part of the presentation gives an overview about chosen the Systems Engineering approach. In this project we decided to set up a central model to manage the design. The modelling language is SysML. Tailored profiles have been developed to handle problems like mass management but also communication protocols. The organization of the model will be explained followed by a short overview about the developed profiles. It will also discussed how the model serves as a communication means between the different organizations and most significant lessons learnt will be explained.

The presentation concludes with the current status of the project and an outlook to the next steps until the flight tests, which are scheduled for 2024.

Presentation#44

The Need for Cyber-Physical Digital Twins for Resiliency Studies

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Keywords. cyber-physical modeling;virtual twins;digital twins;resiliency studies;virtualized I&T

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

Abstract.

This presentation will highlight the importance of combining cyber and physical models in a virtual environment to benefit resiliency studies. The presentation will also explore specific use cases for when physical behaviors impact the cyber domain, when cyber actors can impact the physical domain, and the value of the virtual environment to explore these scenarios. Lastly, the presentation will discuss some risks of virtualizing non-COTS hardware, and some approaches to mitigate these risks. Software Defined Infrastructures (SDIs) provide researchers the opportunity to create, control, and maintain virtual architectures that can mirror physical, operational environments. There are several on-going efforts that have started to incorporate physics-based models and simulations to allow for accurate representation of satellites or aircraft in the virtual environment as well. Such an environment can play a key role during the architectural and design phases of an acquisition due to the ability to conduct a variety of trade studies early in the life cycle, and this exploration is vital to properly balance specialization vs. generalization of subsystem functions. Trade studies can start to unravel which subsystems require resiliency, how much resiliency is value-added, and what the impact is to mission. As the hardware design starts to mature, the use of a cyber-physical virtual twin that can interact and collaborate with its physical counterpart provides even more value. This is the value proposition for cyber-physical digital twins, since this real-time connection with the physical system provides value during development, manufacturing, production, operation, maintenance, and even disposal. In modern military terms, resilience is defined as robustness that is achieved through thoughtful, informed design that makes systems both effective and reliable in a wide range of contexts. Pursuit of resilient systems, however, necessarily involves the design of complex systems that successfully balance subsystem implementations that span the spectrum of implementation: specialization thru generalization. The promise of resilient systems can be more readily achieved through the use of cyber physical digital twins because the virtual environment provides opportunities to tailor the fidelity of the analysis and focus on the risk areas of most importance. This presentation will demonstrate examples of tailoring the fidelity of space-ground communication links and interactive command-and-control with virtual spacecraft.

Biography

Steven Huang (ManTech International) - steven.huang@mantech.com
Mr. Steven Huang has two decades of experience in systems engineering, technology integration, field test planning and execution, and mathematical programming. He is currently responsible for leading digital twin development and advanced modeling & simulation efforts within ManTech's Intelligent Systems Engineering Technical Focus Area. Mr. Steven Huang has been recognized for his professional work with several letters of commendation and appreciation from Government customers across the Defense and Intelligence communities.

Douglas Orellana (ManTech) - douglas.orellana@mantech.com
Dr. Douglas Orellana has over a decade of experience in transformation, systems engineering, and technology integration, and is currently responsible for ManTech's digital transformation of systems engineering and developing the next generation solutions for intelligent systems engineering powered by advanced computing, modeling and simulation, automation, and artificial intelligence. Currently, Dr. Orellana serves as ManTech's Technical Focus Area Lead for Intelligence Systems Engineering. Dr. Orellana has been recognized for his academic excellence, professional work and community involvement. In 2021, he was named Top 40 Under 40 by AFCEA, for his innovation and thought leadership in digital transformation supporting Aerospace and Defense. In 2019, the Engineer's Council awarded him the Outstanding Engineering Achievement Award for his research contributions to the Systems Engineering Body of Knowledge. In 2012, INCOSE awarded him the JHU APL Alexander Kossiakoff SE Research Award.

Presentation#74

The Power of Connections in a Digital Asset Exchange

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Keywords. Digital Asset Exchange;Digital Model Wrapper;Model Characterization Profile;Sociotechnical Value;Marketplace

Topics. 22. Social/Sociotechnical and Economic Systems; 5.3. MBSE & Digital Engineering; 5.6. Product Line Engineering; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract.

Connectivity between models in Model Based Systems Engineering (MBSE) and Digital Engineering (DE) ecosystems is most often focused on tools and languages, with limited and ad hoc model exchange. This leads to model-based solutions that vary widely both internally and between organizations, have brittle technical architectures, and have high up-front costs due to lack of reuse. Technical architectures require frequent rework due to the pace of change in the tool industry and advancements in MBSE and DE. The approach also has a significant risk that if these connections are not updated for contextual changes, model or data corrections. While automated connections between models could be used to synchronize analytics, model changes, and updates, if not properly managed would more rapidly propagate errors and lead to systemic failures.

We believe engineers must be an integral part of the model lifecycle. How models are used, fitness for purpose, and a dynamic confidence level – improved by feedback from the digital twin – are essential. Existing automation in tooling, languages, models and workflows with data models hidden within platforms can lack context and not be easily reconfigured, changed or modified to improve fitness for use. In contrast, a reinforcing loop of a model ecosystem with openly available trust, reliability, and suitability for use will further develop and grow existing model assets. With careful thought to the social, technical, and economic value system of exchange, digital engineering will flourish with the power of connectivity.

As an illustration, a group of digital asset creators, model owners, SMEs and project team members can meet in an IPT meeting whiteboard, discuss, debate and often effectively and rapidly adapt to changes in inputs, models, or data to arrive at a decision. Confidence in model assessments, and context where the models are used is implicitly understood by their owners. The decision, however, often lacks a digital representation even through these individuals may have used models for their input. Digital engineering needs to couple the rigor of models with the speed of team communications. We need improved connectively between models, model users, model owners and contextualized model representations that are not slowed down by barriers (languages, tools, network and technology boundaries, etc.). Based on experience working with DoD, defense and aerospace companies, and commercial MBSE/DE ecosystems, we have identified several common boundaries limiting connectivity between models:

• Unintentional barriers (e.g. networks, technical domains, languages, tool environments, etc) disconnect digital assets, owners and users

• Centralized architectures, where ecosystems need to “own” rather than “use” models tend to obscure model usage

• Poor visibility of models - you cannot connect what you cannot discover or even know exists

• Digital Thread and Digital Twin are notional, but lack formal representations that can themselves be referenced and reused.

To meet these challenges, we propose the idea of a “digital model wrapper”, or model characterization profile, that can describe a model in terms of context, required parameters, and usage in the digital thread. The wrapper would respect the authoritative model source, and not require a centralization of model assets. Publicizing wrappers to an appropriate audience would create a digital asset exchange (DAX) that provides a structured and effective way to package digital assets, making them both locatable and immediately exploitable.

The model wrapper adds a unifying metadata layer to the digital engineering environment, which encapsulates lower-level complexity, increases performance, and addresses growing scalability issues, while remaining neutral to tools and hosting locations. It pulls from several industry standards and best practices such as the Dublin Core technology used by leading libraries worldwide to track and catalog hundreds of millions of diverse information artifacts, the Functional Mock-up Interface (FMI) standard, SysML, and many other standard and model types.

The combination of a digital wrapper and DAX will empower connectivity:

• Unifying metadata layer, common system representation and language

• Coupling the digital asset creator and content through a distributed network

• A digital asset exchange network provides a modern sociotechnical network to form dynamic problem-solving organizations

• Formally defined models that describe connected digital assets included in Digital Threads and Digital Twins

DAX and digital model wrappers addresses many of the Digital Engineering challenges identified in the OSD DE Strategy, and is applicable to the DoD and industry partners, and directly aligns with the USAF goal for “Implementation of a Digital Enterprise Environment framework which integrates models, data and artifacts”. These approaches are also applicable to commercial clients operating in a decentralized and distributed engineering environment. Many of the elements of DAX have been discussed and tested with academic and commercial clients.

Presentation#27

The Unified Risk Assessment and Measurement System (URAMS)

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Keywords. Cybersecurity;Resilience;Risk Management

Topics. 2. Aerospace; 3. Automotive; 4.4. Resilience; 4.7. System Security (cyber-attack, anti-tamper, etc.); 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 6. Defense;

Abstract.

In the transportation, automotive, aerospace, and defense domain, non-traditional IT cyber-physical systems such as aircraft and vehicles are increasingly under threat from a wide range of threat actors. One of the most pressing problems with cyber-physical systems' security is the lack of an agreed upon methodology for measuring and presenting mission or business risk for a given system within its expected operating environment. This problem is especially difficult since there is so little historical data to draw from, and the lack of an agreed upon method to assess or measure risk greatly hampers our ability to know where to position our limited resources. Solving this problem might even be considered a "Gordian knot" that if cut, would clear the way to solutions for a host of other related problems such as selecting between alternative designs and keeping cost under control.

The main reason why a risk measurement system has yet to gain widespread acceptance among the continuing debates over qualitative versus quantitative approaches, is that there is no single approach or tool that is a best fit in all circumstances and environments. Therefore, what is needed is a family of connected tools across the spectrum of qualitative analysis and quantitative measurement that use similar formats and outputs enabling some comparison across the tools.

This Unified Risk Assessment and Measurement System or URAMS provides a diverse set of integrated qualitative and quantitative tools that provides true risk management for weapon systems and aviation platforms throughout the development lifecycle and across a range of contested cyberspace environments. URAMS starts with an engineering analysis, and our most commonly used tool is Systems-Theoretic Process Analysis for Security (STPA-Sec). This tool was developed from leveraging the safety analysis work done at MIT and has since been used with great effectiveness across a range of military weapon systems and civilian aerospace systems. STPA-Sec is grounded in systems engineering and is focused on mission level losses as the true drivers of relevant security design. STPA-Sec also enables analysis of a system's security posture early in the lifecycle, which enables true "baking in" of security.

From the analysis, a set of risk scenarios are developed that are specific to the system under consideration and its expected operating environment. Then, those risk scenarios are scored using any of a wide range of available scoring tools. URAMS scoring tools are characterized first by the model of risk and what factors are assumed to contribute to overall risk, and second by the type of input. Inputs can be provided as single point values, single point values with a confidence, three-point estimates, or 90% confidence intervals depending on the training and experience of the assessors as well as how important uncertainty is to the decision makers. While human subject matter experts (SMEs) are utilized as the basis for scoring in URAMS, automated and algorithmic based approaches can and should be used to inform those SMEs.

The risk scenarios can then be combined utilizing a simple Monte Carlo simulation to determine what the overall risk is for a system or portfolio of systems. With this ability to combine risk a structured assurance case can be built that includes the analyzed mission structure connected to the specific risk scenarios and their scores, with the risk scoring flowed up through the mission elements to the overall system. Perhaps most importantly, specific evidence such as testing results, design features, etc., can also be added to the assurance case to show how the risk scores were determined in a format that allows decision maker to rapidly assess if the scoring is reasonable based on their understanding of the mission and the evidence provided. Thus, the URAMS framework provides a way to cut the Gordian knot of weapon systems and platform risk measurement enabling more secure and better defended systems and missions.

Presentation#75

The Value of Loss-Driven Systems Engineering (LDSE)

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Keywords. Resilient Systems;Loss-Driven Systems Engineering;Adversity;Loss-Driven Quality areas

Topics. 2.4. System Architecture/Design Definition; 20. Industry 4.0 & Society 5.0; 3.9. Risk and Opportunity Management; 4.4. Resilience; 5. City Planning (smart cities, urban planning, etc.); 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract.

Loss-Driven Systems Engineering (LDSE) is the value adding unification of the systems engineering specialty areas that address the potential losses associated with systems. Examples of those specialty areas include resilience, safety, security, operational risk, environmental protection quality, availability. These specialty areas often work separately from one another. We believe there is commonality and synergy among these specialty areas that should be exploited, including vocabulary, taxonomy, modeling and analysis, adversities considered, losses considered, requirements, and architectural & design techniques. We believe SE can harness this commonality to better manage possible system related loss. We call this unification LDSE.

The potential benefits of the unification Loss-Driven approaches include:

• Reduced engineering effort by eliminating redundant activities among the specialty areas

• A more comprehensive consideration of loss

• Eliminating conflicts among the loss-driven solutions

• Effective solutions that address the interests of multiple loss-driven specialty areas

• A holistic loss-based viewpoint addressing the multiple perspectives

• Reducing the load of data generated by multiple specialty areas

• Mutual learning among the loss-driven specialty areas

Presentation#45

Think Globally, Act Locally: Adapting MBSE for the Enterprise Context

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Keywords. MBSE;Model Based Systems Engineering;ESE;Enterprise Systems Engineering

Topics. 5.3. MBSE & Digital Engineering; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract.

Model Based Systems Engineering (MBSE) is becoming increasingly recognized as a critical enabler for significantly improving the effectiveness and efficiency of systems engineering. While MBSE is seeing significant growth in its application to complex system development programs, this application has largely been constrained to the context of individual programs. In other words, MBSE is being used primarily to improve outcomes of individual programs within an enterprise. While this can be of sufficient value to make the investment worthwhile, significantly greater value could be obtained by an enterprise by integrating the individual MBSE efforts and capabilities being developed for its programs into a more coherent enterprise-level MBSE effort. The collection and aggregation of local pockets of knowledge into an integrated global body of knowledge can enable the enterprise to better act as a unified enterprise with speed and agility through use of MBSE-enabled Enterprise Systems Engineering (ESE) processes and methods. This paper will describe some of the principles and methods that should be employed to improve the ability of local MBSE efforts to contribute to the execution of ESE.

Presentation#10

Use of Systems Engineering in Repurposing Coal-Fired Power Plants with Malta Pumped Thermal Energy Storage System

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Keywords. Long Duration Energy Storage;Repurpose Coal-fired Power Plant;Malta Pumped Heat/Thermal Energy Storage;Electricity Grid Reliability

Topics. 15. Oil and Gas; 17. Sustainment (legacy systems, re-engineering, etc.); 2.1. Business or Mission Analysis; 2.3. Needs and Requirements Definition; 2.4. System Architecture/Design Definition; 2.5. System Integration; 22. Social/Sociotechnical and Economic Systems; 8. Energy (renewable, nuclear, etc.);

Abstract.

The electric sector across North America is facing a transition. As economics and policy decisions point towards a broad retirement of fossil assets across markets, owners are facing planning and execution needs

to evolve the asset base of the electric sector. Coal-fired power plants built the modern electricity grid. Their rotating machinery are the beating heart of the grid, providing essential resiliency and reliability services. Power plant retirements are disruptive to plant workforces and cause outsized impacts on surrounding communities. The transition from thermal power plants that use rotating machinery to generate electricity (e.g., coal- and gas-fired plants) to variable, inverter-based generation (e.g., solar and wind) is affecting the reliability of the electric grid. Grid operators and national regulators have issued warnings about known and anticipated risk.

In 2021, Malta Inc. was awarded a Department of Energy (DOE) grant to study how to integrate a Malta 100MW Pumped Heat Energy Storage (PHES) system with a retiring coal-fired power plant to meet emissions requirements, retain plant workforces, preserve communities, and maintain grid reliability. This presentation provides a summary of this study, focusing on how systems engineering approach was used to arrive at a proposed design concept that met multiple objectives and requirements. There will be three main parts for this presentation.

The first part of the presentation will focus on how different systems engineering was applied for this work. In particular, the following areas: stakeholder engagement, site selection process, developing requirements and use cases for the integrated system, defining the system and its boundary, coming up with different system architecture/option, performing a techno-economic analysis to compare the different options and down selection of the preferred option, will be discusses. For these areas, discussion on the decisions on how much breadth and depth to go into each area will be provided. These discussions provide good insights into how to apply systems engineering. The second part of the presentation will provide a deeper dive into the two recommended integration options that repurpose coal-fired power plants with Malta PHES system. The comparison of the two options and general guidance of how to choose an option will be provided. This is particularly useful for utilities who are facing coal-plant retirements. The two options will be compared based on its performance (such as power output, efficiency), complexity, and cost. The final part of the presentation will discuss the impact that this work has had, including Malta Inc. being invited to the White House to discuss progress and outcomes of this work with the Interagency Working Group on Coal and Power Plant Communities and Economic Revitalization.

In summary, this presentation aims to provide a showcase of how systems engineering can be used effectively to create meaningful impact at working group, company, and industry level.

Presentation#39

Using Model Based Systems Engineering Technical Reviews for Complex System of Systems

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Keywords. Model Based;Technical Reviews;Digital;System of Systems;Complex;Design Reviews

Topics. 2. Aerospace; 2.4. System Architecture/Design Definition; 3.7. Project Planning, Project Assessment, and/or Project Control; 4. Biomed/Healthcare/Social Services; 5.3. MBSE & Digital Engineering; 6. Defense;

Abstract.

Systems engineering (SE) provides methods and tools to model and design complex systems of systems (SoS). By identifying and monitoring the critical dependencies and interactions among system components throughout the design lifecycle, SE provides the means to communicate critical information about those systems across a large and diverse set of stakeholders spanning multiple functional and non-functional domains.

As systems become more complex and interconnected, government and industry have turned to digital methods (e.g., Model-Based Systems Engineering) to capture a digital baseline of system architecture, requirements, and more; however, this focus on baseline definition has created a digital communication gap. External stakeholders, who are often beholden to regulatory requirements with extensive certification and authorization requirements, often don’t have access to digital system models and require documents to review. This culture gap creates a need to recreate content from the model and in documents, often with the greatest impact being on SE Technical Review (SETR) events, where this technical content is the focus.

By using the system model as the objective evidence and source of truth for the technical review, stakeholders have access to the latest design of the model in its entirety, and can explore and deep dive into content that would be difficult access in a traditional documentation based review. This also helps during the review when stakeholder inquire about information that may not have originally been used to answer review criteria but still exists in the model, and it is easy to find. Model traceability and simulations allows stakeholders to understand how elements interact with each other, satisfy requirements, and meet key performance metrics. Using model metrics can show gaps in coverage and progress toward completeness over time of the system of systems.

In this presentation, Deloitte will spotlight our approach to performing model-based SETR events (Preliminary Design Review (PDR) and Critical Design Review (CDR)). Model-based SETR events enable a program to balance the development of technical content in the model with the communication and socialization of that content in formats that are familiar to stakeholders who would review the technical baseline. Deloitte’s approach emphasizes identification of (and traceability among) requirements, physical and functional architecture, test cases, risks, and the project schedule in our integrated SoS model, using SysML and the Unified Architecture Framework (UAF). Using this approach, Deloitte progressed from concept to PDR for defense clients in under 6 months; and then to CDR in under 12 months. This presentation will focus on our approach to developing the technical review content, packaging the content for review, and then conduct of the technical review events.

Presentation#20

Using Systems Engineering to Design and Evaluate a Transparent and Accessible Vaccine Appointment and Delivery System

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Keywords. MBSE;Modeling and Simulation;Healthcare/Social Systems/Services

Topics. 2.1. Business or Mission Analysis; 4. Biomed/Healthcare/Social Services; 5.4. Modeling/Simulation/Analysis;

Abstract.

The year 2020 brought trauma, anxiety, and an uncertain future. The coronavirus pandemic coupled with social and political upheavals made life miserable for those of us sitting on the sidelines. We watched the casualty numbers: how many cases, how many hospitalized, how many died based on demographics. Helpless, we waited for fact-based information to determine how we should live our lives. Could we safely go to the grocery store, go to our doctors, visit with our family and friends, or just borrow a book from the library? Did we have to wipe down our groceries, our counters, wear masks everywhere? More questions waited for answers.

As we endured social distancing, mask wearing, staying away from people as we exercised outdoors, we eagerly followed the progress of vaccines. When the FDA approved their emergency use here in the US and similar agencies approved them in other countries, we foresaw the end of the pandemic and the return to something close to a normal existence.

The vaccines represented medical miracles but the system to deliver them to people’s arms did not. We perceived the process and infrastructure to put the vaccine into arms appeared not designed through good systems engineering practice and seemed politically driven and not fact and logic driven.

We saw from media reports and our own experience that vaccine delivery to people’s arms, at least in the US, did not meet expectations. While the rate of production and distribution continued to increase, those eligible to receive the vaccine remained confused or uninformed about how they obtain an appointment to ensure they can get vaccinated on a specific date at specific time.

This project defines a system that permits any resident of a state (of the United States), no matter his/her place of residence or access to technology, to obtain a vaccine appointment for the initial vaccine dose, the second dose (if needed), and a booster dose and maintains the vaccine record for the resident. We present this definition in the form of operational needs, SysML artifacts (Use Cases with Use Case Narratives, Context Diagram, Requirements Diagram, and Activity Diagrams), Measures of Effectiveness (MOEs). Further we present an initial simulation to evaluate how the system might perform under a given scenario and assumptions. The definition doesn’t include a specific implementation but provides a reference model for any government entity wanting to improve its current system for delivering any vaccine, not just the COVID-19 vaccine, into arms.

The authors conduct this project under the auspices of the INCOSE Critical Infrastructure Protection and Recovery Working Group.

Invited Content

Invited Content#SEFun#0

Back to Basics: Thinking Like a Systems Engineering Practitioner

Dave Walden (Sysnovation) - dave@sysnovation.com

Keywords. #SEFundamentals

Abstract.

So, you are new systems engineering practitioner? Congratulations! Perhaps you were previously a lead software or hardware engineer in your organization. Perhaps you are starting your career with a graduate degree in systems engineering. Perhaps you don’t even have an engineering background. Now what? The objective of this half-day tutorial is to provide top-level guidance to new systems engineering practitioners on how to shift their mindset into one that will enable them success in their new position. We will focus our discussions on the following concepts: • You need to look up, out, and down • The lines are just as important as the boxes • Think about the end before the beginning • Form follows function follows purpose • Balance requires trade-offs • Systems engineering is a team sport • The journey is just as important as the destination • It is not enough to be right; people have to accept that you are right • It always depends • So what? Due to the duration of this tutorial, each of these topics will be covered at a high level. However, each student will receive an annotated bibliography to pursue topics of interest in more detail. The tutorial follows the terminology and conventions of the INCOSE Systems Engineering Handbook (SEH), ISO/IEC/IEEE 15288, the INCOSE Systems Engineering Competency Framework (ISECF) and the Guide to the Systems Engineering Body of Knowledge (SEBoK). As part of this tutorial, each participant will be encouraged to develop an initial Personal Action Plan to guide their future development plans.

MBSE Lightning Round: MBSE Implementation progress reports from the field

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Abstract.

Dramatically increasing product complexity has taken us past the debate of whether MBSE is needed to a discussion on how to best implement it in organizations. Given the breadth of experience, the MBSE Initiative has started concentrating information into 18-minute TED-like Lightning Round talks on MBSE implementation in a variety of industries and applications with the goal to transfer insights in a rapid way so you can apply the lessons, approaches, etc. in your own organizations. We hope you can join us for our next MBSE Lightning Round at the International Symposium. Agenda: · 15:30-15:45 MBSE Initiative Update/Lightning Round Introduction - Mark Sampson · 15:45-16:05 Topic: MBSE in problem definition: “MBSE in the Problem Domain--even more valuable than Model-Based Design?” - Robert Halligan · 16:05-16:25 Topic: MBSE in Medical Devices: “Transforming development from documents to model-centric design” - Elise Higgins · 16:25-16:45 Topic: MBSE in Space Exploration: “Model-Based Qualification for Europa Clipper Remote Engineering Unit Testbed” - Emilee Bovre · 16:45-17:00 Panel Q&A session

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Invited Content#TOIC#1

Transforming Mobility: Automotive Executive Roundtable

Carla Bailo (Center for Automotive Research, CAR)
Anne O’Neil (Systems Catalyst & Strategist for Mobility and Infrastructure, AOC Systems Consortium) - systems.oneil@gmail.com
Soheil Samii (Motional)
Denise Gray (LG Energy Solution Michigan Inc.)
Richard Nesbitt (Bosch Chassis Systems) - richard.nesbitt2@us.bosch.com

Abstract.

Mobility sectors are currently undergoing a tremendous evolution – from electrification to advancing connected and autonomous vehicles. There have been new market entrants, supply chain challenges alongside trends for software defined vehicles, digitization and enhancing sustainability and cybersecurity.

Facing substantive levels of integration and complexity while innovating on multiple fronts – it's timely to consider how and where tailored Systems practices and approaches can both shape and respond to these challenges and changes.

While hosted in the Motor City, we’ll convene automotive executives to exchange perspectives on these industry dynamics, emerging Systems challenges and where Systems Engineering can play a greater role.

Biography

Carla Bailo (Center for Automotive Research, CAR)
Carla Bailo is the President and CEO of the Center for Automotive Research (CAR), and is a leader in engineering and vehicle program management with 42 years of experience in the automotive industry. Under her leadership, CAR continues to be a preeminent resource of objective and unbiased research, analysis, and information regarding the North American automotive industry. In addition to her role at CAR, Ms. Bailo is currently an Independent Director on the corporate boards for SMEnergy (SM) and Advance Auto Parts (AAP). Prior to joining CAR, she was most recently the assistant vice president for mobility research and business development at The Ohio State University. She also has 25 years of experience at Nissan North America, Inc., where she served as senior vice president of research and development. Ms. Bailo also spent 10 years at General Motors. She has a MS degree in mechanical engineering from the University of Michigan and a BSdegree in mechanical engineering from Kettering University.

Anne O’Neil (Systems Catalyst & Strategist for Mobility and Infrastructure, AOC Systems Consortium) - systems.oneil@gmail.com
A Systems Engineering catalyst and founder of AOC Systems Consortium, Anne advises mobility executives seeking to adopt Systems practices and apply Systems Engineering (SE) capability to achieve and improve their business outcomes. She counsels the increasingly diverse range of mobility sectors facing complexity and integration challenges as a result of leveraging technology and digitalization to add operational and service capability. She has a proven track record of supporting businesses across a spectrum of maturity levels – from assessing where applying a Systems expertise offers the strongest business benefit, to establishing or enhancing internal Systems capability.
From 2005-2013 as the founding Chief Systems Engineer for New York City Transit (NYCT), Anne established and integrated SE capability to improve capital project delivery. Former chair for APTA's Systems Engineering Subcommittee, she actively served as executive outreach liaison.
Anne has accumulated over 29 years of experience guiding large-scale organizations and program teams to successfully deploy technology-based solutions that address operational performance expectations and overall business priorities. She serves as a Systems catalyst within transportation/mobility sectors, and actively mentors industry WGs.

Soheil Samii (Motional)
Soheil Samii is Lead Systems Architect, Vehicle and Product Systems, at Motional. Prior to joining Motional, he was with General Motors (GM) for 8 years as a technical lead defining system and network architectures for GM's Super Cruise, Ultra Cruise, and next-generation E/E architecture. Soheil holds 25 granted patents and has co-authored more than 40 conference and journal publications. He has served as a voting member of the IEEE 802.1 standardization group for Ethernet in real-time and dependable systems, and he has chaired and co-chaired the program committee of the IEEE-SA "Ethernet & IP @ Automotive Technology Days." Soheil holds a PhD degree in Computer Science from Linköping University, Sweden, where he is an adjunct associate professor in embedded and cyber-physical systems.

Denise Gray (LG Energy Solution Michigan Inc.)
Denise Gray is Head of External Affairs and Government Relations LG Energy Solution Michigan Inc. (LGES MI), a U.S subsidiary of LG Energy Solution, Ltd. a South Korean corporation. Former positions included President and Board of Director Member, LG Energy Solution Michigan Inc. In that position, her team provided battery solutions for automotive and non-automotive applications.
Denise holds several board of director positions: Tenneco Automotive; Canadian National Railway; The National Academies of Sciences, Engineering, and Medicine, Member of the Board on Energy and Environmental Systems, and Original Equipment Supplier Association. Other memberships include: The National Academy of Engineering and Secretary of Energy (Granholm) Advisory Board.
Prior to her LG positions, Denise held automotive leadership positions with AVL List in Graz, Austria and Atieva in Redwood City, California. The vast majority of her professional career (30 years) was with General Motors, where she spearheaded efforts in vehicle electrical and propulsion systems controls and software, including battery systems. Denise holds a BSEE degree from Kettering University and a MSES from Rensselaer Polytechnic Institute.

Richard Nesbitt (Bosch Chassis Systems) - richard.nesbitt2@us.bosch.com
Richard Nesbitt is the Head of Marketing Business Development and Product Management at Bosch Chassis Systems in North America. Prior to his current role, he lead the Systems Engineering department. He also spent time in Germany leading new brake systems product development for autonomous vehicles.
Prior to his 17 years at Bosch, he worked at General Motors as a Performance Integration Engineer for Chassis Controls.
He has a Masters in Mechanical Engineering from Michigan Technological University, where his interest in automotive Chassis System grew.

Key Reserve Paper

Key Reserve Paper#80

A generic hierarchical Systems of Systems Engineering (SOS) Approach for Model based System Engineering (MBSE) Projects

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Keywords. Systems of Systems (SOS);MBSE;SysML;ASPICE;AUTOSAR;Functional decomposition;Logical architecture;Physical architecture

Topics. 1.1. Complexity; 1.4. Systems Dynamics; 1.5. Systems Science; 1.6. Systems Thinking; 14. Autonomous Systems; 2. Aerospace; 2.1. Business or Mission Analysis; 2.3. Needs and Requirements Definition; 2.4. System Architecture/Design Definition; 2.5. System Integration; 3. Automotive; 5.12 Automation; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 5.5. Processes; 5.7. Software-Intensive Systems; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.);

Abstract.

Model based systems engineering (MBSE) has been accepted worldwide by many industries, including the automotive industry, for several years. Hundreds of projects have already been developed and deployed using MBSE approaches. MBSE is gaining importance because it provides systems advantageous life cycle processes, such as returns of investments and meeting the demands of global marketplaces, as they become increasingly complex. Consequently, the number and pace of deployment using MBSE approaches will increase in the future.

Our current work objective is to define a generic MBSE methodology using the ‘systems modelling language’ (SysML) compatible with functional decomposition principles, ‘Automotive open systems architecture’ (AUTOSAR) developments and compliant to ‘Automotive software performance improvement and capability determination’ (ASPICE) processes. We have proposed a generic SysML process framework, a hierarchical systems of systems (SOS) engineering approach and automation solutions. We have shown that the proposed solution helps meet the defined objectives. The work is targeted and relevant for automotive industry MBSE practitioners. In general, the research, apart from transportation and mobility industries, can also be used in other industries.

Key Reserve Paper#148

Collaborative Systems-Thinking Culture: A Path to Success for Complex Projects

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Keywords. Systems Thinking;Collaboration;Project Execution;Workplace Culture;Organizational Change

Topics. 1.1. Complexity; 1.6. Systems Thinking; 20. Industry 4.0 & Society 5.0; 22. Social/Sociotechnical and Economic Systems; 3.5. Technical Leadership; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. The world is filled with hard and complex problems, oftentimes requiring involved solutions. In large organizations attempting to solve these types of problems, a mindset shift and key candidate methodologies centered on collaborative systems thinking culture (CSTC) can assist significantly. The paper explores the state of the practice, change involved with implementing systems thinking, impacts of a collaborative approach within an organization, as well as the seven phases that a reader can introduce into their organization to realize some of the benefits. The same approach was used to create this paper under collective authorship from Cohort 6 of the INCOSE Technical Leadership Institute (TLI); an international group of individuals collaborating exclusively through virtual platforms. From writing papers to executing large technical programs, the CSTC approach will prepare technical teams for tackling challenging problems in an inclusive way with the intent to finish projects on time while also cultivating healthy systems engineering habits and practices. This lessens the reliance on corporate engineering procedures to drive collaborative behavior by fiat. Finally, blending CSTC into the fabric and culture of an organization is emphasized as being needed for the full benefit. The programs we save, by moving to a CSTC, may be our own.

Key Reserve Paper#79

Engineering Complicated Systems Still Needs Systems Engineering and Thinking

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Keywords. Complicated;Complex;Emergence;Coupling;Modularity;Capability

Topics. 1.1. Complexity; 1.6. Systems Thinking; 2. Aerospace; 2.4. System Architecture/Design Definition; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. In recent years there has been a totally valid move in Systems Engineering circles to consider and focus on capability / complex systems (of systems). This is important as the world is getting more inter-connected and the consequences of undesired emergence more significant. Unfortunately this has led to a “marginalization” of (simply) complicated systems, which were the bedrock of Systems Engineering practice. Whilst practice obviously needs to adjust when the system of interest is complex, the fundamental principles still apply and the Systems Engineering profession must not simply abandon consideration of complicated systems. This paper is intended to act as a reminder of how important the application of Systems Engineering is to complicated systems.

Key Reserve Paper#74

Exploiting Synergies Between Decision Analysis and Complex Systems Engineering

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Keywords. Decision Analysis;Systems Engineering;Engineering Economy;Complex Systems

Topics. 1. Academia (curricula, course life cycle, etc.); 2.6. Verification/Validation; 22. Social/Sociotechnical and Economic Systems; 3.3. Decision Analysis and/or Decision Management; 4.1. Human-Systems Integration; 5.11 Artificial Intelligence, Machine Learning; 5.3. MBSE; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract.

This paper investigates the synergies between decision analysis and systems engineering along multiple dimensions including: Humans and groups, Uncertainty quantification, Preferences, Reasoning, and aggregation. We discuss the implications of these findings in developing practical approaches to systems engineering and their implementation including potential changes to the existing systems engineering curricula. In particular, we discuss the role of humans, role of method, role of data and machine learning, updating information, and valuing information in uncertainty quantification. We also discuss the risk-taking propensity (individual vs corporate or group), and the role of cognitive and motivational biases in group decision making.

Finally, we discuss the role of reasoning when methods such as Internal Rate of Return are insufficient.

Key Reserve Paper#102

Heuristic-Based Architecting for Autonomous Vehicle Systems

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Keywords. systems architecting;heuristic architecting;autonomous vehicles

Topics. 12. Infrastructure (construction, maintenance, etc.); 14. Autonomous Systems; 2.4. System Architecture/Design Definition; 3. Automotive; 3.7. Project Planning, Project Assessment, and/or Project Control;

Abstract. Humans have always had a need to improve travel, whether that be for ourselves or for the goods we need. Technological advancements have all fundamentally performed the task of moving people and goods with the objective to continuously improve convenience and be more efficient. There is another pending revolution in human mobility, one that is leading towards autonomous transportation where the human driver is replaced, and the driving of the vehicle is performed autonomously by machine. With continued research and technology, automotive Original Equipment Manufacturers (OEMs) have started to implement autonomous enabled features to transform today's vehicles traveling our roads to driverless vehicles. This paper evaluates the fundamental problem of architecting a system responsible of transporting occupants and cargo from point A to point B via autonomous vehicles (AVs) and compares it to current architecture being proposed by OEMs. To facilitate the mission, the authors studied the user needs of an AV, performed functional analysis and how they relate to each other. Utilizing guiding heuristics and lessons learned, the current architecture is examined and critiqued. The results show that the current methodology used by OEMs is to simply create smarter vehicles within a non-intelligent infrastructure. The heuristics, or in other words the process to learn and improve using experiences, give insights and guidance on how to address the main high-level functions to enable an elegant and robust architecture for autonomous transportation.

Key Reserve Paper#146

Inconsistent and Incomplete Datasheets: The case for systematic use of requirement engineering

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Keywords. MBSE;Datasheet;System-driven Engineering

Topics. 3.1. Acquisition and/or Supply; 5.5. Processes; 6. Defense;

Abstract. The lifecycle of a system is extended from its early conception to its retirement of service. The lifespan of Unmanned Ground Vehicles (UGVs) can be expected to last over 50 years in the de-fense market. In this context, the rising complexity of UGV systems imposes engineering steps that would ensure both capabilities of the system and resilience to its future inclusion in a sys-tem-of-system context. During its operational usage, the UGV is supposed to be maneuvered for specifically designed purposes following user manual datasheet of the components off-the-shelf (COTS) that were integrated. This paper exposes the public user datasheet relevance compared to the system engineering requirements that are the artifacts of system design architecture. The use of connecting COTS user manual to system requirements is discussed, all the more if the systems are to be re-used in a system production line.

Key Reserve Paper#90

MBSE approach for complex industrial organisation program

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Keywords. MBSE;Data Model;Interoperability

Topics. 2. Aerospace; 2.4. System Architecture/Design Definition; 3.1. Acquisition and/or Supply; 5.3. MBSE; 6. Defense;

Abstract.

As Model Based System Engineering methodology becomes THE standard approach for system engineering, it is applied for large programs development based on complex industrial organizations.

The purpose of this paper is to present the various rules and mechanisms supporting this model interoperability across industries and agencies in terms of:

• Modelling structuration (or multi-layer)

• Data object in a tools agnostic’s representation (data model)

• Data Format and recommended standard interfaces

• Centralized configuration control mechanisms

This solution is implemented at Airbus level within the MBSE framework initiative to provide a company-wide flexible and configurable solution supporting the entire Airbus program portfolio (e.g. satellite, helicopter, commercial/military aircraft, drone or ground segment). It is under deployment on several programs, in particular for Future Combat Air System (FCAS), which is a key instrument in ensuring future European autonomy and sovereignty in defence & security.

Key Reserve Paper#73

Modeling and Analysis Method and practice of helicopter system quantitative requirement

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Keywords. MBSE;requirement analysis;functional and logic model;quantitative performance index;simu-lation validation

Topics. 2.3. Needs and Requirements Definition; 2.5. System Integration; 2.6. Verification/Validation;

Abstract.

In view of the problems that unclear source, loose connection with other system requirements and over-reliance on professionals' subjective decision-making during the quantitative requirements analyzing with MBSE traditional methodology, this article aims to study the method about defining performance indexes based on functional requirement and adding general design element into MBSE model. The process and source of requirement analysis of each level indexes are also defined in this study. By means of scaling up the CPU time and integrating the representative disciplines models into MBSE functional logic model, the requirements of quantitative indexes can be verified by the integrated simulation. The feasibility of the improved methodology and modeling method is validated through the modeling and simulation practices on MagicDraw software.

Key Reserve Paper#103

Prioritization of Best Practices in the Implementation of Model-Based Systems Engineering

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Keywords. MBSE;Model based systems engineering;Best practices;Implementation;Adoption

Topics. 20. Industry 4.0 & Society 5.0; 22. Social/Sociotechnical and Economic Systems; 5.3. MBSE; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Model-based systems engineering (MBSE) is a modern approach to perform systems engineering activities on complex systems. Although MBSE poses many benefits, including improved con-sistency, complexity management, and requirements traceability, few companies have successfully implemented MBSE, likely in part due to a lack of consistent recommendations regarding its adoption. This paper uses a combination of a literature review and eight semi-structured interviews to evaluate the hypothesis that the applicability of best practices varies on a case-by-case basis due to dependence on factors such as company size, industry, and location. A list of best practices is compiled from analyzing existing works, and a set of corresponding interview questions is devel-oped to assess applicability. Data collected from the interviews is then used to illustrate how unique circumstances in each organization results in the need to have different prioritizations of best practices. Ultimately, the findings presented in this paper contribute to providing a clearer under-standing of the challenges and best practices associated with MBSE implementation.

Key Reserve Paper#106

Systems Engineering and Industrial Engineering

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Keywords. Systems Engineering;Industrial Engineering;Bodies of Knowledge

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

Abstract. Systems engineering overlaps with many fields, such as industrial engineering, engineering management, operations research, project management, and design engineering. In fact, the main industrial engineering body of knowledge, the Industrial and Systems Engineering Body of Knowledge, includes systems in the title and includes a section on systems design and engineering, which references the Systems Engineering Body of Knowledge. This paper describes the similarities and differences between systems engineering and industrial engineering based upon the respective standards, handbooks, and bodies of knowledge. Based on this assessment, we describe potential roles systems engineers and industrial engineers perform during a system’s life cycle. We conclude with a summary of our paper.

Key Reserve Paper#29

Systems Engineering Integration and Test Challenges due to Security Measures in a Cloud-Based System

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Keywords. Cloud Security;Integration and Test;Cyber-Physical Systems

Topics. 1. Academia (curricula, course life cycle, etc.); 2. Aerospace; 2.5. System Integration; 2.6. Verification/Validation; 4.7. System Security (cyber-attack, anti-tamper, etc.); 6. Defense;

Abstract. Cloud-based security threats and mitigations are well documented in technical publications, and address multiple client side, network and cloud side (service/application and data) vulnerabilities. Defined mitigations include the use of access control, encryption, key management, digital signatures and intrusion detection/prevention systems to yield a secure cloud-based system. Implementing these security measures adds significant system functionality to the already complex cloud-based system that must be assessed by the system architect. The additional requirements and development must be managed by the systems engineering team, and the increased integration and test must be addressed by the systems engineering integration and test lead. This paper will highlight the scope growth realized when a system interfaces into the cloud. The added scope will be shown to include; the development, integration and test of security related hardware and software configuration items, development of significant integrated test equipment/test vectors to verify the security functionality over a wide range of conditions, multiple cooperative systems/software led activities to analyze and test software throughout its development, and the system accreditation efforts to get authorization to tie into the cloud. With this information, the systems engineering leads will have a better understanding of the challenges involved with integrating and testing a cloud-based system, and can then properly plan and budget for this activity.

Key Reserve Paper#31

Systems Engineering your MBSE implementation: Where are you on your MBSE Journey

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Keywords. MBSE;Model Based Systems Engineering;Organization Change Management

Topics. 1. Academia (curricula, course life cycle, etc.); 2.4. System Architecture/Design Definition; 2.5. System Integration; 5.3. MBSE; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Those attending the annual INCOSE MBSE Workshops may have noticed a move away from tool-type discussions to organization culture change discussions. INCOSE MBSE Initiative be-lieves that tools and technology are no longer the problem, organization adoption and culture issues are standing between you and MBSE benefit realization. MBSE-enabling organization change will require a systems approach to bring about significant culture changes to take ad-vantage of these MBSE tool solutions. A critical first step is knowing where your organization is in this journey. As one of the fundamental systems engineering (SE) tenets states, “define the problem before you solve it”.

Key Reserve Paper#37

The Evaluation of the Effectiveness of a Digital Engineering Tool in a Project Engineering Company

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Keywords. Digital engineering tools;Systems and Software Engineering;Evaluation criteria;Effective engineering process

Topics. 15. Oil and Gas; 5.5. Processes; 5.7. Software-Intensive Systems;

Abstract.

The research for this paper focused on the evaluation of digital engineering tools that aid industrial engineering processes. The paper aims to investigate how to evaluate the effectiveness of such a tool to provide insight into how it fits the needs of a project engineering company. The research carried out a case study in a Norwegian subsidiary of a worldwide consulting and project engineering company. The company had previously implemented the digital engineering tool SmartPlant for information management, engineering drawings, interdisciplinary collaboration, and data exchange. The focus of the industry case study was to customize and use an evaluation method in practice on SmartPlant. The research used an evaluation method based on quality characteristics from the ISO/IEC 25010:2011 standard. We collected qualitative data on the digital engineering tools' usage in practice from semi-structured interviews and a survey. In addition to this, we investigated the appropriate analysis methods for survey results, such as mean value vs. net promoter score. The research concluded that the evaluation method provided the company with valuable insight into the tool's benefits and drawbacks.

Key Reserve Paper#107

The Power of Connection between Systems Engineering and 3D Wire Harness: Model-Based Wire Harness Engineering at Lockheed Martin Skunk Works

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Keywords. MBSE;Wire Harness;Electrical;3D Design

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

Abstract. Lockheed Martin Skunk Works has expanded their concept of a system model for wire harness engineering to incorporate 3D design and manufacturing representation. Their Model-Based Wire Harness Engineering realizes the promise of Model-Based Systems Engineering through significant improvements in integrating SysML models and 3D designs.

Key Reserve Paper#110

Why System Models Need the RDS 81346 Reference Model

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Keywords. Representaion of a system;Common language about systems;Reference model;Reference designation system;Relations among system elements;Proof of concept in digital project

Topics. 1.1. Complexity; 1.6. Systems Thinking; 15. Oil and Gas; 2. Aerospace; 2.4. System Architecture/Design Definition; 20. Industry 4.0 & Society 5.0; 3.2. Configuration Management; 4.1. Human-Systems Integration; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.);

Abstract.

Informative representation of a system is provided by a model. For systems engineers, models are used to represent different information from different disciplines, e.g., electrical engineering, pro-cess engineering, mechanical engineering etc. But how do the different disciplines know that they in fact are representing different information but about the same system (partly or fully) in var-ious models?

In a digital world, where models are stored and information exchanged by computer systems as well as humans, one need an unambiguous common language about systems which is understood by humans as well as digital solutions across disciplines.

This paper introduces the ISO/IEC 81346 Standard series which defines a Reference Designation System (RDS). It is used to create a reference model with unambiguous identifiers for systems and their elements in different views called aspects. The views are stored in a common neutral ref-erence model, which holds systems and their elements and their relations for the purpose of being referred to from any other model.

One of the RDS fundamentals confirms the quotation by Niclas Luhmann (1927-1998): “a system is the total amount of relations between the (system) elements”. In this context, the relations are used to create a system reference model. Any other model refers to the reference model by means of reference designations defined by RDS.

However, relations come in many flavors. The separation and distinguishing among these very different relations is a key to understand the common language used for reference purpose.

As selected proof of concept, the Digital Design, Manufacturing & Services (DDMS) digitalization project at AIRBUS S.A.S. (Toulouse / France) has started to use RDS at scale since 2017 and share their positive observations and conclusions to support the RDS 81346 Technique in this paper.