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Book of Abstracts

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Plenary featuring Keynote

Plenary featuring Keynote#1

”Sustainability”

Matthew Kamakani Lynch (The University of Hawai'i System) - matthewklynch@gmail.com

Presented on: Monday, 08:00-09:25 HST (KALAKUA BALLROOM C)

Biography

Matthew Kamakani Lynch (The University of Hawai'i System) - matthewklynch@gmail.com

Matthew Kamakani Lynch is an artist & polymath who has consistently worked his way to the top tier of performance in the varied sectors where we has participated: banking, community development, higher education, public service, and the arts.
After surviving a 10-year career in mortgage banking & real estate finance through the turn of the century, Matt worked to replenish his karmic bank accounts by participating in a broad range of community-based sustainable development projects around the world.
He returned to Hawai'i and became a founding board member of the Hawaii Green Growth Local 2030 Hub, a c-founder of The Albizia Project, and after almost 10 years of service has recently stepped away from his role as the first Director of Sustainability Initiatives for the ten campuses of the University of Hawai'i System, where he helped to establish a diverse array of programs ranging from the Office of Energy Management to the UH Månoa Truth Racial Healing & Transformation Center.
Matt has now dedicated his life towards creating conditions to catalyze cultural healing and transformation. He currently serves as a teaching faculty member on Harvard's Executive Education for Sustainability Leadership program, and is working on a suite of land-based restoration projects.

Plenary featuring Keynote#2

Inspiring Systems Engineers: the Wonder Woman & Superman methodology …different actions first

Sir Julian Young

Presented on: Tuesday, 08:00-09:25 HST (KALAKUA BALLROOM C)

Abstract. INCOSE has raised the bar by issuing the 'SE Vision 2035'. It is a genuinely inspiring piece, setting major challenges for the Systems Engineering profession and wider society. INCOSE members should seek to meet these: those who don't jump will never fly. A significant anchor, however, are executive seniors rooted to the limits of their knowledge and constraints of their environment. Coaching them to understand the vision and play their enabling part will be key to realizing success. Julian will give his reflections as an ex-Chief Engineer, and a call to be superhuman and jump higher than ever before.

Biography

Sir Julian Young

Sir Julian Young is the immediate past-President of the Institution of Engineering and Technology and retired 2-years ago from the Royal Air Force (RAF) after more than 40 years of service as an Engineer Officer having reached the rank of 3-star Air Marshal. Sir Julian is a keen advocate for the continued professional development of engineers, to keep up with technology - especially our digital future - and to make an appreciable difference in sustaining our planet.

In his last military appointment, he was Director-General Air within the Defence Equipment & Support (DE&S) organization in the UK's Ministry of Defence (MOD). In this role, he led some 2,265 military and civilian specialists and was responsible for putting to work £3.7 billion annually on equipping and supporting all the MOD's aircraft. He was a member of the Air Force Board and the RAF's Chief Engineer, and he had a MOD-wide role concurrently as the Defence Engineering Champion.

Throughout his long career, Julian held a variety of in-command, manpower policy, operational, engineering, training, logistics and staff appointments, including Project Team Leader for the Harrier GR7/T10 fleet and on the Support Helicopter Force (Falkland Islands, Cold War Germany and Gulf War I).

Julian's first degree was in Air Transport Engineering, and he is a Fellow of the Royal Academy of Engineering. He is also a Trustee of the RAF Charitable Trust and Chair of 'The STEM Code' Advisory Board.

He was awarded his KBE in 2020, a CB in 2013 and an OBE in 2000.

Plenary featuring Keynote#3

Intersection of data visualization, data science, and AI

Rahul Basole (Accenture)

Presented on: Wednesday, 08:00-09:25 HST (KALAKUA BALLROOM C)

Biography

Rahul Basole (Accenture)

Rahul C. Basole, Ph.D., is Managing Director and Global Lead for Visualization and Interaction Science (VIS) at Accenture. In his prior role, he was a tenured professor in the College of Computing at the Georgia Institute of Technology. He is a globally recognized thought leader in visualization, enterprise analytics, and AI strategy and has authored award-winning publications in leading management, computer science, and engineering journals and conferences. In 2022 and 2023, he was named to Stanford University's Global List of Top 2% Scientists for both single-year and overall career impact. He holds a B.S. in industrial and systems engineering from Virginia Tech, a M.S. in industrial and operations engineering from the University of Michigan, and a Ph.D. in industrial and systems engineering from Georgia Tech.

Contact: @basole

Plenary featuring Keynote#4

Closing plenary

Presented on: Thursday, 12:30-13:30 HST (KALAKUA BALLROOM C)

Invited Content

Invited Content#400

A Systems Approach to Sustainable Transport and Mobility Solutions

Erika Palmer (Cornell)
Dale Brown (Hatch)
Carrie Cabak (NSI Engineering, Inc.)
Tom Lusco (Iteris, Inc.)
Sarah Sheard (self employed)
Marcel van de Ven (Heijmans Utiliteit b.v.)

Presented on: Monday, 10:00-12:10 HST (KALAKUA BALLROOM C)

Abstract. Achieving Systems Engineering Vision 2035 with respect to major societal challenges must integrate PESTEL factors. In this context, this panel frames a systems approach to sustainable transport and mobility solutions including aspects of resourcing, scale, interconnectedness, and uncertainties. Application cases, current practices, and gaps in systems engineering foundations and methodologies to realize the system approach will be highlighted.

Invited Content#403

Multi-Disciplinary Approaches to Addressing the Wicked Problems of Cyber-Physical-Social Systems

Jon Wade (University of California, San Diego) - jpwade@eng.ucsd.edu
Michael Bruno (University of Hawaii, Manoa)
Olivier de Weck (MIT)
Javier Calvo-Amodio (Oregon State University)
Erika Palmer (Cornell)
Hortense Gerardo (University of California, San Diego)

Presented on: Wednesday, 13:30-14:55 HST (KALAKUA BALLROOM C)

Abstract. Cyber-Physical-Social Systems (CPSS) are self-adaptive, complex systems that integrate data, physical systems, software and the social world whose emergent behaviors often pose wicked problems. They require novel multidisciplinary approaches and techniques for their understanding, design, and management. In the context of Vision 2035 and new methodologies in the Future of Systems Engineering (FuSE), this session will connect experts from various disciplines to discuss how they address these wicked CPSS problems. We will consider what we can learn from analyses in different domains and how systems engineers can contribute to some of our most challenging CPSS systems.

Invited Content#405

No Lifeboat: Climate lessons from the middle of the Pacific

Jeff Mikulina - jmikulina@gmail.com
Erika Palmer - erika.palmer@incose.net

Presented on: Monday, 13:30-14:55 HST (KALAKUA BALLROOM C)

Abstract. Hawaii's clean energy story is a lesson for our shared sustainable energy future – one that can provide wisdom to those working towards INCOSE’s Vision 2035. This talk, and the following “oceanside chat”, explores our changing energy landscape, the social and human aspects driving it, and opportunities for climate leadership in the systems engineering community. This will include how "island thinking" can accelerate innovation, the need for systems solutions-and what they actually look like for our energy system, and why we have every reason to be excited about our abundant clean energy future. Surveys, questions, and opportunities for sharing will keep the audience engaged throughout the presentation.

Invited Content#401

Space Workforce 2030: Advancing Diversity, Equity and Inclusion (DEI)

Marilee Wheaton (The Aerospace Corporation) - marilee.wheaton@incose.net
Michael Hollis, Jr. (Stellar Solutions)
Lt. Gen. Larry D. James (USAF (Ret.))
Prof. Lydia Kaiser (Technische Universität Berlin)
Rosalind Lewis (The Aerospace Corporation)

Presented on: Tuesday, 10:00-12:10 HST (KALAKUA BALLROOM C)

Abstract. From launching private citizens and building the commercial economy in low-Earth orbit to placing habitats on the moon, today's space initiatives require a robust systems engineering workforce. Diversity—of race, gender, experience, and perspective—enable the innovation required to make this reality. Space Workforce 2030 is an executive leadership pledge to significantly increase the number of women and employees from underrepresented groups in our technical workforce, and also those who hold senior leadership positions. Join our panelists as they share lessons learned, best practices and practical suggestions for meeting the Space Workforce 2030 pledge in support of advancing DEI goals.

Invited Content#404

The Innovative Edge of Participatory Methods in Systems Engineering

Jennifer Russel (Garver) - jlrussell@garverusa.com
Dale Brown (Hatch) - dale.brown@hatch.com
Randall Iliff (Project Performance International) - riliff@ppi-int.com
Dana Polojarvi (Maine Maritime Academy) - Dana.Polojarvi@mma.edu

Presented on: Tuesday, 13:30-14:55 HST (KALAKUA BALLROOM C)

Abstract. Stakeholders are central to systems engineering, but where are we in terms of innovating stakeholder engagement? How can we strengthen and foster new participatory methods as part of the Future of Systems Engineering (FuSE)? Who is doing what and why in industry, government and academia with participatory methods in systems engineering? This panel highlights how systems engineering can employ new methods for elucidating stakeholder knowledge on both the individual and community level. The state of participatory methods in systems engineering is fragmented, and this panel seeks to bring those at the front lines of innovation together to pave the way forward.

Invited Content#402

Towards a Systems Engineering Foundation

Ricardo Valerdi (University of Arizona)
Olivier de Weck (MIT)
Garry Smith (Airbus)
Prof. Lydia Kaiser (Technische Universität Berlin)

Presented on: Wednesday, 10:00-12:10 HST (KALAKUA BALLROOM C)

Abstract. Systems Engineering Vision 2035 asserts the imperative for formal theoretical foundations. How fit for purpose are current empirically derived heuristics and principles? What role do they play along with theory, including systems science, to realize stronger scientific and mathematical grounding for engineering technical and socio systems? Can these formalized foundations be suitable across domains? The outcome of this session will stimulate and infuse the Future of Systems Engineering foundations stream to realize the vision.

Biography

Ricardo Valerdi (University of Arizona)

Paper

Paper#175

A CASE STUDY ON MIGRATING TOWARDS FUNCTIONALLY SAFE ZONAL ARCHITECTURE USING MBSE

Neha Surjekar (Tata Consultancy Services) - neha.surjekar@tcs.com
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Karthikeyan Madhumathrubutham (Tata Consultancy Services) - karthikeyan.madhumathrubutham@tcs.com

Presented on: Thursday, 10:00-11:05 HST (Virtual)

Keywords. Model Based Systems Engineering Automotive Electrical and Electronics architecture Re-Architecture Functional Safety Connected Autonomous Shared and Electrification

Topics. 1.1. Complexity; 1.6. Systems Thinking; 17. Sustainment (legacy systems, re-engineering, etc.); 2.4. System Architecture/Design Definition; 3. Automotive; 4.6. System Safety; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis;

Abstract. The increasing market demands in recent times are driving complexity in machines and their control architectures. To satisfy these demands, their architecture needs frequent updates and upgrades which in turn require significant efforts from architects. This paper presents a case study on architecture migration in automotive industry using Model Based System Engineering (MBSE) which will lend a helping hand in successfully rearchitecting any complex system. The Automotive industry is currently undergoing a massive transformation towards software defined vehicles driven by Connected, Autonomous, Shared and Electrification (C.A.S.E). This is possible only with the support of a robust and flexible vehicle Electrical and Electronics (EE) architecture. Taking the C.A.S.E driven transformation into consideration, the present domain control architecture is migrating towards zonal architecture. This paper presents RAZA (Rearchitecting Approach for Zonal Architecture) which is based on the INCOSE defined technical process and ISO/IEC/IEEE 15288:2015 Systems and software engineering — System life cycle processes

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Paper#221

A Conceptual Framework for the SE of AI-Intensive Systems (SE4AI) – Considering Data Through the Life-Cycle

Jawahar Bhalla (JB Engineering Systems / Shoal Group Pty Ltd) - jawaharb2413@gmail.com
Stephen Cook (University of Adelaide) - stephen.cook@adelaide.edu.au
David Harvey (University of Adelaide) - david.harvey@adelaide.edu.au

Presented on: Thursday, 10:45-11:25 HST (316A)

Keywords. Artificial Intelligence Machine Learning SE4AI Systems Engineering Conceptual Framework Autonomous Systems Situational Awareness Mental Models Modelling and Simulation Verification and Validation Data

Topics. 1. Academia (curricula, course life cycle, etc.); 13. Maritime (surface and sub-surface); 14. Autonomous Systems; 2.3. Needs and Requirements Definition; 5.11 Artificial Intelligence, Machine Learning; 5.5. Processes;

Abstract. This paper considers the challenge of the systems engineering of AI-Intensive Systems (SE4AI) with a particular focus on their high reliance on data for design verification, model training and model validation. The paper opens by describing the contextual background and reviewing contemporary AI/ML development approaches. The finding of this section is that the development of AI/ML applications tends to be inherently “bottom-up” driven by technological advancements rather than driven from the top-down from a holistic “end-to-end” systems-based perspective. Concepts and principles from systems thinking, modelling and simulation, and situation awareness are then identified as exaptive building blocks for consideration to be integrated into a SE life-cycle process suited to systemically engineering AI/ML application. A typical SE life-cycle process is then outlined, with the identified concepts integrated, that can represent the beginnings of a conceptual framework for the SE of AI Intensive Systems that features a specific focus on ML model training and assurance. The proposed life-cycle framework is described through each phase in turn, in terms of the phase objective, the proposed refinement to the phase activities to cater for ML systems and the proposed phase outcomes. Related initiatives of direct relevance to this research are identified, followed by a summary and conclusion.

Paper#159

A Geo-Spatial Method for Calculating BEV Charging Inconvenience using Publicly Available Data

Aaron Rabinowitz (Colorado State University) - aaron.rabinowitz@colostate.edu
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John Smart (Idaho National Laboratory) - john.smart@inl.gov
Thomas Bradley (Colorado State University) - thomas.bradley@colostate.edu

Presented on: Thursday, 10:45-11:25 HST (313C)

Keywords. Electric Vehicles Electric Vehicle Support Infrastructure Electric Vehicle Equity City Planning

Topics. 21. Urban Transportation Systems; 3. Automotive; 5. City Planning (smart cities, urban planning, etc.);

Abstract. A sustainable transportation sector is only possible if everyone can participate. In this session a novel, quantitative metric for expected BEV operational inconvenience due to charging is presented along with a practical geo-spatial implementation.

Paper#43

A Social Enterprise Approach for Parenting in the Japanese Society

Raquel Hoffmann (Keio University) - raquel.hoffmann@keio.jp
Ana Maria Bori (Soka University) - e21m3503@soka-u.jp

Presented on: Tuesday, 11:30-12:10 HST (313B)

Keywords. UAF Social Enterprise Society 5.0 Enterprise Architecture

Topics. 20. Industry 4.0 & Society 5.0; 22. Social/Sociotechnical and Economic Systems; 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.); 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Japan has one of the world's most family-friendly parental leave systems. However, a government survey conducted in 2020 found that less than 13 percent of male respondents exercised their right to take paternity leave, leaving the burden of child-rearing to the mothers. Although Japan’s Government has made parental leave a top priority, the effects on society are still modest. Work culture, labor regulation, and gender bias are some of the challenges in the imbalanced parenting problem. Solving a society-related issue requires a holistic approach to consider complex multidimensional aspects. This paper uses the Unified Architecture Framework to model a Social Enterprise by investigating the Japanese parenting problem. We use the challenges and drivers identified in the Japanese case to explore viewpoints that place the human aspect of parenting together with business and policymaking. Lastly, we introduce the next parenting phase considering principles from Society 5.0.

Paper#156

A Systematic and Traceable MOSA Evaluation Process for Systems Architectures: A Digital Engineering Tool

Awele Anyanhun (Georgia Tech Research Institute) - engrawele@gmail.com
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Whit Matteson (Georgia Tech Research Institute)

Presented on: Thursday, 08:00-08:40 HST (313B)

Keywords. MOSA Evaluation MBSE Digital Engineering Tool

Topics. 3.6. Measurement and Metrics; 5.3. MBSE; 5.5. Processes; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. A systematic and traceable MOSA evaluation process for evaluating the degree to which an architecture embraces Modular Open Systems Approaches (MOSA) is germane to ensuring that MOSA principles are actually used in the development of defense systems architectures.

Paper#228

A Systems Approach to Reducing Mis-pulls and Misplaced Trailers for Trucking Fleets

Sean Bumgarner (Colorado State University) - sean.bumgarner@colostate.edu
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Jeremy Daily (Colorado State University) - jeremy.daily@colostate.edu

Presented on: Thursday, 11:30-12:10 HST (313C)

Keywords. Trucking Heavy Vehicles Automation Model Based Systems Engineering Geo-Reference

Topics. 17. Sustainment (legacy systems, re-engineering, etc.); 2.4. System Architecture/Design Definition; 21. Urban Transportation Systems; 3. Automotive; 5.12 Automation; 5.3. MBSE;

Abstract. This work demonstrates a novel solution following a systems approach for a trailer tracking system design, delivering a trailer tracking capability fielded through minimal changes to existing hardware and software. This automated trailer location system would reduce mis-pulled and temporarily misplaced trailers saving time and money for fleet operations world-wide.

Paper#130

Agile Processes Applied to Los Alamos National Laboratory SE approach: The Agile Processes and Technology (APT) Team

Owen Dominguez (Los Alamos National Laboratory) - odomingu@lanl.gov
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Presented on: Wednesday, 14:15-14:55 HST (313C)

Keywords. MBSE Agile Lean

Topics. 5.1. Agile Systems Engineering; 5.2. Lean Systems Engineering; 5.3. MBSE;

Abstract. APT intends to demonstrate a concurrent and collaborative design process by delivering a qualifiable and certifiable prototype in three years, in contrast to current efforts that can take up to 12 years. APT at Los Alamos National Laboratory's product realization, seeks establish a new set of practices and guidance to approach a new way of doing business at the National Laboratories level. Given the complexity of this task, APT has chosen to adoption of MBSE for the core system management.

Paper#69

Agile Systems Engineering – Eight Core Aspects

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Presented on: Wednesday, 13:30-14:10 HST (313C)

Keywords. agile systems engineering situational awareness iterative incremental development common mission teaming

Topics. 2. Aerospace; 3. Automotive; 5.1. Agile Systems Engineering; 6. Defense;

Abstract. INCOSE's Vision 2035 calls for action on nine system engineering challenges. The purpose of this paper is to addresses one of those challenges directly: "Systems engineering anticipates and effectively responds to an increasingly dynamic and uncertain environment." This paper addresses that challenge by identifying the need and behavior of eight core aspects for a basic comprehensive solution and provides some examples of those aspects in operation.

Paper#104

An Approach to Integrated Digital Requirements Engineering

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Presented on: Monday, 13:30-14:10 HST (313A)

Keywords. Digital Requirements Engineering Digital Engineering MBSE V&V

Topics. 2. Aerospace; 2.3. Needs and Requirements Definition; 2.4. System Architecture/Design Definition; 2.6. Verification/Validation; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis;

Abstract. The goal of this paper is to present the outcomes and perspectives, as developed within our company, of setting up an Integrated Digital Requirements Engineering approach. This approach seeks to benefit from emerging model-based and digital approaches, while addressing difficulties met in applying them. The result is improved usability, while maximizing benefits all along the development life cycle and for the overall V&V activities.

Paper#133

An Evaluation of the Boeing Diamond Process Model's Effectiveness for T-7A Red Hawk Development

Grace Wilson (United States Air Force Academy) - c25grace.wilson@afacademy.af.edu
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Presented on: Wednesday, 14:15-14:55 HST (316B)

Keywords. Process Model T-7A Red Hawk Boeing Diamond Process Model Systems Engineering Vee Evaluation

Topics. 1. Academia (curricula, course life cycle, etc.); 2. Aerospace; 3.3. Decision Analysis and/or Decision Management; 3.7. Project Planning, Project Assessment, and/or Project Control; 5.5. Processes; 6. Defense;

Abstract. The Boeing-Saab built T-7A Red Hawk advanced trainer aircraft being built for the United States Air Force represents a systems engineering breakthrough because it was developed through a digital effort. This aircraft will replace the aging T-38 Talon fleet, providing increased capability and safety for future pilot trainees. Its creation was indubitably the result of persistent systems engineering efforts and a dedication to digital development. This study analyzed how Boeing engineers created their own version of the systems engineering vee process model to advance the design process of the T-7A physically and digitally. Their "Boeing Diamond" process methodology of top-down system design utilized a digital engineering process and modern computer techniques. They emphasized the importance of maintainability to expand lifecycle utilization and lower system costs. Based on a literature review of the T-7A Red Hawk and other aircraft, a comparison was drawn between the Boeing Diamond systems engineering design processes and the vee model to determine which could provide greater benefits. Through analysis, this study demonstrated that the T-7A processes used encouraged engineers to adapt to the digital world. The study results indicated that the Boeing Diamond process for modeling and digital design supported an efficient approach to the development of the T-7A Red Hawk and is applicable to other major weapon systems or capital equipment. This research recommends further study of the Boeing Diamond model and incorporation of its elements into traditional systems engineering models and other organizations.

Paper#109

Applying a System-of-Systems Perspective to Hyundai-Kia's Virtual Tire Development

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Presented on: Thursday, 10:45-11:25 HST (313B)

Keywords. Virtual Tire Development MBSE System of Systems Architecture

Topics. 2.4. System Architecture/Design Definition; 3. Automotive; 3.3. Decision Analysis and/or Decision Management; 5.3. MBSE; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.);

Abstract. Systems engineering has become important in almost every complex product manufactur-ing industry, especially automotive. Emerging trends like vehicle electrification and autonomous driving now pose a System of Systems (SoS) engineering challenge to automotive OEMs. This paper presents a proof-of-concept (PoC) that applies a top-down SoS perspective to Hyundai-Kia Motor Corporation's (HKMC) Virtual Product Development process to develop a performance-critical component of the vehicle, the tire. The PoC demonstrates using the Arcadia MBSE method to de-velop a consistent, layered, vehicle architecture model starting from the SoS operational context down to the lowest level of system decomposition in the physical architecture thereby capturing top-down knowledge traceability. Using the concept of functional chains, several vehicle performance views are captured that serve as the basis for architecture verification orchestration across engineer-ing domains using a cross-domain orchestration platform thereby validating key vehicle/tire perfor-mance metrics that influence the tire design parameters. Preliminary results of the study show that applying a method-based modeling approach could provide several benefits to HKMC's current prod-uct development approach such as reduced time to model, SoS knowledge capture and reusability, parameter/requirement traceability, early performance verification, and effective systems engineer-ing collaboration between the OEM, tire design supplier and tire manufacturers.

Paper#114

Applying MBSE in Space Based Systems Development

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Presented on: Wednesday, 10:00-10:40 HST (313B)

Keywords. Model Based Systems Engineering Digital Engineering Space Systems Systems Engineering Agile

Topics. 2. Aerospace; 2.4. System Architecture/Design Definition; 5.3. MBSE; 6. Defense;

Abstract. This paper presents the experience and lessons learned in applying MBSE to a real world space based system development effort. The MBSE methodology is first presented followed by its application in constructing a sensor system to a CDR level of detail. Lessons learned are provided as well as future research opportunities.

Paper#27

Architecting Descriptive Models for MBSE

Ryan Noguchi (Aerospace Corporation) - ryan.a.noguchi@aero.org

Presented on: Thursday, 08:45-09:25 HST (313A)

Keywords. MBSE Model Based Systems Engineering Model Architecting Descriptive Models Systems Architecting Software Architecting Modeling Patterns Modeling Principles Modeling Heuristics

Topics. 5.3. MBSE;

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, the growth of MBSE adoption and realized value is often stymied by the growth of technical debt in the descriptive models that serve as the foundation of knowledge capture and communication in an MBSE environment. The methods and practices of system and software architecting can be readily adapted to address the technical debt growth problem often seen in the development of descriptive models. This paper describes the emerging discipline of “model architecting,” comparing and contrasting it with system and software architecting practices. The paper describes a representative set of model architecting patterns that illustrate model architecting principles, then identifies some of the key roles, responsibilities, and competencies required of the model architect.

Paper#89

Architecting Digital Engineering Requirements for Risk Management & Systems Architecting

Shannon Dubicki (The Johns Hopkins University Applied Physics Laboratory) - Shannon.Dubicki@jhuapl.edu
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Presented on: Tuesday, 15:30-16:10 HST (313B)

Keywords. System Architecting Risk Management Model Based Systems Engineering Digital Engineering

Topics. 2.4. System Architecture/Design Definition; 3.9. Risk and Opportunity Management; 5.3. MBSE; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. In this session, we will describe the risk management and system architecting digital thread. We will present the systems engineering methodology we used to understand this digital thread and will describe how the risk management and system architecting digital thread was analyzed throughout each step of the systems engineering methodology. The methodology used is also presented as a way other DE digital threads can be analyzed from source processes to component-level requirements.

Paper#229

ASPICE compliance development of Cyber-Physical Systems by using Model-Based Systems Engineering

Gauthier Fanmuy (Dassault Systemes) - gauthier.fanmuy@3ds.com
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Guillaume Terpant

Presented on: Tuesday, 11:30-12:10 HST (313C)

Keywords. Standard Compliance Model-Based Systems Engineering Methodology

Topics. 3. Automotive; 5.3. MBSE; 5.5. Processes;

Abstract. Automotive Industry is facing numerous challenges. Business model is switching from ownership to shared mobility. Mobility of the future is becoming more smart, safe, secured and connected: sys-tems will interact with other systems in a network to deliver added-value mobility services. In the meantime, standards require higher levels of systems engineering practices as well as justification. ASPICE for example which was at the origin to support the development of system and software now include hardware and cybersecurity. In this global context, traditional systems engineering de-velopment approaches are not any more appropriate. This system complexity require new approach-es like Model-Based Systems Engineering, using modeling and simulation. To address compliance to standards, traditional quality approaches consisting defining a quality system with a set of pro-cesses are no more sufficient. Addressing these challenges require a digital transformation with 2 pillars. The first pillar is an MBSE methodology such as Cyber MagicGrid to define a set of best practices to develop a system. The second pillar is a quality management system that relies on the MBSE methodology rather than a set of enterprise processes to address compliance to standards. Benefits of this approach is to accelerate the digital transformation of the Enterprise by capitalizing the know-how with the constraints required by the standards.

Paper#234

Balancing Digital Forensic Investigation with Cybersecurity for Heavy Vehicle Traffic Crashes

Mars Rayno (Colorado State University) - mars.rayno@colostate.edu
Jeremy Daily (Colorado State University) - jeremy.daily@colostate.edu

Presented on: Wednesday, 10:45-11:25 HST (313C)

Keywords. cybersecurity digital forensics crash investigation end of life retirement phase

Topics. 2.3. Needs and Requirements Definition; 3. Automotive; 4.7. System Security (cyber-attack, anti-tamper, etc.); 5.3. MBSE;

Abstract. After a traffic crash event, traffic crash investigators collect evidence and data to assist in reconstructing the events to determine crash causation. Some of the data collected in a crash investigation is in the form of digital data from event data recorders built into the electronic control units in the vehicles. Occasionally, traffic crashes are severe enough to destroy the typical network-based communications protocols to extract the digital forensic data. In these cases, more invasive techniques of gathering forensic data through in-circuit programming ports or direct reading of data bearing memory chips is needed. While a digital forensic investigation satisfies a virtuous need for society in determining the truth of a traffic crash, the same techniques can be applied by nefarious actors interested in stealing intellectual property (IP) from the same data bearing chips. The exposure of the executable binary containing the IP of the manufacturer has prompted auto makers and suppliers to eliminate access to these sources of digital forensic data by disabling the JTAG and obfuscating or encrypting the binary data. Herein lies the purpose of this paper, which is to take a systems engineering approach to balance the needs and requirements for a manufacturer to provide sufficient forensic artifacts in the case of an investigation while improving their cybersecurity posture and limiting their exposure to the theft of intellectual property or cyberattack. An activity diagram is presented to show a system model for responding to and investigating a crash event. These activities inform the needs of an improved event data recorder technologies that contain information necessary to reconstruct the crash. Some proposed top level system requirements are presented with a discussion of how they satisfy the needs of the manufacturer and the crash investigator. Specific requirements of recorded data gives a notion of a minimal set of recorded data to help investigators. These requirements will ensure both the availability and adequacy of forensic data needed for crash event reconstruction. In addition, a separate requirement governing the preservation of OEM proprietary software is made, such that their intellectual property is protected to encourage the requirement compliance. Finally, a discussion of how the proposed requirements help determine if a crash event was a result of a cyber-attack demonstrates the important nature of addressing these needs in future systems.

Paper#236

CANLay: A Network Virtualized Testbed for Vehicle Systems – Improving System Integration and Verification Efforts

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Presented on: Monday, 10:00-10:40 HST (313A)

Keywords. Digital Twin networking verification testing controller area network Cyber-Physical Systems Cybersecurity

Topics. 11. Information Technology/Telecommunication; 14. Autonomous Systems; 2.6. Verification/Validation; 21. Urban Transportation Systems; 4.7. System Security (cyber-attack, anti-tamper, etc.); 5.4. Modeling/Simulation/Analysis;

Abstract. Integration and Verification activities for cyber physical system networks is a complex task requiring multiple iterations of hardware and software configurations and topologies. This testing is critical for the system's functionality and safety and security in operation. An efficient strategy to rapidly create multiple testing setups is to employ a software-defined system, vehicle in this case, and encapsulate in-vehicle networking messages in a switched packet network, like Ethernet. The purpose of this paper is to present the design and utility of CANLay, the net-working backbone of a software-defined vehicle, which is a network virtualized test bed for in-vehicle network testing. CANLay, is responsible for carrying controller area network data as well as sensor signals emanating from the vehicle control units and sensor systems. CANLay acts as a communication media between a vehicle simulator and real-world electronic control units located on different network segments. CANLay is demonstrated for heavy vehicle network performance testing in a highly configurable digital engineering environment that can be rapidly changed and iterated streamlining system integration and verification efforts.

Paper#134

Case Studies in Disaster: Modern Digital Engineering Methods and Error Detection

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Presented on: Wednesday, 13:30-14:10 HST (313B)

Keywords. Model Based Systems Engineering (MBSE) Digital Engineering Model Evaluation

Topics. 2. Aerospace; 2.4. System Architecture/Design Definition; 4. Biomed/Healthcare/Social Services; 5.3. MBSE; 5.6. Product Line Engineering; 6. Defense;

Abstract. Could modern MBSE techniques could have averted engineering disasters of the past had they been employed at the time? Three case studies are presented: Apollo XIII, Therac-25, and a modern surface naval system. For each, the nature of the system and the error are discussed, and an abbreviated architectural model is presented with advanced analytical techniques. Practitioners of systems engineering interested will benefit through these technical examples in leveraging MBSE.

Paper#15

Children’s after school club on Systems Thinking and Sustainability

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Presented on: Wednesday, 02:00-02:40 HST (Virtual)

Keywords. Systems Thinking School Club Sustainability

Topics. 1.6. Systems Thinking; 10. Environmental Systems & Sustainability; 5.10. Diversity (cultural boundaries, diverse engineering teams, training underserved groups, etc.); 5.9. Teaching and Training;

Abstract. Systems thinking is deemed to be a key brick to systems engineering professionals and not only. But how early can we start building that knowledge? The author argues and has demonstrated in this paper that you can start as early as primary school with children aged 7-8. The paper provides the details of the club run in the summer term (last term of the year) of the UK year 2 of primary school in a way that it can be re-used widely.

Paper#23

Combining System Models and CAD for Change Scenario Management

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Presented on: Monday, 10:45-11:25 HST (316A)

Keywords. Model Based Systems Engineering MBSE Engineering Change System Model Computer-Aided Design CAD

Topics. 2.6. Verification/Validation; 3. Automotive; 3.2. Configuration Management; 5.3. MBSE;

Abstract. In the development of complex mechatronic systems, interdisciplinary cooperation requires an exchange between stakeholders in order to ensure fulfillment of requirements and related functions. The cooperation of the stakeholders from different disciplines must be well coordinated to address systems changes. The system model as essential aspect of model-based systems engineering, has to be linked to specific models of involved disciplines (mechanical, electrical/electronical and software) to enable a basis for automatic identification e.g., of affected subsystems and functions. This contribution discusses the potential of model linking from the perspective of change scenarios by considering published approaches to link system models and computer-aided design (CAD). A methodical approach on how descriptive system models can be used as base for computer-aided design is presented. This approach is analyzed by reviewing a use case for a design change scenario of an automotive eAxle.

Paper#65

Common Language for Systems by the ISO/IEC 81346 Reference Model

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Presented on: Wednesday, 02:45-03:25 HST (Virtual)

Keywords. Common language System architecture Reference designation system (RDS) Reference model for systems and their elements

Topics. 1.1. Complexity;1.6. Systems Thinking;15. Oil and Gas;2. Aerospace;2.4. System Architecture/Design Definition; 5.11 Artificial Intelligence, Machine Learning ;5.4. Modeling/Simulation/Analysis

Abstract. The presentaion will intoduce you the the practical common language by ISO/IEC 81346 standard series: The reference designation system (RDS). RDS is used for reference purposes and are well known and implemented outside the environment of systems engineering. RDS has demonstrated to be very useful when creating a reference model for a system and its relations. Besides the basic theory, practical application examples at large scale will be given.

Paper#220

Complex System Reliability Analysis using a Model-Based Shared Systems Simulation

Jeremy Ross (Ford Motor Company) - jross117@ford.com

Presented on: Monday, 15:30-16:10 HST (KALAKUA BALLROOM C)

Keywords. Model-based systems engineering Modeling Simulation Analysis Reliability Systems reliability Systems architecture

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

Abstract. The continued growth of system complexity is challenging traditional qualitative, heuristics-based approaches to architecting system emergence. As these emergent attributes are products of the architecture and established early in the system development lifecycle, where ambiguity is most pronounced, a shift to a model-based approach is viewed as essential to understanding system interdependencies and the impacts of tradeoff decisions. This paper discusses how model-based systems engineering methods and a coupled architecture-simulation can be used to model complex system reliability. Employing a probabilistic model of system element failure, the coupled simulation is shown to predict system reliability for various architecture configurations early in the system design process. The advantages this quantitative system performance assessment provide to stakeholder decision-making are reviewed, and the simulation model is extended to demonstrate how the complexity-resilience tradeoff can impact system reliability.

Paper#19

Constructing a Digital Thread to Support Mission Analysis & System of Systems Engineering

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Presented on: Thursday, 10:00-10:40 HST (313B)

Keywords. Digital Thread Mission Engineering Systems of Systems Digital Engineering

Topics. 2. Aerospace; 2.1. Business or Mission Analysis; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 6. Defense;

Abstract. This paper presents a digital thread composed of MBSE and M&S in support of military mission analysis. The experience of creating this work as well as digital engineering lessons learned are discussed.

Paper#3

Coping with Verification in Complex Engineered Product Development

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Presented on: Tuesday, 14:15-14:55 HST (313C)

Keywords. Complex Systems Engineering Integration Metrics Test Verification

Topics. 2.5. System Integration; 2.6. Verification/Validation; 3.6. Measurement and Metrics; 6. Defense;

Abstract. This paper is a case study in a Norwegian high tech product development company engineering complex systems to an international market, researching its compliance to the literature on product verification. Further, the discrepancies found are evaluated to find a rationale for the discovered delta between theory and practice. Finally, we propose what the company should do to close the gap, challenges taken into account.

Paper#240

Cyber Security at the Enterprise Level

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Presented on: Wednesday, 11:30-12:10 HST (313C)

Keywords. Security UAF SysML MBSE

Topics. 11. Information Technology/Telecommunication; 4.7. System Security (cyber-attack, anti-tamper, etc.); 5.3. MBSE; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. When building systems, it is tempting to start with the customer requirements and jump straight into implementing a preconceived solution and then mapping it to the requirements as best one can. This is referred to as “solutioneering”. To avoid this, systems engineers build models of the requirements, elaborating them into use cases, activity diagrams, IBDs, and other more concrete modeling steps. However, part of a system engineer’s job is to validate these requirements against the customer needs, capabilities, and goals to ensure you build the right system. This assumes that the customer knows and understands their needs and problems, which we have dubbed “Problemeering”. The systems engineer can never take the requirements at face value, assume that they are correct and have captured the customer needs and can solve their problems. This is true across many cross-cutting aspects and domains, where a Subject Matter Expert (SME) is required. This is especially true regarding security issues where is it unlikely that customers are aware of the current threat landscape and risks and can fully elaborate them. This will require the knowledge and experience of a cyber-security SME who can adequately analyze the system vulnerabilities from the right perspective. In this article, we will detail how Capability-Based security engineering is used to ensure that the true needs of the customer are articulated and ultimately implemented in the delivered system.

Paper#106

Data and Knowledge-Driven Systems Architecting for a Hydrogen-Powered Concept Aircraft

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Presented on: Wednesday, 10:00-10:40 HST (316A)

Keywords. Systems Architecting Knowledge Conservation Knowledge Reuse Aircraft Conceptual Design

Topics. 10. Environmental Systems & Sustainability; 2. Aerospace; 2.4. System Architecture/Design Definition; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Aircraft development takes many years. Concept aircraft with new energy sources and disruptive systems technologies are investigated during conceptual design to achieve sustainability. To accel-erate time to market, reduce development costs, and still handle complexity, a holistic framework for knowledge-based systems architecting using a model-based systems engineering approach is presented. This framework has the purpose to conserve and reuse knowledge about existing systems architectures.

Paper#154

Defining Collaborative Control Interactions using Systems Theory

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Presented on: Wednesday, 15:30-16:10 HST (KALAKUA BALLROOM C)

Keywords. teaming human-machine teams systems theory system safety collaborative control

Topics. 1.4. Systems Dynamics; 1.6. Systems Thinking; 14. Autonomous Systems; 2. Aerospace; 4.6. System Safety; 6. Defense;

Abstract. Human teams collaborate by establishing roles, changing functional authorities, maintaining team cognition, coordinating, and mutually helping one another close control loops. These complex interactions are inspiring novel concepts to improve human-machine and multi-machine collabo-ration. However, these new systems face engineering gaps in modeling, analysis, design, and as-surance. As such, few have been fielded in safety-critical domains like aerospace. To analyze safety, this paper introduces a system-theoretic framework to describe interactions that are—or are planned to be—used in multi-controller systems. It outlines a taxonomy of seven structural di-mensions that influence controller interactions and nine dynamics observed in collaborative control that are defined using Systems Theory. An analyzed set of 101 controller interactions in aerospace systems demonstrates how to apply the framework and that designers are trying to create more sophisticated systems. This framework provides the foundation to extend system-theoretic hazard analysis techniques to systematically find collaborative-control causal factors.

Paper#129

Democratizing Systems Security

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Presented on: Monday, 10:00-10:40 HST (313C)

Keywords. systems security stakeholders FuSE Future od Systems Engineering STAMP STPA

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

Abstract. As systems security joins the top concerns of systems engineering, availability and affordability of already scarce security expertise presents a resource barrier. Investigating means and effects of aligning stakeholders on security requirements in the Future of Systems Engineering (FuSE) led to the understanding that security expressed as loss-driven needs and capabilities would be accessible to everyone, independent of how those needs and capabilities would be realized.

Paper#22

Developing Effective Space Systems With Earlier Integration, Verification, and Validation

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Presented on: Wednesday, 11:30-12:10 HST (313B)

Keywords. Integration Verification Validation Space Systems

Topics. 2. Aerospace; 2.3. Needs and Requirements Definition; 2.6. Verification/Validation; 5.7. Software-Intensive Systems;

Abstract. Addressing integration, verification and validation early is crucial towards assuring a space system is developed quickly while still achieving the objectives of the mission. This paper highlights the activities from the INCOSE Needs and Requirements Manual by applying the concepts to an example space system, using the FireSat II example from the Space Mission Engineering: The New SMAD, to show how they can support early integration, verification and validation of new space systems.

Paper#218

Enterprise Digital Transformation using a Sociotechnical System Approach

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Presented on: Tuesday, 13:30-14:10 HST (313B)

Keywords. Digital Transformation Digital Twins Sociotechnical Systems

Topics. 1.5. Systems Science; 2.1. Business or Mission Analysis; 2.3. Needs and Requirements Definition; 20. Industry 4.0 & Society 5.0; 22. Social/Sociotechnical and Economic Systems; 3.5. Technical Leadership; 5.5. Processes; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Digital transformation is gaining increased attention due to its potential to change the way companies operate and unveil new business strategies. In consideration of the fact that digital transformations occur under specific sociotechnical environments and with particular intentions, success highly depends on the ability of companies to explicitly characterize their sociotechnical context and intended transformation. This paper sheds some light on how companies might approach digital transformation efforts through an enterprise-level digital twin. Research findings and intervention strategies are derived from observations and interviews on ongoing projects, supplemented by findings from the literature. Core systems en-gineering analysis methods such as Concept of Operations analyses are part of such strategies given their potential to accelerate the sociotechnical system redesign cycle and generate actionable decisions toward digital transformation. A sociotechnical system analysis framework intended to guide organizations in developing their strategic approaches for adopting digital twins is also shared. This framework and the entire paper assert the importance of taking a sociotechnical system perspective in defining, designing, and implementing an enterprise-level digital twin.

Paper#2

Evaluating 50,000 Drone Concepts Against Volatile Requirements

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Presented on: Thursday, 05:00-05:40 HST (Virtual)

Keywords. requirement volatility set-based design utility concept evaluation

Topics. 2.3. Needs and Requirements Definition; 3.3. Decision Analysis and/or Decision Management; 6. Defense;

Abstract. This paper proves that concepts should be scored against a non-volatile requirement using a cumulative normal or lognormal utility function. If the requirement is volatile, then the concept can still be scored using a normal or lognormal utility function. Concepts can then be scored against multiple interrelated requirements using a multivariate version of the normal or lognormal utility. Cilli, Specking, Whitcomb, Parnell, Goerger, Kundeti an Parnell previously used set-based design to analyze a database of 50,000 UAV concepts against 11 draft requirements with piecewise linear utilities. This paper reanalyzes that database with the cumulative normal/lognormal utilities. This analysis can recognize volatility and interdependencies between the draft requirements. Because the analysis is computationally trivial when physical uncertainties are normal, the approach can be tractably applied when the number of concepts is much larger.

Paper#94

Exertional Heat Strain Detection: Application of the Human Performance Model Based Systems Engineering System Architecture (MBSE-SA)

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Presented on: Wednesday, 14:15-14:55 HST (313B)

Keywords. Model Based System Engineering MBSE Human Health Performance Cost Benefit Simulation Wearable Devices Military

Topics. 1.6. Systems Thinking; 4. Biomed/Healthcare/Social Services; 4.1. Human-Systems Integration; 5.3. MBSE; 6. Defense;

Abstract. Exertional Heat Illness (EHI) is a health concern for the US military. However, wearable devices can help military leaders to preemptively respond to EHI cases if the correct wearable system is used. To expedite the process of matching wearable systems to military use cases, a Wearables Model Based Systems Engineering System Architecture (MBSE-SA) was used. In addition, a cost-benefit simulation within the MBSE-SA was used to visualize the impact a chosen system has on EHI costs.

Paper#33

Function-Based Architecture Optimization: An Application to Hybrid-Electric Propulsion Systems

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Presented on: Monday, 16:15-16:55 HST (313C)

Keywords. architecture optimization system architecture MBSE MDO aircraft propulsion hybrid-electric

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

Abstract. System architecting suffers from large combinatorial design spaces and high uncertainty in behavior and performance. Decisions arising in architecting processes greatly impact the success of the final product, however are subject to high uncertainty and large combinatorial design spaces. Selecting the best architecture for the problem at hand is non-trivial and can be supported by architecture optimization techniques. In this paper, we demonstrate how architecture optimization can used for designing hybrid-electric aircraft propulsion systems. The function-based architecture optimization problem is formulated from an Architecture Design Space Graph (ADSG) created using the ADORE tool. Automatically generated architecture alternatives are evaluated using a multidisciplinary analysis framework coupling an overall aircraft design tool to mission and propulsion system simulation code. Architectures are optimized for fuel burn and aircraft weight using a multi-objective genetic algorithm. It is demonstrated that a large architecture design space can be effectively searched and a Pareto front can be obtained.

Paper#53

I-SHARE – INCOSE Systems Heuristics Application Repository: Sharing Systems Engineering Knowhow and Experience

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Presented on: Wednesday, 14:15-14:55 HST (316A)

Keywords. Heuristics System Lifecycle Systems Engineering Expertise

Topics. 1.6. Systems Thinking; 17. Sustainment (legacy systems, re-engineering, etc.); 2.1. Business or Mission Analysis; 22. Social/Sociotechnical and Economic Systems; 5.9. Teaching and Training; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Since 2020, a team of INCOSE Fellows has been creating I-SHARE – INCOSE Systems Heuristics Application Repository, in which over 600 SysE-related heuristics are curated, covering subjects that include SysE competencies, lifecycle stages, expertise, operational domains, and system attributes. We describe I-SHARE, the motivation and stages of its creation and compilation, and ways through which the knowhow and experience it holds can be shared and passed across generations of systems engineers.

Paper#98

Improving Systems Engineering Competency and Capability in an Organization

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Presented on: Tuesday, 10:00-10:40 HST (313C)

Keywords. competency capability assessment culture shift workforce development

Topics. 4.5. Competency/Resource Management; 5.9. Teaching and Training; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. This paper is based upon a multi-year effort to improve the skills and capabilities of the Systems Engineering workforce at a medium sized organization. Themes include: identifying the systems engineering workforce, facilitating capability development for this workforce, motivating and inspiring the workforce to continue improving their skills, and assessing the level of competency developed. Lessons learned from the effort will provide important insights to those pursuing a similar goal.

Paper#151

Integrated Systems Architectural Modeling (MBSAP) with Architectural Trade Study of a UAV Surface-less Flight Control System for Wildfire Detection and Communication

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Presented on: Monday, 15:30-16:10 HST (313C)

Keywords. UAV Wildfire Flight Controls MBSE MBSAP Systems Thinking Fan-In-Wings eVTOL MEA Aerospace Actuations Surface-less Flight Controls System Security

Topics. 1.1. Complexity; 1.6. Systems Thinking; 10. Environmental Systems & Sustainability; 14. Autonomous Systems; 2. Aerospace; 2.4. System Architecture/Design Definition; 2.5. System Integration; 21. Urban Transportation Systems; 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; 5.5. Processes; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.);

Abstract. In this paper, we report our progress on integrating a model-based system engineering methodology with a system architectural trade study applied to flight control of a locally owned and operated, cost effective UAV concept. The primary objective of the UAV is to monitor wildfires and to gather information and to provide surveillance data for predicting and preventing wildfires [1]. Here we report our experience with a holistic approach to architect flight controls (the system of interest), in a way that is tightly coupled with higher level stakeholder needs (and concerns), operational scenarios, (normal, inadvertent, and mis-) use cases, Context System and Enabling Systems. Several architectural variants were traded. Our systemic approach showed that classical flight controls is feasible for the baseline UAV. It also helped us identify a novel architecture with a potential to drastically improve UAV performance (range, survey time), UAV weight and specific cost. 1 Integration of UAV Flight Control Trade Study with MBSAP

Paper#92

Integration of Cameo Systems Modeler with Simulink for Co-Orbital Engagement Mission Engineering

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Presented on: Wednesday, 11:30-12:10 HST (316A)

Keywords. Mode-Based Systems Engineering Cameo Systems Modeler Simulink Executable model Mission analysis

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

Abstract. Testing the suitability of tactics for never-used complex systems in a brand-new warfare domain and forecasting the impact of these new tactics on the system's requirements and design is challenging. The MBSE approach seems to be the key to dealing with such complexity. However, connecting the descriptive and physics-based models is necessary to be truly effective. This connection creates an executable MBSE model that enables mission analysis of system architecture before physically prototyping it. An executable model should significantly improve and enhance the feasibility of the analysis of any mission during the early design phases. This paper aims to enhance the use of the Cameo Systems Modeler to execute high-fidelity models in the MATLAB/Simulink development environment. This paper also presents a co-orbital engagement model of two satellites and walks through the integration process. The example shows how the model can be applied to mission analysis and reshape the design space.

Paper#165

Involving Non-Technical Stakeholders in System Architecture Design; a Case-Study on the Cleaning Industry

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Presented on: Wednesday, 05:45-06:25 HST (Virtual)

Keywords. Stakeholder Involvement Problem Exploration Systems Architecting Human Centered Design Approach

Topics. 18. Service Systems; 2.4. System Architecture/Design Definition; 22. Social/Sociotechnical and Economic Systems; 4.1. Human-Systems Integration; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. There is a grey area between market-pull and technology-push markets, in which stakeholders are aware of an issue they want solved, yet do not have clear expectations or technical affiliation. This paper presents a method to meaningfully include stakeholders coming from a non-technical back-ground in the design process. We propose and evaluate a combination of Systems Engineering for indirect involvement and a Human Centered Design approach for direct involvement of such stakeholders. We present this with a relevant case study on technological advancements in the cleaning industry (lack of technical background). The indirect approach helped creating a high-level system view, while the direct approach shed light on the low-level functions. As expected cleaners showed a clear difference in creative thinking when compared to design experts (by adopting a more pragmatic approach). Despite this, our approach showed promise in engaging non-technical stake-holders with shaping the architecture of a technical system.

Paper#44

LEAP – A Process for Identifying Potential Technical Debt in Iterative System Development

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Presented on: Tuesday, 15:30-16:10 HST (316B)

Keywords. Technical Debt Identification Iterative Development

Topics. 17. Sustainment (legacy systems, re-engineering, etc.); 2.3. Needs and Requirements Definition; 3.3. Decision Analysis and/or Decision Management; 5.5. Processes; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. By the time that a system developer realizes that early decisions have a negative impact on the system, it is often too late to correct that decision. The LEAP process defined in this paper provides a mechanism to proactively identify development pathways that have substantial impact on the ability to meet the stakeholder needs and to model the impacts of investing in one or more of those pathways.

Paper#49

LEAPing Ahead – The Space Development Agency's Method for Planning for the Future

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Presented on: Wednesday, 16:15-16:55 HST (313B)

Keywords. Rapid capability development Technology development Space Development Agency

Topics. 2. Aerospace; 2.3. Needs and Requirements Definition; 3.3. Decision Analysis and/or Decision Management; 5.5. Processes; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. The Space Development Agency is a constructive disruptor within the Department of Defense, tasked with rapidly acquiring and delivering space-based capabilities. To enable this rapid pace, SDA has developed a process called LEAP to identify the technologies that require investments to meet current and future needs. This paper presents an example of applying the LEAP process to determine the best investments for SDA's optical communication terminal technology development.

Paper#70

Lessons Learned and Recommendations for the Application of Systems Engineering as an Emerging Discipline in Transportation & Infrastructure Projects

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Presented on: Monday, 10:45-11:25 HST (313B)

Keywords. Lessons learned systems engineering application infrastructure systems development life cycle

Topics. 1.6. Systems Thinking; 12. Infrastructure (construction, maintenance, etc.); 16. Rail; 2.2. Manufacturing Systems and Operational Aspects; 2.3. Needs and Requirements Definition; 2.4. System Architecture/Design Definition; 2.5. System Integration; 2.6. Verification/Validation; 3.1. Acquisition and/or Supply; 3.5. Technical Leadership; 3.8. Quality Management Process; 5.5. Processes;

Abstract. While systems engineering (SE) has been a well-established discipline focusing on interdisciplinary systems and engineering management of complex systems over their life cycles, SE is still widely unknown in the U.S. infrastructure industry. The U.S. has recently passed a $1 trillion infrastructure bill (H.R. 3684), calling for investments in roads, bridges, rail, ports, airports, power, water, broadband, and other major projects. It is the intent of this paper to provide practical guidance to infrastructure owners and operators who are interested in reaping the benefits of applying SE to their transportation and infrastructure projects. This paper memorializes the lessons learned from over a of decade of real-world, hands-on experience of introducing and gradually increasing the application of systems engineering to building the civil infrastructure of the California High-Speed Rail System (CHSRS), starting with the environmental impact review, preliminary engineering, final design, construction, inspection and testing, and finally the certification and planned handover of 119 miles of civil work and over 225 individual structures to the following track and systems contracts. As the first three CHSRS civil works construction packages (CP) are currently nearing completion, three new civil work and passenger station procurement contracts have recently been awarded, extending CHSRS to 171 miles and close to 300 structures, including four passenger stations, with additional track and systems, trainset, and train operator contracts planned in the near future. The extension of the CHSRS presented a timely opportunity to incorporate the SE lessons learned during the first three construction packages and update the systems engineering process requirements for the new CHSRS extension projects going forward. The SE requirements are presented in form of Systems Development Life Cycle (SDLC) requirements and have been prepared as tailored requirements for both civil infrastructure and track and systems contracts. This paper intends to share the lessons learned and present them as specific and actionable recommendations, providing practical guidance for the application of SE to transportation and/or infrastructure projects.

Paper#1

Linking UAF and SysML Models: Achieving Alignment Between Enterprise and System Architectures

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Presented on: Thursday, 08:00-08:40 HST (316A)

Keywords. MBSE SysML UAF UAFML Enterprise Enterprise Architecture System Architecture

Topics. 2. Aerospace; 2.1. Business or Mission Analysis; 2.4. System Architecture/Design Definition; 5.3. MBSE; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Even though SysML is the most commonly used way to model a system, modelers are starting to realize that there are some clear advantages in using the UAF Modeling Language (UAFML) for that purpose. The Unified Architecture Framework (UAF) is designed to facilitate the modeling of a system (at a high level) along with the driving enterprise objectives and strategies, operational activities and mission threads, capability objectives and roadmaps, and a variety of other considerations that apply to the system under development. However, when the system (or a collection of systems) is modeled using UAFML, there is a challenge in linking the UAF model to the corresponding system models created using SysML to ensure proper alignment is established and maintained. This paper examines four alternative ways of achieving this alignment and discusses the benefits and drawbacks of each approach.

Paper#29

Managing Knowledge Transfer in Innovative Complex Systems Development: Case Study of Renewable Energy Project in the Oil and Gas Industry

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Presented on: Thursday, 08:00-08:40 HST (316B)

Keywords. System engineering System architecture A3AOs Renewable energy project Oil and gas industry

Topics. 1. Academia (curricula, course life cycle, etc.); 1.1. Complexity; 1.5. Systems Science; 1.6. Systems Thinking; 15. Oil and Gas; 2.4. System Architecture/Design Definition; 3.4. Information Management Process; 4.3. Reliability, Availability, and/or Maintainability; 5.2. Lean Systems Engineering; 5.3. MBSE; 8. Energy (renewable, nuclear, etc.); 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Industry system engineering

Paper#197

MBFHA: A Framework for Model-Based Functional Hazard Assessment for Aircraft Systems

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Presented on: Tuesday, 10:45-11:25 HST (316A)

Keywords. Model-Based Systems Engineering MBSE Safety assessment Safety analysis model-based safety analysis Functional Hazard Assessment FHA ARP4761 Aircraft systems UML

Topics. 2. Aerospace; 2.4. System Architecture/Design Definition; 20. Industry 4.0 & Society 5.0; 4.6. System Safety; 5.3. MBSE;

Abstract. To address growing system complexity in the aerospace industry, MBSE has been increasingly adopted for the development of aircraft systems. This calls for a corresponding model-based approach for performing safety assessment to maintain consistency between the system and safety domains. We introduce the MBFHA framework which describes the language, method, and tool needed for implementing a model-based approach to performing Functional Hazard Assessment and integrating it into MBSE activities.

Paper#128

MBSE Model Management Pain Points – Wait, this looks familiar!

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Presented on: Monday, 15:30-16:10 HST (316A)

Keywords. MBSE Model Lifecycle Management Digital Engineering

Topics. 2. Aerospace; 5.3. MBSE; 6. Defense;

Abstract. It has been almost 20 years since INCOSE and the OMG kicked off an effort to create a standardized model-based systems engineering modeling language. That effort culminated in 2006 with the creation of the Systems Modeling language (SysML) based on the UML language for modeling object-oriented software and systems. Over the past several years, numerous industries have increased their adoption of SysML and MBSE as a core practice within their engineering lifecycles. However, the introduction of SysML and MBSE methodologies has not yet yielded many of the originally envisioned benefits. On closer inspection, many of the challenges and barriers MBSE practitioners are currently struggling with were encountered and resolved decades ago by the software development community regarding scale and complexity. System models are becoming larger and more complex. In the US DoD, several programs have engaged in model-based acquisition to the point that some RFPs now include government reference architectures. Yet, in this expanding and maturing MBSE environment, projects continue to experience problems with model integration, repository performance and model lifecycle management. These problems are remarkably similar to the problems seen in large DoD software programs from the 1970s and 80s. It is time to go back and take another look at how that community attacks problems of extreme scale. The similarity of MBSE's model management pain points to those experienced years ago by the software industry is not unexpected. Adoption of MBSE requires the replacement of the largely manual, document-based engineering processes with a complex engineering information processing system. Unlike documents, the models produced by that system are living artifacts that require management over the project lifecycle and which have all the characteristics and complexity of software. This paper presents a framework for MBSE planning and model lifecycle management based on the key practices from Systems Engineering and Software Engineering to provide an actionable set of best practices that can be applied today, to address current MBSE lifecycle management issues. These best practices are organized around three key MBSE Model Management Imperatives.

Paper#164

Model Based Verification and Validation Planning for a Solar Powered High-Altitude Platform

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Presented on: Monday, 14:15-14:55 HST (313A)

Keywords. Verification Validation MBSE UAV Modelling

Topics. 2. Aerospace; 2.6. Verification/Validation; 5.3. MBSE;

Abstract. Model-based engineering can be an important asset to improve project organization. This paper presents the approach to conduct verification and validation planning based on SysML within a large project to develop an unmanned high-altitude platform. Key benefits are the development of a single source of truth, better management overview, unified processes and document styles within the project, improved change management, as well as reduced workloads when generating readable export documents.

Paper#222

Model-Based Acquisition (MBAcq): Uniting Government and Industry around a Common Standard

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Presented on: Thursday, 10:45-11:25 HST (313A)

Keywords. Model-Based Acquisition MBAcq Acquisition Digital Engineering MBSE

Topics. 3.1. Acquisition and/or Supply; 5.3. MBSE; 6. Defense;

Abstract. This paper will discuss the OMG MBAcq User Group, which is a broad industry body with participation from INCOSE, Armed Services, OUSD, DoD CIO, NDIA, DAU, FFRDCs and many industry suppliers such as Boeing, Northrup Grumman, Lockheed Martin, etc. working together to successfully create the standards and guidance to successfully deploy MBAcq to the larger community.

Paper#18

Model-Based FMEA & FTA with Case-Based Reasoning

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Presented on: Tuesday, 10:00-10:40 HST (313A)

Keywords. Model-Based Systems Engineering MBSE SysML FMEA FTA Safety Reliability Case-Based Reasoning Machine Learning

Topics. 4.3. Reliability, Availability, and/or Maintainability; 5.11 Artificial Intelligence, Machine Learning; 5.3. MBSE;

Abstract. The main challenge of performing safety & reliability analysis in multi-disciplinary products is the lack of information and knowledge within an organization to guide them in the beginning. In fact, such knowledge can be extracted and consolidated from historical data, technical experi-ences, and system architectures. This paper proposes an approach to leverage the value of system architecture models, safety & reliability models, and the CBR method to enable a systematic, adaptive, and multi-disciplinary knowledge management system. As a result, the engineers can retrieve and reuse the information from historical failures to guide their analysis in their existing or new product development. To improve the knowledge in CBR casebase, this paper demon-strates a conceptual idea to leverage the values of FMEA-FTA integration and SysML relation-ships. The idea enables a broader analysis and more systematic way for information correctness.

Paper#179

Modeling & Simulation SPICE: Assessing the Capability of Credible Simulation Processes

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Presented on: Tuesday, 10:45-11:25 HST (313C)

Keywords. Credible Modeling and Simulation Process Capability Assessment Credibility Assessment Assessment Model SPICE M&S

Topics. 11. Information Technology/Telecommunication; 3. Automotive; 3.3. Decision Analysis and/or Decision Management; 3.8. Quality Management Process; 4. Biomed/Healthcare/Social Services; 5.4. Modeling/Simulation/Analysis;

Abstract. While systems or products are becoming increasingly complex, the potential of virtualized or simulation-based product development is not yet fully exploited. This is mainly since simulation results are still not trusted enough. Therefore, a possible approach to derive and ensure required levels of modeling and simulation credibility from the criticality of a simulation task is presented. Furthermore, a framework is introduced for assessing the implementation of a credible simulation process.

Paper#241

Modeling System Configurations Over Time

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Presented on: Tuesday, 13:30-14:10 HST (316B)

Keywords. PLM PLE Variability MBSE SysML UAF

Topics. 17. Sustainment (legacy systems, re-engineering, etc.); 2.2. Manufacturing Systems and Operational Aspects; 20. Industry 4.0 & Society 5.0; 5.3. MBSE; 5.6. Product Line Engineering; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. One of the most troublesome and challenging parts of systems engineering is that systems keep changing. Some of the changes are planned as part of a phased system rollout. Others can occur because of changes in the environment, technology, customer need, unexpected emergent properties, competition, discovered system vulnerabilities, etc. Regardless of why, the systems engineer needs to document these configurations as part of a digital thread leading to physical systems that need to be manufactured and installed. When using SysML as part of MBSE, there are advantages and disadvantages regarding the modeling variability using inheritance and other structural modeling techniques. Elements in a so-called superclass will be inherited by all members. This is advantageous for additive systems but can cause issues when configurations require removal of systems. This paper will examine system configuration over time showing how to model configurations and changes. It will also look at other techniques such as Product Line Engineering (PLE) with OVM and Feature Based Modeling.

Paper#95

On Evaluating System Resilience by the Degree of Order Disruption

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Presented on: Wednesday, 10:45-11:25 HST (316B)

Keywords. Theoretical Foundations Measure Theory Risk Management Policy Analysis

Topics. 1. Academia (curricula, course life cycle, etc.); 1.6. Systems Thinking; 3.3. Decision Analysis and/or Decision Management; 3.8. Quality Management Process; 3.9. Risk and Opportunity Management; 4.4. Resilience;

Abstract. Resilience curves describe the diminished performance of a system over time following a shock, with the area integral above the curve representing the persistence of the lost performance. For example, in a power system, the lost power generation is measured in megawatts, and the persistence of the disruption is in megawatt hours; in a communications system, the performance in gigabits per second can be integrated over time as gigabits. The persistence metrics from the examples are not comparable. Ongoing engineering systems work is focused on disrupted order rather than disrupted performance. The Kendall's tau statistic is used to compare an initial, pre-shock set of priorities with the priorities after the shock. This paper will describe complementing system performance with system order in the estimation and integration of resilience curves, thus enabling a new quantification of resilience as a disruption of system order can be used across application domains of risk analysis.

Paper#79

Organizational System Resilience to Disinformation: A Viable Systems Model Exploration

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Presented on: Wednesday, 14:15-14:55 HST (313A)

Keywords. Viable systems model Disinformation Organizational systems Resilience

Topics. 1.1. Complexity; 1.2. Cybernetics; 22. Social/Sociotechnical and Economic Systems; 4.4. Resilience; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. This paper will introduce work in understanding how to model and measure an organizations resilience to disinformation within their information analysis and processing.

Paper#40

Orion SysML Model, Digital Twin, and Lessons Learned for Artemis I

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Presented on: Monday, 16:15-16:55 HST (316A)

Keywords. SysML model-based systems engineering MBSE digital twin Orion NASA

Topics. 2. Aerospace; 2.2. Manufacturing Systems and Operational Aspects; 5.3. MBSE;

Abstract. In 2015 it was recognized by NASA’s Orion Chief Engineer that NASA’s design insight into the Orion subsystems for Artemis I was not sufficient to provide standard engineering support to flight operations. To address these concerns, provide an opportunity to apply emerging model-based systems engineering and digital twin methodologies, and provide opportunities for employees across NASA to get hands-on training, an Orion Digital Twin pilot project was initiated in 2020 as part of the Agency’s Digital Transformation initiative. With the increase in complexities of spacecraft, and decreased time to made decisions during missions in critical or emergency situations, digital modeling and integration of design can reduce the time to answer questions by days and the required human resources by an order of magnitude over conventional approaches and was identified to be a critical capability for NASA’s future. This paper describes the genesis of the Orion Digital Twin pilot project, efforts undertaken, a reproducible methodology to take available system information from a mature program to create an executable SysML model that supports a link to the physical asset, and associated lessons learned and project deliverables.

Paper#192

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

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Presented on: Wednesday, 06:30-07:10 HST (Virtual)

Keywords. Space life support space systems engineering mental mistakes

Topics. 1.5. Systems Science; 1.6. Systems Thinking; 2. Aerospace;

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 di-vide-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 fo-cused 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 ig-noring 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#174

Phased Demonstrations of MBSE in Small Demonstration Satellite Series: Development of System Model and Environment for Full MBSE application

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Presented on: Thursday, 10:00-10:40 HST (313A)

Keywords. Small Satellite Development MBSE Methodology

Topics. 2. Aerospace; 2.3. Needs and Requirements Definition; 2.4. System Architecture/Design Definition; 5.3. MBSE;

Abstract. In order to establish a practical methodology of the Model-Based Systems Engineering (MBSE) application to satellite projects, to promote its practices, and to infuse MBSE to the Japanese space community, the Japan Aerospace Exploration Agency (JAXA) has been implementing phased and progressive demonstrations of MBSE applications, using small demonstration satellite series, so called the Rapid Innovative Payload Demonstration Satellites (RAISE), as a demonstration pre-cursor. These RAISE satellites are 100kg-class flagships in the Innovative Satellite Technology Demonstration Program, which provides on-orbit demonstration opportunities for new technologies and key-components. This paper presents the phased demonstration strategy, an overall approach, and the technology development of a system model being built for the full application of MBSE to RAISE-4. For the technology development, the paper covers framework, modeling scope, system model building, system model collaboration with analysis/simulation tool, introduction of design rationale and concerns, information sharing through OpenMBEE, for our full MBSE application.

Paper#131

Physics-Informed Gas Lifting Oil Well Modelling using Neural Ordinary Differential Equations

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Presented on: Wednesday, 10:45-11:25 HST (316A)

Keywords. Grey-box modelling Hybrid model Gas lifting oil well State estimation

Topics. 15. Oil and Gas; 5.4. Modeling/Simulation/Analysis; 5.5. Processes;

Abstract. Modelling of oil well systems is important for a wide range of petroleum scientific and oil industrial processes. Considering the uncertainty of the measurements and the demand for empirical knowledge, a purely first-principle model and a black-box model based on data are not sufficient for accurately describing an oil well system. Thus, there is a growing body of literature that recognizes the importance of data-driven methods combined with physical knowledge. However, the application of combination methods for dynamic nonlinear systems is still challenging. In this work, we demonstrate the application of a physics-informed neural network to a gas lifting oil well system. The neural ordinary differential equation is the main tool for the modeling and the simulation is examined in Julia programming language. The advantage and drawbacks of the physics-informed data-driven method are analyzed.

Paper#225

Preserving and Sharing Knowledge – Extending the UAF Security Views with Libraries, Patterns and Profiles

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Presented on: Monday, 11:30-12:10 HST (313C)

Keywords. MBSE UAF Security Pattern Reuse Architecture SysML

Topics. 3.9. Risk and Opportunity Management; 4.7. System Security (cyber-attack, anti-tamper, etc.); 5.3. MBSE; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Knowledge and experience are gained during the execution of every project. In MBSE projects, this knowledge can include problem solving techniques, algorithms, libraries of types, patterns, interfaces, components, etc. One of the ways to preserve this knowledge is by creating libraries of these reusable assets. Security patterns publicly provided as a curated, searchable, solution set library could be leveraged by projects and augmented over time, preserving the IP and knowledge.

Paper#201

Proposing a DEI Strategy for INCOSE Based on the Diversity and Inclusion Progression Framework 2.0

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Presented on: Tuesday, 10:45-11:25 HST (313B)

Keywords. diversity equity and inclusion (DEI) International Council on Systems Engineering (INCOSE) strategy development strategy implementation strategic planning

Topics. 17. Sustainment (legacy systems, re-engineering, etc.); 20. Industry 4.0 & Society 5.0; 22. Social/Sociotechnical and Economic Systems; 3.5. Technical Leadership; 3.6. Measurement and Metrics; 5.10. Diversity (cultural boundaries, diverse engineering teams, training underserved groups, etc.);

Abstract. We develop a partial INCOSE DEI strategy based on the Royal Academy of Engineering and Science Council’s Diversity and Inclusion Progression Framework 2.0. We investigate four of the eleven areas of the framework, benchmark INCOSE’s progress, and develop a set of initiatives to support INCOSE’s DEI progression. Based on this paper’s research DEI progression requires a comprehensive strategy consistently implemented over time and the passion and motivation of the organization's members.

Paper#101

Proposing a novel combination of Earned Value Management and Requirements Management

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Presented on: Thursday, 05:45-06:25 HST (Virtual)

Keywords. earned value earned value management systems engineering management project management project monitoring technical measures requirements management requirements attributes

Topics. 13. Maritime (surface and sub-surface); 15. Oil and Gas; 3.7. Project Planning, Project Assessment, and/or Project Control;

Abstract. A wide range of methodologies is used to report progress in projects, all with different strengths and limitations. One such methodology is Earned Value Management. However, both industry and academia highlight substantial issues when applying Earned Value Management on complex projects, creating a need for organizations to seek for ways to improve Earned Value Management. This paper presents the current ways of reporting progress within an organisation using Earned Value Management, its shortcomings, and how combining Earned Value Management with Systems Engineering and Requirements Management may improve the methodology. The proposed solution uses an ap-plication of requirement attributes to report previously excluded aspects, such as technical progress, the risk to schedule and budget, and customer concerns.

Paper#166

Safety Assurance of Autonomous Systems using Machine Learning: An Industrial Case Study and Lessons Learnt

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Presented on: Tuesday, 10:45-11:25 HST (313A)

Keywords. Safety Safety Assurance Artificial Intelligence Machine Learning Case Study MBSE MBSA

Topics. 14. Autonomous Systems; 4.6. System Safety; 5.11 Artificial Intelligence, Machine Learning; 5.3. MBSE;

Abstract. In order to assess AI/ML-based autonomous systems in terms of safety, is it not sufficient to assess the system w.r.t. potential failures that could lead to hazards (e.g., as proposed by standards such as IEC 61508, ARP 4761, etc.). Also, functional weaknesses/insufficiencies of the used algorithms according to Safety Of The Intended Functionality (SOTIF) standard ISO 21448 must be considered. In this paper, we present an approach for the safety assessment of systems incorporating AI/ML models using a Model-based Systems Engineering (MBSE) and a Model-based Safety Assurance (MBSA) approach. Therefore, we introduce with Component Fault and Deficiency Trees (CFDTs) an extension of the model-based Component Fault Tree (CFT) methodology. Thereby, we are able to describe cause-effect-relationships between individual failures as well as functional insufficiencies and system hazards and show that all risks are mitigated. In this paper, we apply our approach to an industrial case study of a self-driving toy vehicle (the PANORover) and present our lessons learnt.

Paper#121

Scalable, Flexible Implementation of MBSE and DevOps in VSEs: Design Considerations and a Case Study

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Presented on: Thursday, 08:00-08:40 HST (313A)

Keywords. MBSE DevOps VSE Small business

Topics. 11. Information Technology/Telecommunication; 19. Very Small Enterprises; 2.1. Business or Mission Analysis; 5.1. Agile Systems Engineering; 5.3. MBSE; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Model-based systems engineering (MBSE) and development operations (DevOps) both provide organizations with increased system development capabilities by defining development process controls and defining sequential development, testing, and other processes. As the use and complexity of MBSE and DevOps processes for software systems development continues to rise, very small entities (< 25 employees) may struggle to implement full scale implementations of these engineering project management processes. This paper uses principles from MBSE and DevOps models to explore a reduced, simplified scope of both system development paradigms that VSEs can implement to obtain benefits of both processes.

Paper#169

Seamless Transitions from Logical to Physical Avionics Architecture Models for Preliminary Aircraft System Design

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Presented on: Thursday, 10:00-10:40 HST (316A)

Keywords. Preliminary Systems Design Aircraft Avionics Architecture Seamless Model Transition Safety-Critical Systems

Topics. 11. Information Technology/Telecommunication; 2. Aerospace; 2.4. System Architecture/Design Definition; 5.12 Automation; 5.5. Processes;

Abstract. The transition to Integrated Modular Avionics (IMA) concepts leads to a higher integration of functions, reducing amount of equipment and aircraft system mass. However, this results in a strong increase in system complexity and more interdependencies. In order to meet these challenges, seamless model-based design approaches are being broadly investigated. For this purpose, standard and semi-automated interfaces between different design steps, tools, and stakeholders are developed.

Paper#63

Shoring Up Atlantis: Knowledge Management for MBSE

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Presented on: Monday, 13:30-14:10 HST (313B)

Keywords. Model Based Systems Engineering MBSE Knowledge Management KMS MBSE Methodology

Topics. 2. Aerospace; 5.3. MBSE; 5.9. Teaching and Training; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. The benefits of model-based systems engineering have been widely lauded - but many of us struggle to hire enough competent engineers for effective implementation. This session will discuss staffing challenges companies face as they seek to implement MBSE and will present foundations for building an optimized knowledge management system (KMS) to train new and legacy engineers. Attendees will leave this session with step-by-step guidance on implementing a KMS for MBSE at their company.

Paper#85

Sustainability: A Complex System Governance Perspective

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Presented on: Thursday, 08:45-09:25 HST (313C)

Keywords. Sustainability Complex System Governance Systems Theory

Topics. 1.1. Complexity; 1.5. Systems Science; 10. Environmental Systems & Sustainability; 17. Sustainment (legacy systems, re-engineering, etc.); 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. This paper explores the sustainability field from a Complex System Governance (CSG) perspective. In general, sustainability suggests maintenance at a specific rate or level. It is also frequently held as maintaining ecological balance to negate the depletion of natural resources. CSG offers sustainability a theoretically grounded, model informed, and methodologically driven approach to deal with sustainability design, execution, and development for complex systems. CSG examines sustainability as an outcome-based product resulting from effective governance of an underlying system which produces sustainability. Thus, sustainability is pro-posed as a ‘systems engineered product’, whose design, execution, and development will be favored by CSG systems engineering. Following an introduction, two primary objectives are pursued. First, Systems Theory is used to provide an alternative view of sustainability. Second, a perspective of sustainability is developed through the paradigm of the emerging CSG field. The paper closes with the contributions, opportunities, and challenges for deployment of CSG for enhanced development, transition, and maintenance of sustainable systems.

Paper#233

SYSTEM MODEL VALIDATION: A FRAMEWORK AND SYSML PROFILE FOR MODEL-BASED SYSTEMS ENGINEERING

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Presented on: Wednesday, 11:30-12:10 HST (313A)

Keywords. Validation System Models Systems Modeling Language Model-based Systems Engineering Digital Engineering

Topics. 1. Academia (curricula, course life cycle, etc.); 2. Aerospace; 2.3. Needs and Requirements Definition; 2.6. Verification/Validation; 5.3. MBSE; 6. Defense;

Abstract. It is recognized that Digital Engineering (DE) and Model Based Systems Engineering (MBSE) are transforming existing acquisition processes. One process that has received little extant re-search is validation. In a more traditional “design-build-test” approach, validation of stakeholder requirements predominantly happens toward the end of the development lifecycle. However, DE has been described as a more “model-analyze-build” approach. In this case, validation will be required earlier in the lifecycle, prior to build as part of refining the authoritative source of truth. This paper describes a framework that extends work by Hecht and Chen and focuses application on design reviews, particularly a tailored preliminary design review (PDR). The framework emphasizes use cases to capture the intent (why) and evidence (what) to enter and exit a PDR. Model requirements can then be derived from use cases, and test cases allow automated and manual methods to assess quality, completeness and consistency of the system model. While the framework is prototyped on a small unmanned airborne system (sUAS) model created for a PDR in a graduate course, there appears wide interest across the US Air Force for a similar framework.

Paper#64

System Requirements Development under a Dual Prime Contracting Model

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Presented on: Tuesday, 16:15-16:55 HST (316B)

Keywords. Requirements Contracting Collaboration

Topics. 13. Maritime (surface and sub-surface); 2.3. Needs and Requirements Definition; 3.1. Acquisition and/or Supply; 3.7. Project Planning, Project Assessment, and/or Project Control; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Developing requirements for a highly coupled complicated system is a challenging prospect for any project. The task gets more complicated if multiple organisations are needed to deliver the required solution. This session relates the practical experience of ‘dual prime contracting’ where two organisations take the lead for the delivery of a system in response to the requirements of a common customer.

Paper#50

System verification via Model-Checking: A case study of an autonomous multi-differential drive robot

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Presented on: Monday, 10:45-11:25 HST (313A)

Keywords. SysML Formal Verification Model Checking NuSMV DDR

Topics. 14. Autonomous Systems; 2.6. Verification/Validation; 5.3. MBSE; 5.7. Software-Intensive Systems;

Abstract. Model-Based Systems Engineering (MBSE) has been utilized in practice for the design and behavioral modeling of cyber-physical systems. The Vee model helps frame MBSE's lifecycle approach, with system verification a vital aspect of the qualification process. However, popular modeling language tools in MBSE, such as Systems Modeling Language (SysML), are incapable of formally verifying these systems. Model checking allows for the development of formal system models similar in abstraction to SysML models for automatically checking if these formal models satisfy formal specifications. We propose an approach to translate behavioral diagrams in SysML, such as state-machine diagrams, to the popular symbolic model checker NuSMV for formal verification. As a case study, we apply this process to autonomous multi-differential drive robots (DDR). Subsequently, the NuSMV model is verified against some formal operational specifications obtained from the requirements diagram of the DDR. This system verification approach can help System Engineers identify design flaws or incorrect modeling or specifications that could be missed during the design phase through the results of the model checking process.

Paper#34

Systems Engineering Approach for the SPHEREx Telescope Mission

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Presented on: Thursday, 08:00-08:40 HST (KALAKUA BALLROOM C)

Keywords. Telescope Astrophysics Systems Engineering

Topics. 2. Aerospace; 2.1. Business or Mission Analysis; 3.7. Project Planning, Project Assessment, and/or Project Control; 5.5. Processes;

Abstract. The Spectro-Photometer for the History of the Universe, Epoch of Reionization and Ices Explorer (SPHEREx) was selected in 2019 as a NASA Astrophysics Medium Class Explorer mission to perform the first infrared all-sky spectral survey. The mission consists of a single wide field of view telescope mounted on top of a Ball Configurable Platform (BCP) spacecraft bus. Over the course of its two-year mission, the SPHEREx observatory will perform four all-sky surveys and provide spectroscopic measurements of hundreds of millions of galaxies and a diversity of astronomical phenomena. SPHEREx is currently in phase C, post-Critical Design Review (CDR) and is in the process of building and testing hardware in preparation for observatory Assembly, Test, and Inte-gration (AI&T) in early 2024. The observatory is expected to launch on a Falcon 9 rocket no earlier than February 2025. Project level systems engineering support is provided by the Jet Propulsion Laboratory (JPL) and oversees the technical development of the observatory and its ground operations. Systems engineers are staffed throughout the all systems and act as a key interface between the mission’s many partners. This paper focuses on the systems engineering approach for the SPHEREx mission including its architecture, verification and validation methodology, and its risk and resource management approach.

Paper#183

Systems Thinking Applied to Higher Education Curricula Development

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Presented on: Wednesday, 13:30-14:10 HST (316B)

Keywords. systems systems thinking higher education curricula development

Topics. 1. Academia (curricula, course life cycle, etc.); 22. Social/Sociotechnical and Economic Systems; 3.5. Technical Leadership; 3.7. Project Planning, Project Assessment, and/or Project Control; 3.8. Quality Management Process; 5.5. Processes; 5.9. Teaching and Training; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. This paper considers the application of Systems Thinking (ST) principles to the field of higher education curricula development. Evaluation of system boundaries, external influences, internal factors, and educational curricula development feedback mechanisms are addressed. Preliminary results suggest that proper use and implementation of ST principles to higher education curricula development and refinement can produce efficiency of development and improvement in student learning outcomes.

Paper#48

The AGILE 4.0 Project: MBSE to Support Cyber-Physical Collaborative Aircraft Development

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Presented on: Monday, 14:15-14:55 HST (313B)

Keywords. mbse mdao aircraft design requirements logical architecture

Topics. 11. Information Technology/Telecommunication; 2. Aerospace; 2.4. System Architecture/Design Definition; 20. Industry 4.0 & Society 5.0; 5.3. MBSE; 5.5. Processes;

Abstract. The AGILE4.0 MBSE-MDAO Development Framework leverages MBSE and Multidisciplinary Design Analysis & Optimization (MDAO) techniques to enable collaborative development of complex aeronautical systems. Processes, methods, and implemented tools are presented. The development framework is demonstrated using a business jet family design application case.

Paper#46

The INCOSE Systems Engineering Heuristics: What Are They Telling Us About the Discipline?

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Presented on: Wednesday, 10:00-10:40 HST (316B)

Keywords. heuristics natural language processing bibliometrics

Topics. 1. Academia (curricula, course life cycle, etc.); 1.6. Systems Thinking; 5.11 Artificial Intelligence, Machine Learning; 5.5. Processes; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. The INCOSE Fellows have been leading an effort to develop heuristics that will help systems engineers pass on their knowledge regarding the best practices within the discipline. We performed bibliometric analysis on the text corpus of 164 heuristics and of the sources cited in them to gain insights into what the heuristics data is telling us about the discipline of systems engineering. We performed co-occurrence analysis using VOSviewer, which is a software application that identifies pairs of terms and connects them. This analysis found terms that occur together across multiple heuristics by applying a natural language processing algorithm that identified the terms and formed clusters of terms that are strongly related to each other. To gain further insight into the co-occurrence results, the INCOSE Fellows participated in a contest to name the clusters and create narratives that provide a rationale for the cluster names and why it would make sense for the terms to belong to the clusters they were assigned to. Finally, a ballot was created to send out to a broader collection of INCOSE members to vote on the best name for each cluster among the names provided by the Fellows. The three-step process of bibliometric analysis, cluster naming by the Fellows, and voting by the members identified emergent disciplines essential to the practice of systems engineering. We also performed bibliographic coupling analysis and co-citation analysis using VOSviewer. A bibliographic coupling link is a link between two heuristics that both cite the same source. A co-citation link is a link between two sources that are both cited by the same heuristic. The coupling analysis identified clusters among the heuristics that revealed communities of practice within systems engineering, and the co-citation analysis identified clusters among the cited references to reveal communities of theory in systems engineering.

Paper#61

The MBSE competence at the German Aerospace Center

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Presented on: Wednesday, 15:30-16:10 HST (313B)

Keywords. MBSE Competence Map Aeonautics Space Transport Energy Digitalization Security

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

Abstract. Model Based Systems Engineering (MBSE) is gaining more and more popularity among different practitioners in academia, research centers and industries, due to all the claimed advantages, e.g. in terms of improved collaboration and communication between system developer teams, in-creased traceability, possibility of reusing models. Different MBSE approaches and tools are in use since several years also at the German Aerospace Center (DLR), where research is addressed in multiple domains, namely aeronautics, space, energy, transport, security and digitalization. However, all the MBSE initiatives done at the DLR are now focusing within single domains, while an increased interoperability of MBSE approaches and tools across the different DLR do-mains would greatly improve engineering processes and knowledge of the whole DLR. The re-search described in this paper therefore addresses the recent activities performed to consolidate and harmonize the MSBE approaches and tools in DLR and to make them interoperable among the different research domains. In this context, the entire MBSE competence spread among the entire organization is collected and assessed, showing that DLR is very active in MBSE-related research performed in different domains.

Paper#235

Think Like an Ecosystem: Transitioning Waste Streams to Value Streams

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Presented on: Wednesday, 13:30-14:10 HST (313A)

Keywords. Systems Thinking Ecology Environment Sustainable Design Circular Economy Model-Based Systems Engineering MBSE SysML

Topics. 1.3. Natural Systems; 1.6. Systems Thinking; 10. Environmental Systems & Sustainability; 22. Social/Sociotechnical and Economic Systems; 4. Biomed/Healthcare/Social Services; 5.3. MBSE;

Abstract. To meet the material demands of the future, transitioning waste streams to value streams is a vital step in ecological and economic sustainability. The development and implementation of circular systems is key to the evolution of global pro-duction. Through the analysis of the copper used in medical devices we illustrate some considerations systems engineers can make to close the waste-resource gap.

Paper#239

Toward Systems Engineering Meta-Methodology

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Presented on: Wednesday, 11:30-12:10 HST (316B)

Keywords. systems engineering methodology method design meta-methodology

Topics. 1. Academia (curricula, course life cycle, etc.); 1.5. Systems Science; 1.6. Systems Thinking; 5.5. Processes; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. While significant Systems Engineering research deals with systems engineering methodologies, guidance for systems engineering methodology building is lacking. We apply the systems approach to the process of designing systems engineering methods. This paper discusses a meta-methodology for building systems methodologies, which are in fact systems. We introduce fundamental insights about systems methodological research, that may be of great use to systems engineering method designers and users.

Paper#60

Towards an approach to co-execute system models at the enterprise level

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Presented on: Tuesday, 11:30-12:10 HST (313A)

Keywords. MBSE UAF SoS System MagicGrid System simulation

Topics. 11. Information Technology/Telecommunication; 2.4. System Architecture/Design Definition; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Industry 4, the Internet of Things, and large-scale system-to-system interactions are driving digital transformation in the industry. Model-based systems engineering (MBSE) is one of the core paradigms behind this transformation. MBSE practices are widely applied to enterprise (including system of systems and mission) architectures, which become a crucial part of successful digital transformation. The core challenge today is not only how digital continuity can be maintained by connecting different layers of models (such as system models to system-of-systems models), but also how to perform detailed analysis and simulation at the enterprise level model. This paper studies Systems Modeling Language (SysML) as the standard language to model systems, Unified Architecture Framework (UAF) as the framework, Unified Architecture Framework Modeling Language (UAFML) as the language to model enterprise architectures, and proposes an approach for end-to-end co-execution of the integrated enterprise model.

Paper#135

Understanding Interface Criticality in Large Infrastructure Projects

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Presented on: Monday, 10:00-10:40 HST (313B)

Keywords. interface management systems engineering criticality infrastructure

Topics. 12. Infrastructure (construction, maintenance, etc.); 16. Rail; 2.4. System Architecture/Design Definition; 2.5. System Integration;

Abstract. Managing interfaces has been recognised as key to mitigating the risk of project failure and is becoming more prominent in complex infrastructure projects. We review how interfaces in infrastructure projects are traditionally identified, defined, owned, assessed, and managed and provides recommendations on how to better align this with a whole-of-system approach through an assessment of interface criticality. We the apply this to the redesign of two rail-enabled ferry terminals.

Paper#56

Using HOQ Methodology to Prioritise Organisational Resilience Decisions in Training Establishments

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Presented on: Wednesday, 15:30-16:10 HST (316A)

Keywords. Organisational Resilience House of Quality Training Organisations Enterprise Architecture

Topics. 3.8. Quality Management Process; 4.4. Resilience; 6. Defense;

Abstract. We report a novel adaptation of the HOQ approach to prioritise organisational resilience decisions, demonstrated in a large Defence Training Establishment. Weights of various organisational functions derived from survey-based stakeholder engagements are combined with organisational performance assessments to determine the value of the organisation under the stress arising from the adversity. In turn, this knowledge enables decisions that target improvement of organisational resilience.

Paper#11

Using the Unified Architecture Framework in Support of Mission Engineering Activities

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Presented on: Thursday, 08:45-09:25 HST (316A)

Keywords. Mission engineering Mission architecture Enterprise architecture Unified architecture framework Enterprise systems engineering Architecture modeling

Topics. 2. Aerospace; 2.1. Business or Mission Analysis; 2.4. System Architecture/Design Definition; 5.3. MBSE; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Mission Engineering is the deliberate planning, analyzing, organizing, and integrating of current and emerging operational and system capabilities to achieve desired warfighting mission effects. A Mission Engineering process was developed to capture the approach defined in the DOD's Mission Engineering Guide. The purpose of this is to help train new mission engineers and merge this with standard approaches for capturing mission architectures. The Unified Architecture Framework (UAF) provides a framework of standardized views from which to model different aspects of an architecture, including the various concepts and properties of the mission being engineered. The Mission Engineering steps are tied to the workflow steps in the Enterprise Architecture Guide for UAF to help inform mission engineers of which UAF views can be used during the Mission Engineering effort. This paper will discuss mapping between the UAF workflow and steps in the Mission Engineering Guide and how to use UAF when doing Mission Engineering activities.

Paper#113

Using the Unified Architecture Framework to perform hazard analysis for system of systems

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Presented on: Thursday, 10:00-10:40 HST (313C)

Keywords. Architecture framework System of systems Hazard analysis

Topics. 2.4. System Architecture/Design Definition; 21. Urban Transportation Systems; 5.3. MBSE;

Abstract. Safety analysis of systems of systems.

Paper#83

Value-driven Optimization Campaign Addressing Manufacturing, Supply Chain and Overall Aircraft Design Domains in the Early Development Stage

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Presented on: Thursday, 11:30-12:10 HST (316A)

Keywords. MDO supply chain managment manufacturing aircraft design value engineering

Topics. 1.1. Complexity; 2. Aerospace; 2.2. Manufacturing Systems and Operational Aspects; 3.1. Acquisition and/or Supply;

Abstract. In the last decades, several studies, demonstrate how the integration of manufacturing and supply chain in the early design phase brings significant advantages to industries. Within the European Project (Anonymous 2022), a value-driven methodology concurrently coupling design, manufacturing and supply chain has been developed. This study aims at addressing a new challenge: the identification of the global optimum simultaneously accounting for manufacturing, design and supply chain variables. For this purpose, a design campaign has been addressed in this research activity and the main results are-here presented.

Paper#82

Value-driven Systems Engineering Approach addressing Manufacturing, Supply-chain and Aircraft Design in the Decision-Making Process

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Presented on: Tuesday, 13:30-14:10 HST (313C)

Keywords. value-driven systems engineering concurrent engineering decision-making supply chain management aircraft design

Topics. 2. Aerospace; 2.2. Manufacturing Systems and Operational Aspects; 3.3. Decision Analysis and/or Decision Management; 5.6. Product Line Engineering;

Abstract. In the last decades, some studies have highlighted that the integration of the product design and supply chain management leads to an increase of the profitability and efficiency of companies. However,considering manufacturing, supply chain and overall aircraft design variables in the early design phase increases the size of the solutions tradespace and thus the complexity in performing the decision-making process. This paper demonstrates how to leverage the systems engineering approach and the value-model theory to simplify the decision-process when multiple criteria leading to different domains (manufacturing, supply chain and overall aircraft design) are accounted in the design phase.

Paper#161

Variability on System Architecture using Airbus MBPLE for MOFLT Framework

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Presented on: Wednesday, 10:45-11:25 HST (313B)

Keywords. MBPLE PLE MBSE Airbus Variant Modeling System Architecture Framework Aerospace

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

Abstract. The session presents how MBPLE and variant modeling approaches can be integrated within the Airbus System Architecture Framework (MOFLT) and provides practical insights from several aerospace developments, including a practical modeling example.

Paper#203

Verification and Validation Test Framework Using a Model-Based Systems Engineering Approach

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Presented on: Thursday, 08:45-09:25 HST (313B)

Keywords. digital engineering digital transformation digital thread model-based systems engineering MBSE SysML verification validation V&V test case test framework test pattern cyber-physical systems

Topics. 2.6. Verification/Validation; 5.3. MBSE;

Abstract. This project describes a test framework for verification and validation (V&V) planning and execution using a model-based system engineering (MBSE) approach that is suitable for large-scale cyber-physical systems. The test framework (TF) is defined using the systems modeling language (SysML) and a MBSE tool and describes and links to external test plans, test procedures, and other relevant test documents. This test framework approach includes the following considerations: level of abstraction of systems for testing, multiple types of testing across the development lifecycle, design vs. system V&V approaches, verification vs. validation, and the use of test patterns, instances, inheritance, and libraries. The libraries contain distinct types of tests to maximize model element reuse. An example is provided that illustrates application of this V&V Test Framework (V&VTF) to a lubrication system. This method demonstrates that the proposed V&VTF is desirable as part of Systems Engineering metamorphosis to support an organization's digital transformation.

Presentation

Presentation#31

A Discussion of Engineering Archetypes and What They Mean to You

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Presented on: Tuesday, 10:00-10:40 HST (313B)

Keywords. Risk Opportunity Decision Expert Teams Soft Skills Communication Interpersonal Dynamics Engineer Architect

Topics. 3.5. Technical Leadership; 3.9. Risk and Opportunity Management; 5.10. Diversity (cultural boundaries, diverse engineering teams, training underserved groups, etc.); 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. What's the difference between an Architect and a Systems Engineer? What's the difference between a Project Manager and a Systems Engineer? If I'm the expert, why does it seem like everybody needs my input, and yet nobody ever listens to me? Why is it that whenever I ask the technical team what they need from our environment, they always respond what can you give us? If you've ever found yourself asking any of the above questions, this presentation is for you. Because in this presentation we're going to focus on similar—often overlapping—roles that are inherently different. If risk management and opportunity management is just a difference between uncertain positive and negative outcomes, why do the activities feel so different? And why is the Project Manager so frustrated with me when I tell them about the risk to their decisions? In a professional setting, regardless of our roles (e.g., Test Engineer, Systems Analyst, Division Manager, etc.) Systems Engineers tend to rotate through three archetypes—"Decision Maker", "Expert", and "Support"—with clear patterns of responsibilities that tend to overlap with closely aligned organization roles (e.g., managers, architects, etc.) that lead to frustrating interactions day-to-day. In this presentation, we will focus on those archetypes and the relationships between them to identify everyday best practices. Through understanding what archetypes your teams are fulfilling from moment to moment, and what those archetypes need to feel empowered and impactful, those best practices will help you build stronger, high-functioning multi-disciplinary teams faster and more efficiently. And (perhaps, most importantly) will help you to expand your influence as a Systems Engineer while reducing your day-to-day stress.

Presentation#9

A Methodology for Model Federation Applied Across Defense Systems Development Programs

Chris Swickline (SAIC) - crs098@gmail.com

Presented on: Thursday, 11:30-12:10 HST (313B)

Keywords. Model Based Systems Engineering Digital Engineering Systems of Systems Model Federation SysML

Topics. 2.4. System Architecture/Design Definition; 5.3. MBSE & Digital Engineering; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 6. Defense;

Abstract. As system complexity increases, a greater number of organizations are being asked to contribute architecture/design content for systems development. An essential challenge to overcome is how to ensure digital continuity in connecting system models to form Systems of Systems (SoS) models. A method is presented for SysML model federation enabling multiple contributing organizations to provide peer models for inclusion within a federation SoS model. This method builds upon previously published Systems Architecture Model (SAM) development method reinforced with automated model syntax validation, Cameo implemented style guide, and example model. Systems engineers applying this method are able to reuse constituent systems model content, from the problem and/or solution space, to describe the larger SoS behavior and structure while promoting reusability and commonality. This method is designed to permit style diversity across peer constituent models and ensure that every piece of data has an Authoritative Source of Truth (ASOT) within the federation. Multiple applicable examples within the defense industry are presented as well as real world example showing specific evidence of a measurable improvement. Systems engineering practitioners engaged in Model Based Systems Engineering (MBSE) will take away a multi-model management approach to construct SoS descriptive models in SysML in line with the DOD’s Digital Engineering (DE) Strategy.

Presentation#59

A Telecommunications Primer

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Presented on: Tuesday, 15:30-16:10 HST (KALAKUA BALLROOM C)

Keywords. ICT Telecommunications Primer

Topics. 1.6. Systems Thinking; 11. Information Technology/Telecommunication; 2.4. System Architecture/Design Definition; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.);

Abstract. The ICT Working Group (previously Telecommunications WG) are creating a telecommunications primer to assist systems engineers and network/communication engineers to apply the systems engineering knowledge to the application of communications networks. As a society, we have become exceedingly dependent on our communication devices and the communications networks supporting them. Even short duration network outages can: result in chaos within public transport systems (air traffic control of commercial flights, traffic signalling of rail networks); disrupt financial systems (electronic payments, stock market transactions) and; reduce business productivity (phone and email). Yet it is inherently difficult to apply the systems engineering body of knowledge to communications networks, as they are distributed, generally do not have clean systems boundaries, are continually changing their structure, and have an infinite number of system interfaces. Being able to model these networks as systems enables the application of the systems engineering knowledge to the betterment of the everyone. This primer brings a Systems Engineering approach to simplify the understanding of underlying communications networks whose elements are owned and managed by multiple different organizations and are controlled outside of the system of interest, and provide guidance on how to model communications networks as systems, thus enabling the application of the systems engineering body of knowledge.

Presentation#20

Automated Creation of the INCOSE Systems Engineering Handbook

Thomas Shortell (Lockheed Martin) - thomas.shortell@gmail.com

Presented on: Thursday, 10:45-11:25 HST (316B)

Keywords. Systems Engineering Handbook Automation International Team New Technology

Topics. 5.12 Automation; 5.5. Processes;

Abstract. The International Council on Systems Engineering (INCOSE) Systems Engineering Handbook is INCOSE's premier product. For the Fifth Edition, the editors re-system engineered how the handbook was to be created. The handbook describes the state-of-the-good-practice for Systems Engineering (SE), is the authority for INCOSE SE certification, and is led by an Editorial Team from across the globe with the support of the INCOSE Working Groups (WGs) and Subject Matter Experts (SMEs). This presentation will explain the complexities of working with authors across the globe (including all three INCOSE sectors). The editors had to incorporate 131 text files along with 140 figures and tables that were being continually refined and updated over several years. This presentation will describe how automating the handbook creation processes helped the editors cope with these challenges. This presentation will discuss an approach that used standard Microsoft Office tools to automatically and continually integrate all the text, figure, and table submissions from the authors. It will discuss the improved productivity provided by the automation that enabled the successful creation and review of the Fifth Edition . As the Fifth Edition is released at this IS, this presentation provides an opportunity to see how the handbook moved into the future by using automation.

Presentation#66

Barriers to implementing DevOps for Complex Safety-Critical Systems

Robin Yeman (Robin Yeman) - robinyeman@gmail.com
Suzette Johnson (Northrop Grumman) - suzette.johnson5@gmail.com

Presented on: Tuesday, 14:15-14:55 HST (316B)

Keywords. DevOps Systems Engineering Agile

Topics. 2. Aerospace; 5.1. Agile Systems Engineering; 5.2. Lean Systems Engineering; 5.6. Product Line Engineering; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. In 2009 Patrick Debois coined the term DevOps at a Velocity event in Belgium. 12 years later there have been countless books to describe this cooperation between development and operations to deliver capability rapidly to the user. We further have extended that term into Industrial DevOps to account for complex system of systems which include hardware, firmware, and software. Many of the practices such as small batch sizes, limit work in progress, and organizing around value are not new. The benefits of these practices in quality, schedule, cost, transparency, value are undisputed facts that have been shown repeatedly in periodicals such as the DORA report. The question is if the ideas are not new, and the benefits are proven why is it so difficult for organizations to move to DevOps and almost impossible to move to Industrial DevOps. Robin Yeman and Suzette Johnson Senior Northrop Grumman Fellow will walk through the common barriers to adoption they see in these two large scale companies as well as invite the audience to participate in potential root causes of these barriers. The barriers we will discuss are Organizational Structure, Psychological Safety, Access to Common Language, Understanding the Value Stream, Lack of Trust, Access to patterns to break down systems, and exclusive over inclusive behaviors. In this session you will not only hear stories of programs who are experiencing these barriers you will have the opportunity to collaborate on solutions.

Presentation#46

Beyond Digital: Bridging the Divides

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

Presented on: Tuesday, 13:30-14:10 HST (316A)

Keywords. Digitization Digitalization Sociotechnical Transformation

Topics. 1.6. Systems Thinking; 20. Industry 4.0 & Society 5.0; 5.3. MBSE & Digital Engineering;

Abstract. We live in the age of digital, leveraging unprecedented computational power and storage to improve our lives. As we apply digital to our organizations, the critical business and engineering concepts of today – digital transformation, digital thread, digital twin, digital engineering – are far more than technology. All live at the intersection of human and technology, world view and workflow, culture and organizational change. Yet we tend to focus on technology often to the extreme of doing so in isolation. How can we look beyond digital, embrace the greater scope, and bridge the divides to transform our approaches and deliver success in the digital age? This presentation first establishes the changing context for systems engineering framing the explosion in complexities and expectations. Alongside the six megatrends identified in INCOSE Systems Engineering Vision 2035, we see the growth in system scale, mission complexity, technology complexity, project team complexity, and dynamic complexity (where problems and technologies rapidly evolve inside the solution loop.) As the problems and complexities grow, so does the pressure to reduce cycle time. Within this context, there are four fundamental steps to delivering success in the digital age. First is to embrace 21st century technologies. We do not have to engineer tomorrow's solutions with yesterday's technology. That means educating ourselves on and leveraging digitalization, big data and analytics, AI/ML, augmented reality and virtual reality, additive manufacturing, biotechnology, and more. From the perspective of the systems engineer, it means avoiding the trap of creating new digital silos, instead ensuring the unbroken thread of traceability and provenance throughout the project lifecycle. While digital and technology is where we should begin, it cannot be where we end. Second we must transform for today's world and reconnect with systems thinking. This means shifting from a mechanistic mindset to a life sciences / biological mindset better suited for today's interconnected world. Recognizing the pace of change in problem, solution, and expectation, it means less linear thinking and more agile parallel approaches. In doing so, it means moving from digitizing what we did before to reconceptualizing and digitalizing new approaches better suited for the problems, pace, and uncertainty of today. Third, we must shed some of our arrogance and look beyond engineering. Human expectations, humans inside our systems, and societal needs are fundamental drivers in the complexity we face and in addressing that complexity. That means reconnecting with the socio dimension of sociotechnical embracing the human in the system and human in the engineering of systems. While leveraging new technologies, transforming our mindset, and embracing the socio in sociotechnical are all critical enablers, we cannot deliver success until we commit to deploying and transforming new approaches suited to both our problem, our organization, and our business value. As systems engineers, it can be helpful to frame this as an enterprise systems problem leveraging classical systems tools: stakeholder identification, requirements elicitation, black box thinking, and journey mapping. Defining and undertaking the journey is the fourth key step. Whether we change is not in question. The future demands that we change. Changes in our context, technologies, and workforce guarantee change and some form of digitization for all but the simplest of circumstances. But will we go beyond digital, and how successful will we be? Without focus, approaches tend to devolve to accidental, fragmented, or assembled. The path to success lies in embracing our systemic and holistic foundations, engineering the transformation, and bridging the divides across the technological and socio dimensions.

Presentation#33

Bridging Systems Engineering Models and Multi-Fidelity Analytical Models - MBSE Application to a Medication Auto-Injector Design

Steve Cash (Zuken Vitech Inc.) - steve.cash@vitechcorp.com
Alexandre Luc (Ansys) - alexandre.luc@ansys.com

Presented on: Tuesday, 15:30-16:10 HST (313C)

Keywords. Model-Based Systems Engineering (MBSE) Analytics Medical

Topics. 4. Biomed/Healthcare/Social Services; 5.3. MBSE & Digital Engineering; 5.4. Modeling/Simulation/Analysis;

Abstract. Systems engineering in all industries has been increasingly turning to Model-Based Systems Engineering (MBSE) to meet market expectations. This helps in designing ever more complex systems while reducing development cost and time, maximizing system performance, and improving product safety. By aligning people, processes, and technology around a single product vision, MBSE promises to dramatically reduce the cost and risk of developing complex systems. One challenge is connecting systems engineering architectural models to detailed engineering analytics to achieve the full potential of MBSE. We will discuss an approach to unlock the promise of MBSE by connecting a systems architectural model with analysis/simulation models and workflows, assuring that the product vision remains in sync with the underlying analysis throughout the product lifecycle. This allows engineers to validate requirements, simulate system behavior, and carry out Multi-Disciplinary Analysis & Optimization (MDAO) to optimize system design at any time during the design process. Rigorous traceability between requirements, design, and analysis results in improved quality. This presentation will use the example of an auto-injector for medication delivery to show how to setup the system architectural model to capture the required information and the needed analyses, create and parameterize the analytical models, integrate the system architectural model and the analytical models, run trade studies, and close loop with detailed design analyses to ensure requirements compliance and traceability.

Presentation#29

Connecting the Dots: digital threads benefits and best practices

Eran Gery (IBM) - eran.gery@il.ibm.com

Presented on: Tuesday, 14:15-14:55 HST (313B)

Keywords. digital-engineering digital-threads interdisciplinary engineering lifecycle integration digital exchange standards OSLC configuration management semantic web impact analysis

Topics. 2. Aerospace; 3. Automotive; 3.2. Configuration Management; 5.3. MBSE & Digital Engineering; 5.6. Product Line Engineering; 6. Defense;

Abstract. Digital transformation of engineering is one of the key transformational areas of interest within the complex systems industry, and it is also part of INCOSE Vision 2035. This transformation is also referred to as digital engineering. While digital engineering embraces usage of model-based engineering, the main challenge nowadays is to integrate the various digital models, from SoS models to systems models downstream to discipline specific models, such as electrical, mechanical, software designs etc. Digital-threads is an information architecture which is an essential backbone for effective digital engineering. Digital threads architecture supports the necessary capabilities to integrate the various models and data sources, which we refer to as digital data. Digital threads foster data connectivity, consistency, and streamline the engineering process to support the necessary velocity and agility needed by modern engineering. There are technological challenges to implement digital threads, as it requires to establish a digital fabric across various modeling and engineering domain tools, provided by different vendors. Surprisingly, despite the popularity of the topic, the industrial adoption is still at the infancy stage, where most systems engineering lifecycle environments consist of siloed domain tools, or partially integrated at best. In this talk we discuss the benefits of digital threads and how they are leveraged, the challenges and different approaches on how to realize them: from centralized architectures, to federated open architectures. After, we describe in more detail a digital threads architecture based on the open services for lifecycle (OSLC) standard. OSLC is referred to by the INCOSE 2035 vision as the standards-based architecture for digital transformation, and is also part of the upcoming SysML V2.0 proposed standard. OSLC utilizes the W3C semantic web stack to establish a digital fabric across the systems engineering domains, models, and other engineering data providers. We describe how the OSLC architecture addresses the following key concerns: (i) data continuity, meaning how to practically establish digital relationships across domain models provided by different domain tools, (ii) how to enable data exchange across different domain tools using different data schemas, (iii) how to deal with different baselines and configurations of engineering data in a consistent way, and enable reuse of digital data across product lines (iv) how to perform analytics such as impact analysis and KPI metrics across all data sources, and (v) how to integrate agile process enactments into such an engineering data fabric. To put all this together, we will provide an illustration of digital thread based engineering process of a surveillance UAV system, using a heterogeneous toolchain, starting from requirements and systems modeling, through to software and electronics domain tools. As part of this illustration, we demonstrate the various benefits of such a digital engineering process.

Presentation#76

Cyber Resilient Design Patterns

Brooke Guare (JHU/APL) - brooke.guare@jhuapl.edu

Presented on: Thursday, 06:30-07:10 HST (Virtual)

Keywords. Design Patterns Systems Engineering Cyber Cybersecurity Resilient Systems System Design

Topics. 1.6. Systems Thinking; 11. Information Technology/Telecommunication; 17. Sustainment (legacy systems, re-engineering, etc.); 2.4. System Architecture/Design Definition; 5.1. Agile Systems Engineering; 5.9. Teaching and Training; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Existing cybersecurity frameworks and other high-level guidance are intended to help organizations satisfy requirements for resilient infrastructures and information systems. The majority of systems in the non-cyberspace, physical realm have been designed to meet performance and functional requirements, as well as be resilient to a set of kinetic threats. However, there has not been as much attention paid to the resilience of a system to cyberspace threats. The resilience objective ensures mission accomplishment in spite of a particular cyberspace threat event, or a set of cyberspace threat events. Being able to prove or validate a system is resilient to specific threat events is challenging, non-repeatable, and a time-intensive process. Integrating good design principles early in the systems engineering lifecycle will help ensure the system will be able to be resilient to the threat event, or set of threat events. Given the early identification of threat events, a system could be susceptible to, the application of good, repeatable cyber-engineering processes that are discussed in this paper will help give engineers a head start in developing and deploying a resilient system. In order to aid engineers in designing sufficiently resilient systems, the Office of the Under Secretary of Defense for Research and Engineering (OUSD (R&E)) / Science and Technology Program Protection is sponsoring the Johns Hopkins University Applied Physics Laboratory (JHU/APL) to curate and develop design patterns that can assist in achieving system security and resilience. A design pattern is a general, reusable solution to commonly occurring problems within a given context in system design. The patterns are not meant to act as an implementation guide, but they do provide a template for how to help ensure a system will be resilient to one or more cyber threats in a variety of scenarios. In the context of this paper, a design pattern is intended to be a fundamental building block that engineers can use to put together their system to achieve a series of cybersecurity properties for resilient system design. The patterns are based on design principles and representative use cases for weapon system functions and operations. Embodied in these patterns are many concepts which are likely to already be intuitive to engineers. For example, an engineer may design redundant flight controls and monitoring computers into an aircraft flight control system to ensure safety of flight despite individual computer or component faults. The concept of such redundancy is, in essence, a design pattern, applicable and re-usable to any number of use cases where fault-tolerance is critical. The intent of our work is to aid engineers in applying intuitive principles to system designs to ensure they meet cybersecurity requirements, in addition to complying with cybersecurity policy. Having a standard set of good design principles will also help engineers replicate good design decisions. To extend the patterns beyond a paper artifact, the JHU/APL team has begun to implement and test a subset of the design patterns in a laboratory setting. Developing a physical implementation enables analysis of the efficacy and applicability of a design pattern. The implementation helps provide a tangible example for engineers to better develop guidance on how to effectively deploy the patterns in both legacy and new tactical systems. The design patterns will be presented in a template that can inform the development of systems that are resilient to cyberspace threat events. They are intended to be available for continuous improvement and development of additional design patterns by the engineering community (government, industry, and academia). These patterns combine principles, concepts, and techniques to advance the engineering practice of designing resilient systems to operate in a contested cyberspace environment.

Presentation#92

Digital and physical experiences in a concept car

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Presented on: Wednesday, 03:30-04:10 HST (Virtual)

Keywords. MBSE Journey Collaborative Digital Twin Immersive experience Automotive

Topics. 3. Automotive; 5.3. MBSE & Digital Engineering; 5.4. Modeling/Simulation/Analysis;

Abstract. Through a digital MBSE journey, Accenture and Dassault Systèmes created an immersive customer experience for a concept car of Forvia, the automotive supplier. We transformed the way of developing car interiors by introducing a wide ‘design thinking’ approach and generalizing the use of models to gather all enterprise disciplines. It enables teams to be more focused on the customer needs and co-innovate easily, reducing the time to market. This transformation relied on the setup of a collaborative and digital framework, especially developed. We connected the modeler CATIA Magic, the runtime manager ControlBuild, CATIA V6, and 3D Excite to get the cockpit immersion and even physical components. As a result, the experience showed a 3D interactive cockpit highlighting automotive suppliers' assets like a postural comfort management system, an efficient thermal regulation system, and new kinds of HMI. This experience takes away much success at the CES Las Vegas and the Hannover Messe.

Presentation#74

Digital Development and Analysis of SOPs

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Presented on: Thursday, 11:30-12:10 HST (316B)

Keywords. Digital Assistance Standard Operating Procedures (SOP) NLP Architecture

Topics. 2. Aerospace; 3. Automotive; 3.8. Quality Management Process; 4.1. Human-Systems Integration; 5.4. Modeling/Simulation/Analysis; 6. Defense;

Abstract. Standard Operating Procedures (SOP) is a set of written instructions that defines a step-by-step process and a particular order of actions to meet the end goal of a procedure. An SOP provides: what must be accomplished, when and under what conditions, who is responsible for each step, how each step is performed, and how to confirm it was completed. Currently, SOPs are developed as an afterthought and are published as a text document. When revising SOPs, there is little context added and there can be a knowledge gap for users. This leads to poor performance, lack of efficiency, and safety concerns. The digital assistance tool, Sopatra, is a new approach to improving SOPs. Sopatra's platform is continuously being developed as a digital assistance tool for Standard Operating Procedures (SOP). Sopatra takes a model-based approach to designing, analyzing, and simulating SOPs to prepare them for use in real situations. Sopatra uses natural language processing (NLP) to automate the creation of LML/SysML models from imported SOP document files. Research and development on the procedure representation language (PRL) have led to breaking down each procedure step into perceptual, cognitive, and motor models of human-machine interaction (HMI). HMI is heavily considered when defining the structure of SOPs and has been extended to a canonical structure. Extended PRL (e-PRL) ensures SOP step format is standardized according to human cognitive behavior. These SOP steps have the following components: ●Trigger (Perceptual) ●Decision (Cognitive) ●Action (Motor) ●Waiting/Time (Perceptual) ●Verification (Perceptual) A combination of the SOP components has been grouped to form the following SOP steps: 1.Action ONLY a.Components: Trigger - Action 2.Decision- Action a.Components: Trigger-Decision-Action 3.Action w/ Waiting & Verification a.Components: Trigger-Action-Waiting-Verification 4.Decision-Action w/ Waiting & Verification a.Components: Trigger-Decide-Action-Waiting-Verification This format is currently being implemented in Sopatra's NLP architecture. This will assist in modeling, analyzing, and simulating SOPs. Sopatra with e-PRL will be able to: 1.Convert SOPs into a digital/model-based format 2.Analyze SOPs for: a.SOP Types b.Completeness c.Inconsistencies 3.Simulate the SOP for variance in performance based on time distributions 4.Calculate Probability-of-Failure-to-Complete 5.Generate a revised version of the SOP 6.Provide performance statistics Sopatra will be a digital assistance platform that will aid industries utilizing SOP for guidelines and policies. The software is being funded for NASA's small business technology transfer (STTR). It's currently being used to help the aerospace and defense industry, but it will soon be used in a variety of fields.

Presentation#89

Digital Engineering Standards Development to achieve SE Vision 2035

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Presented on: Tuesday, 14:15-14:55 HST (316A)

Keywords. Digital Engineering Model Based Systems Engineering Standards

Topics. 20. Industry 4.0 & Society 5.0; 3.1. Acquisition and/or Supply; 3.4. Information Management Process; 5.3. MBSE & Digital Engineering; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. The SE Vision 2035 states "the future of systems engineering is model-based, enabled by enterprise digital transformation". As organizations move towards a holistic, integrated digital engineering approach to systems development, there is a growing need in standardization to enable industries to share, cross-reference, integrate, reuse and extend models of various kinds. The Digital Engineering Information Exchange Working Group (DEIX WG) conducted an analysis of current Digital Engineering standardization activities and is currently working with ISO/IEC and IEEE in new standards to address the challenges of using digital engineering in systems engineering lifecylce activities. The presentation will provide an overview of current standard activities and roadmap to mature standards to enable SE Vision 2035.

Presentation#17

Digital Engineering Strategy for DHS

Yonas Nebiyeloul-Kifle (DHS) - nebiyeloul@yahoo.com

Presented on: Monday, 13:30-14:10 HST (316B)

Keywords. Digital Engineering Strategy Acqusition

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

Abstract. Government agencies working in multiple complex business domains need a strong system engineering and acquisition management capability. Digital Engineering (DE) has shown significant promise in large major system acquisition programs. However not all government agencies can afford the infrastructure and the engineering competencies. DHS has partnered with its FFRDC to pursue a novel DE strategy where external resources and expertise are used to implement the technical and business case for DE. DHS Science and Technology Directorate (S&T), Office of Science and Engineering (OSE) used the HSSEDI FFRDC, operated by MITRE, to obtain DE resources and expertise. Resources included an established, sharable DE platform with tools and methods in DE-based architecture, data analysis, modeling, and testing. The DE strategy involved exploring impacts in major system acquisition program. We applied the platform tools and methods in a use case involving Customs and Border Patrol Non-Intrusive Inspection major system acquisition program. The results proved DE effectiveness in managing risks in acquisition. Its utility as an effective tool for system engineers in acquisition programs range from evaluating design and alternatives to traceability of critical performance metrics from measures of effectiveness down to technical specifications. The work done thus far illustrates the promise of DE as a capability to manage complex systems engineering at an agency such as DHS, as well as the FFRDC partnership approach. The promising aspects include successes in the working partnership, rapid standup and execution of DE projects, the integration of tools and data interchange, and rapid modeling of multiple configurations to support design and acquisition decision-making.

Presentation#107

Digital Engineering, The Next Chapter

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Presented on: Monday, 13:30-14:10 HST (316A)

Keywords. Digital Engineering Digital Engineering Body of Knowledge Modeling and Simulation Strategy Digital Engineering Strategy Department of Defense

Topics. 11. Information Technology/Telecommunication; 2.5. System Integration; 3.5. Technical Leadership; 4.5. Competency/Resource Management; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. The Department of Defense (DoD) continues its commitment to Digital Engineering. Shortly after the release of the DoD Digital Engineering Strategy, each of the services developed implementation plans to realize the focus areas in the Strategy. Digital engineering combines model-based techniques, digital practices, and computing infrastructure, enabling the delivery of high pay-off solutions to the warfighter at the speed of relevance. DoD and the defense industrial base are expanding digital engineering across the enterprise by incorporating it into a wide range of programs, systems, components, and subsystems. DE methods, processes and tools are improving communication, lowering risk, optimizing designs in the virtual world, and shortening acquisition timelines. The DoD and the defense industrial base continue to evolve collaborative, integrated digital environments that guide, orchestrate and deliver the means for stakeholders to access data, functions, and elements necessary to do their job digitally. This talk will review the current state of the DoD's digital engineering practice and outline a vision for the future. The presentation will highlight some of the key initiatives in progress, such as the Digital Engineering Body of Knowledge (DEBoK), DoD Modeling & Simulation Strategy and the DE training credentials program.

Presentation#115

Early System Lifecycle Activities - Projects Doomed to Fail before NTP!

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Presented on: Monday, 11:30-12:10 HST (313B)

Keywords. Early Lifecycle Rail and Transit Infrastructure Transportation Marginal SE use Requirements Management Configuration Management Needs and Requirements Analysis Acquisition Procurement

Topics. 12. Infrastructure (construction, maintenance, etc.); 16. Rail; 2.1. Business or Mission Analysis; 2.3. Needs and Requirements Definition; 21. Urban Transportation Systems; 3.1. Acquisition and/or Supply;

Abstract. Many North American Rail & Transit projects are now specifying ISO15288 and demanding Systems Engineering approaches in the RFP documents…yet they are still failing! (with respect to schedule/cost/performance/functionality). This result seems especially pervasive in North America within large infrastructure projects and has been the status quo for many years. Examples and statistics will be presented. Unlike the aerospace, biotech, automotive and medical devices industries, there has been only marginal use of Systems Engineering – many times associated with a negative project ROI with no significant signs of improvement. There have been no “COVID-19 Ventilator Challenge” type success stories to encourage the Rail & Transit sector to truly embrace/enforce a disciplined requirements management approach. Dale Brown (Hatch-LTK) and Jonn Sprakes (Stantec) explore the missing activities desperately needing systems thinking input during the early stages of a project lifecycle – all the way back to business planning and capital budgeting! Project failure modes, root causes and mitigation recommendations are provided. NOTE: This material will form the initial framework for a planned release of an APTA best practices publication: “APTA Systems Lifecycle Engineering Deployment Guide” - also planned to be a joint product release from APTA and INCOSE based on the MOU.

Presentation#108

Engineering Sustainable Products with Collaborative Multi-Domain Modeling

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Presented on: Monday, 14:15-14:55 HST (316B)

Keywords. sustainability environment model-based systems engineering multi-domain engineering simulation cross-discipline collaboration OSLC SysML

Topics. 2. Aerospace; 3. Automotive; 5.3. MBSE & Digital Engineering; 6. Defense;

Abstract. Sustainability is identified as one of the megatrends for Systems Engineering to address in the INCOSE's Systems Engineering Vision 2035 document. The vision document identifies Global Megatrend 1 as “Environmental sustainability becomes a high priority”. On p.11 the document describes changing stakeholder expectations around sustainability: “Sustainability as a system characteristic will be stressed as well as the sustainability ethic of the responsible enterprises.” Sustainability and its various system characteristics become new factors that product engineering teams need to address, while having to adapt their existing methods and tools to do so. Sustainability in context of this session means enabling the balanced natural resource consumption during production and use of a product, at end-of-life and through extending the lifetime by enabling upgrades and enhancements after the original purchase. Sustainable products, such as vehicles, aircraft, and other transportation systems are increasingly shifting to electrification as a way to meet sustainability objectives. The shift to electric powered vehicles, and the enabling changes in the E/E architectures, is a dramatic one, and brings many new requirements around energy consumption, safety, reliability, and even maintenance and disposal considerations. Ensuring that all requirements can be adequately met requires cross-discipline teams to work closely together in ways that were previously made difficult by disconnected tools and data environments. In addition, the push for greater efficiency drives organizations to design more reusable components and flexible architectures. In this session we will describe a new workflow for multi-discipline collaboration that is essential for making the kinds of architectural decisions and supporting trade studies that will be needed for designing sustainable products. It will be more essential than ever for teams to collaborate early and quickly across different engineering disciplines to drive sound decision-making in the engineering process. This session will describe a systems engineering approach that allows Systems Engineers, Electrical Engineers and Software Engineers to work with their individual specialized modeling tools to rapidly develop an integrated set of coherent models that allow validation of design decisions against key sustainability performance objectives. We have implemented model transformations to ensure engineers at every level are working on coordinated up-to-date information. We have also utilized the early model-based simulation and verification capabilities of the modeling environments to support early evaluation of key design tradeoffs. We leverage open standards such as Open Services for Lifecycle Collaboration (OSLC) and SysML to ensure complete traceability can be supported in a multi-tool, multi-vendor environment, while still meeting the organizational needs for greater reusability and complex safety-critical process reporting. We will jointly demonstrate a working environment and approach enabling early multi-domain collaboration for simulating and validating architectural tradeoffs for complex sustainability requirements. We will also show how this environment supports specific recommendations from Chapter 4 “Realizing the Vision” of the INCOSE Systems Engineering Vision 2035.

Presentation#36

Enterprise Adoption of DE and MBSE: Lessons from Research

Tom McDermott (Stevens Institute of Technology) - tamcdermott42@gmail.com
Kaitlin Henderson (Virginia Tech) - karj1@vt.edu

Presented on: Monday, 10:00-10:40 HST (316A)

Keywords. Digital Engineering Model-Based Systems Engineering Enterprise Systems Measurement Workforce Culture

Topics. 2.1. Business or Mission Analysis; 22. Social/Sociotechnical and Economic Systems; 3.5. Technical Leadership; 5.3. MBSE & Digital Engineering; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. This presentation summarizes research on the organizational adoption of Digital Engineering (DE) and Model-Based Systems Engineering (MBSE). For the last five years, the Systems Engineering Research Center (SERC) has conducted a sustained series of research tasks evaluating and developing a model for DE/MBSE adoption. This presentation summarizes the results for each stage of this research, presents the derived model of enterprise adoption factors, then outlines an adoption strategy using lessons learned and the highest impact adoption factors. Organizational adoption of DE/MBSE requires a strong foundation in systems engineering and a multi-year organizational digital transformation strategy. There are two overarching measurable outcomes that should guide this transformation. The first is the increased levels of knowledge gained from integrating a formal systems level model to lower-level component and disciplinary models, resulting in improved system quality and lower total effort. The second is increased efficiency from digital integration of data and models, resulting in reduced cycle times. To scale adoption of DE/MBSE methods, processes, tools, and human capital, the organizations must be able to visualize these outcomes as they grow over time. The body of research summarized here provides a justification and initiating framework for organizations wanting to undergo digital transformation of their engineering practice.

Presentation#39

Explore the Lighter Side of MBSE

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Presented on: Tuesday, 15:30-16:10 HST (313A)

Keywords. MBSE SysML Modeling Process Systems Engineering Digital Transformation Systems Thinking Design Architecture Requirements

Topics. 2.3. Needs and Requirements Definition; 2.4. System Architecture/Design Definition; 5.3. MBSE & Digital Engineering; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. In this presentation, we will explore the lighter side of MBSE and provide attendees with a set of skills they can use - immediately - to enhance their practice of MBSE on the job and in their lives. We'll explore a set of tools in a live modeling activity that begins with foundational MBSE tools and culminates in a SysML model - all based on the audience's responses. This is a very interactive presentation that demonstrates good modeling techniques and stresses the "why" as much as the "how" of those techniques. Topics to be covered include: Setting your modeling effort up for success, approaching MBSE with the correct mindset, and understanding how to translate essential information into a digital environment.

Presentation#54

Forged in Fire: Teaching the Craft of Model-Based Systems Engineering

Michael Vinarcik (SAIC) - michael_vinarcik@msn.com

Presented on: Wednesday, 10:00-10:40 HST (313A)

Keywords. teaching SysML validation

Topics. 1. Academia (curricula, course life cycle, etc.); 2. Aerospace; 5.12 Automation; 5.3. MBSE & Digital Engineering; 5.9. Teaching and Training; 6. Defense;

Abstract. The transition of systems engineering from a document-centric to a model-based discipline has been compared with the migration from drafting boards to computer-aided design (CAD). A more apt comparison may be to the craft of blacksmithing. Blacksmiths in antiquity lacked fundamental understanding of the iron-carbon phase diagram, the impact of alloying elements, and access to modern equipment such as power hammers, gas-fired forges, and other laborsaving devices. These craftsmen still were valued members of their community who provided value and innovation (such as in the American West, where the town blacksmith repaired tools, shod horses, and created bespoke products for the populace). Contestants on Forged in Fire, a television program featuring competitive bladesmithing, have access to all of the metallurgical theory and modern equipment available, as well as generations of best practices...yet many still make easily avoidable blunders. The application of individual skill and knowledge still determines the outcome of each contest...and the practice of system modeling circa 2022 is similar, in that outcomes are still heavily dependent upon the skill of the individuals involved. This presentation will explore the evolution in the author's pedagogy during more than a decade of teaching systems architecture, systems engineering, and systems modeling. It will examine the early use of diagram-centric modeling in support of individual document-based projects, subsequent attempts to model single systems collaboratively, and current practice, in which teams of students are responsible for constructing a complete, consistent, federated system-of-systems model. The value of structured, hands-on lessons ("bringing a hammer to the anvil") supported by task-based videos will be explored. Models from each epoch will be assessed for size, scope, and quality (including the application of the latest validation rules to earlier models to identify and quantify latent errors). The impact of automated validation rules as an instructional and grading aid will be presented and guidelines for structuring language, tool, and process lessons will be included.

Presentation#68

Fundamentals of Cross Domain Solutions: The Department of Defense Perspective

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Presented on: Monday, 10:45-11:25 HST (313C)

Keywords. Cross Domain Solutions System Security Engineering Department of Defense

Topics. 11. Information Technology/Telecommunication; 2.3. Needs and Requirements Definition; 4.7. System Security (cyber-attack, anti-tamper, etc.); 5.9. Teaching and Training; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. A Cross Domain Solutions (CDS) is a capability that can be used to securely connect discrete systems or networks, which may have different security policies to address their exposure to different types of threats and levels of risk, and therefore hold different levels of trust. CDS is an example of technological convergence where discrete security concepts and technologies are carefully combined within a comprehensive system architecture to protect sensitive, critical and classified networks. There is a critical need for secure information sharing and collaboration across all types of boundaries including international, governmental, federal, agency, state, local and security boundaries. Secure information sharing capabilities must support the full spectrum of operations ranging from military to domestic to humanitarian aid and include a diverse set of stakeholders including foreign partners, coalition forces and other information system owners throughout the United States Government (USG). To better support and educate the Engineering workforce and their supporting technical staff, this tutorial is designed to address introductory basic CDS concepts and key topics to help establish a foundation for understanding CDS technology and the associated policies, processes, challenges and risks. Topics addressed in this presentation include: • What is a CDS and why are they needed? • Classes of CDS • CDS Security Requirements, Core Services, and Applicability • System Architecture considerations • CDS Policies

Presentation#84

How to Write a Digital-Ready Standard

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

Presented on: Monday, 11:30-12:10 HST (316A)

Keywords. digital standards natural language processing process improvement

Topics. 5.3. MBSE & Digital Engineering;

Abstract. As the world moves from analog to digital, engineering resources need to be accessed in a digital format. This drive for digitization promotes interoperability between different systems to help drive efficiencies and development of complex products. While the industry hopes to get to a point where a single tool can be used to author both a digital standard and a PDF natively, we are not there yet. In the interim, SAE is using AI models to read and convert PDF standards into a true digital format. Over the past year or two, SAE has digitized over 1500 parts and materials standards into a database format. Throughout this process, SAE has learned a lot of lessons and helpful hints about how to structure tables, content, etc. to make it easier for AI models to be used to digitize a standard. Do you know: • The best way to reference tables and figures in your requirements? • How to best organize data tables for digital conversion? • How to set up your data so that customers can search across multiple digital standards on properties, elemental composition, etc.? • The importance of consistency to minimize the complexity of your AI models? SAE has gathered information together to create awareness and educate others on how to write a digital-ready standard. The information is organized as follows. • Document Structure: This part of the presentation covers how to structure the actual document. Standards authors need to understand how to best organize titles, subtitles, and content and how to reference figures and tables. • Table Structure: This section provides several examples of good and bad tables, in the context of how “digital-friendly” a table is structured. Humans and machines “think” differently. A table that can be read and interpreted by a human may not be so easily understood by a machine. As a result, this section looks in detail at table structure, the organization of rows versus headings, and how notes are referenced in tables. • Content: This dives a bit more into the actual content within standards. It covers how to consider reference properties, elements, data ranges, and units of measure. Most of the recommendations in this section can be summed up in one word: consistency. It is important to understand how an AI model “reads” a standard and how inconsistency can complicate this process. Inconsistency results in more complex AI models, more manual extraction, more manual verification, and the need to maintain mapping tables outside of the system. • Drawings and Variables: This section covers how to handle dimensions shown in variables and the importance of using consistent variable names across standards within a Part Type and Subtype. It also covers the importance of ensuring all relevant data is in the standard and not spread across multiple documents.

Presentation#10

Importing Legacy Visio Diagrams into MBSE Models

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Presented on: Thursday, 10:00-10:40 HST (316B)

Keywords. Model Based System Engineering MBSE Legacy Data Block Diagrams SysML

Topics. 5.3. MBSE & Digital Engineering; 6. Defense;

Abstract. Model Based System Engineering (MBSE) offers a range of benefits to Department of Defense (DoD) programs, from capturing the different aspects of complex systems into one configuration managed location, to reusability. However, because MBSE is still relatively new, there exists a large amount of legacy data that would benefit from being captured in an MBSE model. Capturing such legacy data would both enable users to better understand how and why design decisions were made on previous programs, and enable users to more easily reuse the data in current and future programs. However, the amount of time it takes to manually transcribe the information found in legacy documents, especially in static block diagrams, greatly hinders any effort to capture the legacy data in a model. In response to this problem, we developed a custom plug-in which automatically imports legacy block diagrams from Microsoft Visio to dynamic Internal Block Diagrams (IBDs) in NoMagic’s MagicDraw (Version 2021x). This plugin works by reading in the text, shapes, and connectors in a Visio diagram, translating the aforementioned objects into part properties, ports, and connectors, and positioning the newly created SysML constructs in a near identical way to the original Visio diagram. This poster presentation illustrates how Engineers can use this plugin to easily and quickly import legacy Visio block diagrams into an MBSE model in order to enable efficient reusability of legacy program data.

Presentation#52

INCOSE Systems Engineering Handbook Fifth Edition: Updating the Reference for Practitioners

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Presented on: Monday, 15:30-16:10 HST (316B)

Keywords. handbook process best practices INCOSE

Topics. 5.5. Processes; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. The objective of the International Council on Systems Engineering (INCOSE) Systems Engineering Handbook is to describe the state-of-the-good-practice for Systems Engineering. It serves as the basis for the INCOSE certification examination. The handbook effort is led by an Editorial Team from across the globe (representing all three INCOSE sectors) with the support of the INCOSE Working Groups (WGs) and Subject Matter Experts (SMEs). This presentation provides an overview of the handbook Fifth Edition released in 2023. It describes the overall impetus for change, highlights changes from the previous Fourth Edition, and describes the new content added for this version. The primary purpose of this presentation is to inform the systems engineering community of the changes incorporated into the Fifth Edition.

Presentation#65

Integration of Technical Management and System Architectures

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Presented on: Wednesday, 16:15-16:55 HST (313A)

Keywords. Technical Performance Measures Readiness Levels Trade Studies TPMs TRLs MRLs IRLs MBSE Model-Based Systems Engineering Technical Maturity Management System Architecture

Topics. 3.6. Measurement and Metrics; 5.1. Agile Systems Engineering; 5.3. MBSE & Digital Engineering;

Abstract. Managing the technical development of a new system relies on Systems Engineers to perform Technical Performance Measurement monitoring, Readiness Level Assessments, and Trade Study Management. Historically, these efforts have been completed in parallel with, but independent of, the architecture development; however, Readiness Levels, TPMs, and Trade Studies are interconnected and need to be managed together. With the correct implementation of Model-Based Systems Engineering (MBSE), the architecture models can be utilized to execute these processes in the Authoritative Source of Truth directly, providing a digitally integrated set of technical management processes. This presentation will demonstrate the use of these features and highlight constraints on the system architecture model to implement them. First, the presentation will address incorporating management of Technical Performance Measures (TPMs) into a MBSE Model. TPMs along with Measures of Performance and Measures of Effectiveness, provide valuable information to program leadership on the progress of the technical solution, assessment of risks, and likelihood of meeting the critical objectives of the stakeholders (1). Traditionally these have been tracked through standalone databases, Excel, or PowerPoint charts, relying on Subject Matter Experts to periodically provide a numerical assessment to the database. In a model-based approach, elements within the system architecture contain value properties that can be updated through model execution and linked performance models. The key enabler to integrating real time system values with status trending over time is using a TPM Metric Suite. Linking graphs and reports to the TPM Metric Suite provides program leadership the most accurate and up to date tracking of TPMs critical to program success. The presentation will then address Technical, Manufacturing, and Integration Readiness Levels (TRLs, MRLs, IRLs). These are another technical management process used to verify a system is mature enough to proceed through development milestones with manageable risk. To implement model-based management of readiness levels, the assessed readiness level can be captured as a property of each system element. TRL Metrics Suites are then implemented to track changes over time. The presentation will demonstrate how merging the Readiness Levels with the model allows roll-up analysis for leadership to better understand system risks associated with lower TRL/MRL/IRL elements. Finally, the presentation will discuss model-based trade study management. Trade studies are an essential aspect of downselecting between system elements. Management of the trade studies within the architecture model directly ensures that both the performance and architectural impacts of the trade are considered. The presentation will highlight how the results of the trade can be captured as the rationale for requirement derivation and selection of system elements, providing a fully integrated rationale in the Source of Truth model. This enables future trades to quickly identify previous trades that may be impacted, better understanding of rationale for requirements when changes are requested, and tracking of the completion of trades in one location. Through integrating TPMs, Readiness Levels, and Trade Study management into the system model, systems engineering and program management gain the ability to more holistically manage the technical development of the system by using digital threads and the Authoritative Source of Truth data. The approaches presented expand MBSE beyond architecture and process definition into model-based technical management.

Presentation#97

Lean Model-Based Systems Engineering on the NASA High-Density Vertiplex Subproject

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Presented on: Wednesday, 16:15-16:55 HST (KALAKUA BALLROOM C)

Keywords. Model Based Systems Engineering Air Traffic Management Urban Air Mobility Advanced Air Mobility

Topics. 14. Autonomous Systems; 2. Aerospace; 21. Urban Transportation Systems; 5.3. MBSE & Digital Engineering;

Abstract. The High Density Vertiplex (HDV) subproject of NASA's Advanced Air Mobility (AAM) project adopted Model-Based Systems Engineering (MBSE) in July of 2020, prior to subproject formulation. A small and lean team of HDV Systems Engineers (SE) are utilizing MagicDraw to execute NASA SE processes via MBSE. The SEs learned how to use MagicDraw from scratch and HDV is the first project for which the SEs have utilized MagicDraw. This presentation will demonstrate project technical execution via MBSE, utilizing the digital elements built into the SysML (Systems Modeling Language). SysML provides a model-centric means of carrying out the NASA SE common technical processes by providing tools for complete system modeling, including requirements and interface management and design capture. The authors also leverage and extend SysML to perform other SE tasks, such as Verification and Validation (V&V) tracking. MBSE has two main purposes for HDV: 1) documenting the subproject's logical architecture for distribution outside of the subproject, 2) capturing the subproject's physical architecture in a single-source-of-truth for use by the subproject's members. This presentation details the challenges, lessons learned, and solutions that were encountered in implementing MBSE in the first iteration on a multi-iteration, full-lifecycle design, build, fly project.

Presentation#87

Lessons Learned from Defining an Applied Systems Engineering Ontology at Sandia National Laboratories

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Presented on: Monday, 11:30-12:10 HST (313A)

Keywords. ontologies MBSE lessons learned information management authoritative source of truth

Topics. 2. Aerospace; 2.6. Verification/Validation; 3.5. Technical Leadership; 5.3. MBSE & Digital Engineering; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Systems engineering has many lexicons and guides defining core terminology for the discipline, including ISO 15288, the InCoSE Systems Engineering Body of Knowledge (SEBoK), and the SysML specification. There have been many attempts to encode each source of knowledge in a formal representation known as an ontology. This formal structure can be used for computational reasoning and knowledge management. However, these global definitions rarely reflect the pragmatics of applied systems engineering in a particular organization. We describe the creation of the Sandia Reference Ontology (SRO), which guides lifecycle management for projects at SNL. So that our lexicon definitions are authoritative, we have relied on these sources above to define our systems engineering-based ontology. It contains over 200 classes and over 100 relationship types, with over 26,000 declared relationships between the 1,100 common objects defined in the SRO. We discuss particular friction points in determining when a class should be instantiated, especially as it reflects to tailoring of the standards at different stages of a product development lifecycle. In our domain, we also have privileged requirements from government customers that guide all projects. These federal requirements are instantiated within the SRO so they can be shared by different models. This greatly reduces the effort needed to audit systems models for compliance with regulations. We also discuss mismatches between the different sources of bodies of knowledge and how we reconciled them in the creation of our in-house lexicon. We show how this approach also increases traceability and adherence to best practices by embedding the definitions in our shared knowledge base. Finally, our use of an ontology goes beyond just defining a lexicon. Ontologies unlock powerful machine reasoning tools over instantiated systems models. These automated reasoning systems can help ensure not only model interoperability across an enterprise, but guarantee each model is credible. For example, if a model is created without linking to one of the common lifecycle elements or referencing common federal requirements, that model would not be credible within our enterprise. These formal verification tools are a new domain for systems engineering tools. We show how data science pipelines utilizing natural language processing techniques can accelerate the creation of other applied systems engineering ontologies.

Presentation#41

MBSE Model Integration in a Mixed-Fidelity Environment

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Presented on: Tuesday, 16:15-16:55 HST (313A)

Keywords. Model Based Systems Engineering MBSE Model Integration Model Fidelity MBSE Technique Customer Models Supplier Models

Topics. 14. Autonomous Systems; 2. Aerospace; 2.4. System Architecture/Design Definition; 3.1. Acquisition and/or Supply; 5.3. MBSE & Digital Engineering; 6. Defense;

Abstract. Alex Gaspar, Eric Martens, Brad Kukurza 2022-11-29 Boeing Overview This presentation will examine the realities of Model Based Systems Engineer (MBSE) design and execution for highly complex, integrated systems that are, or were, designed to have long service lives with periodic upgrades and ways to approach them. Issues quickly become apparent when attempting to implement MBSE techniques on legacy platforms that have no MBSE models. Issues also arise when integrating components from many suppliers with different levels of MBSE capability, or when disparate suppliers use varying MBSE techniques and customizations in their modeling, especially for off-the-shelf products. In the ideal approach the system-of-systems integrator would mandate a standardized MBSE approach for all major system suppliers. However, this approach is usually only viable when the product is largely brand-new development using no existing infrastructure such as space science missions (e.g. existing production lines or commercial / already developed components). Using MBSE on legacy platforms, such as Boeing sees on B-52, F-15, and F-18 among others, requires a more focused approach. Care must be taken to determine how, and how much of, the legacy platform needs to be modeled to add value to the development of the new systems. Modeling the entire aircraft would likely be wasted effort since most functions and interfaces remain unchanged. However, failing to model enough of the legacy system’s functions and interfaces that might be affected by the upgraded systems could miss interactions with the new systems, causing cost and schedule impacts from late discovery, missing the benefit of MBSE. In addition, even assuming perfect knowledge of what should be modeled, a source-of-truth issue arises where the MBSE model and legacy documentation contain the same information and must be kept in sync. Similarly, even new platforms that make heavy use of off-the-shelf components, such as Boeing saw with T-7, can lead to a mixed-fidelity MBSE modeling environment. The off-the-shelf components may not have been developed with MBSE or suppliers may not have the capability to do MBSE. Here the systems-of-systems integrator must decide if it’s worth the investment to have suppliers develop MBSE models of their products, potentially before they’ve even been selected. Alternatively, the system integrator could model supplier components, but this runs into the same source-of-truth issue noted above. This presentation will discuss some approaches to solve the above problems using a combination of the black box/white box modeling concept of loose coupling and a middle-out modeling approach. We will discuss the concept of a low-fidelity MBSE model library of components that can be used on new developments to represent off-the-shelf or low-modification components to ensure MBSE integration even when models of specific part numbers do not exist. We will also discuss how the concept of a white box model framework in combination with a solution model framework, with associated profiles and validation rules, can be used to engage MBSE-capable suppliers to ensure smooth model integration. Finally, we’ll also discuss an approach to identify how much of a legacy system needs to be modeled to gain benefits of MBSE when developing upgrades, and managing source-of-truth connections with legacy interface and functional documentation. Industries The content of this presentation will focus on Digital Engineering, examining the practical problems of adopting MBSE in an environment where not everything can have high fidelity models due to real-world limitations in cost, schedule, or MBSE-capable organizations. The issues discussed have been seen in Aerospace and Defense, though are likely applicable to other industries that produce highly complex systems-of-systems such as Transportation and Automotive. Takeaway The audience will have a better understanding of some of the practical limits employing MBSE when the product is not starting from a clean sheet. In addition, they will be shown a set of

techniques that may help overcome those limitations to enable adoption and still gain benefits of MBSE even when it’s not practical to model everything in the system. Presenter Background Alex Gaspar has 13 years’ experience in the defense industry (Boeing, Northrup, Lockheed, DoD), and has been a Systems Engineer for over 10 of those. He is a graduate of the Boeing Systems Engineering Rotation Program, a mid-career program where he focused on MBSE skill development by rotating with Boeing programs in various stages of MBSE adoption. Alex in now a member of the Boeing Defense Systems SEIT Capability, where he is a subject matter expert in systems engineering, with an emphasis in MBSE. He is deployed to programs to support deployment of systems engineering modeling, architecting, processes, program execution and program organizational assessments. He is sought out to support emergent systems engineering program needs as well as represent the SEIT Capability in deployment of SE initiatives. Mr. Eric Martens has over 30 years of experience working as an aerospace, software, and systems engineer in both the defense industry and at commercial software companies. His experience ranges from airbreathing propulsion, a software architect for complex systems, commercial computer networking, autonomous aerospace air vehicles, cyber security, Principal Investigator on defense R&D research contracts at Boeing and starting ten years ago an emphasis on systems engineering. Mr. Martens experience includes extensive usage of UML for complex software design over the last 20 years and now SysML for solving system and system-of-systems integration as part of the MBSE transformation efforts at Boeing. Brad Kukurza leads the Phantom Works MBSE Team at Boeing, with responsibility to define and implement a common MBSE approach across the portfolio of Phantom Works programs. His Systems Engineering leadership is built upon experience with defense and commercial programs, multiple domains (Spacecraft, Aircraft, Subsystems), and multiple companies (Boeing, GE, SS/L). He a B.S. in Aerospace Engineering (Washington University in St Louis) and an M.S. in Engineering Management (Santa Clara University).

Presentation#34

Model-Based Test and Evaluation Framework

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Presented on: Thursday, 11:30-12:10 HST (313A)

Keywords. MBSE Testing Test & Evaluation Test Planning Test Procedures Digital Engineering

Topics. 2.6. Verification/Validation; 5.3. MBSE & Digital Engineering; 6. Defense;

Abstract. As systems are becoming increasingly complex, Test and Evaluation (T&E) is also becoming increasingly complex. Modern Test Engineers must not only determine if a component or system itself meets the requirements, but they also must consider performance at the System of Systems (SoS) level. Many modern systems are distributed networks of sub-systems with embedded logic and software pipelines. Assessing the quality and effectiveness of these types architectures can be very difficult, leading to long, expensive, and challenging test events. Complex integration and test events often lead to programs being behind schedule, over-budget, or even cancelled. While organizations are increasingly turning to Model-Based Systems Engineering (MBSE) tools to model systems and define an authoritative source of truth, T&E is often still a paper-based process with long checklists and huge stacks of documents. Because documents are notoriously difficult to track and link to other changes, these long test documents can very easily fall out of sync with the system model as things change during the development process. A growing gap exists between digital systems engineering processes and manual document-based test processes. In this presentation, Deloitte will explore strategies for modeling a test program and integrating T&E into a system model. Through the use of a custom test profile and stereotypes in Cameo, Deloitte developed a Model-Based T&E Framework that enabled Systems Engineers to model a Test Program and connect test elements with the system model elements. To begin developing the test strategy, Critical Operational Issues (COIs) are captured from relevant stakeholders and traced to related Measures of Effectiveness (MOEs). MOEs are then connected to Test Objectives that are aligned to a series of Test Phases. This framework forms the high-level strategy for the Test Program. Next, Test Objectives are further broken down into sub-objectives and linked to individual Test Cases that can meet each objective. Test Cases are connected to the requirements they verify and the systems under test. Gap analysis between the Test Objectives, Test Cases, and Requirements can be performed to help the team identify gaps in the test plan and find potential risks. Once Test Cases are defined and scoped in the model, executable Test Steps can be created inside each Test Case to form Test Procedures. Automated exporting of Test Procedures using the Velocity Template Language can enable the Test Team to rapidly produce ready-to-print copies of the procedures that could be carried into a test lab or test field environment. By capturing both Test Planning information and Test Procedures in the model, the entire team can easily find, view, and trace T&E information using the single source of truth. Test Case Modeling also provides additional opportunities to simulate Test Cases prior to live system testing and potentially identify issues earlier in the development process. Modeling the Test Program enables an agile, iterative process to Test Planning that is no longer bound by document release dates, endless pages of reading, and manual traceability checks. As the system design and model change over time, the Test Program can adapt along with it. Any changes made to the system model are automatically connected to the definitions of the associated test procedures. This presentation will explore how a model-based framework for T&E can reduce risk, improve stakeholder communication, increase testing effectiveness, and ultimately lead to better systems.

Presentation#40

Modeling Data Management for a Next Generation Photon Counting CT Scanner

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Presented on: Tuesday, 16:15-16:55 HST (313C)

Keywords. Machine data Data Management Medical Imaging Computed Tomography SimEvents

Topics. 1.6. Systems Thinking; 2.4. System Architecture/Design Definition; 4. Biomed/Healthcare/Social Services; 5.4. Modeling/Simulation/Analysis;

Abstract. The Computed Tomography industry is going through a revolution in CT detector technology. Next generation CT detector technology advances spectral and spatial capabilities which should deliver improved patient outcomes. These detectors will dramatically increase the data sizes generated for each patient exam by more than an order of magnitude creating unique data management challenges for system calibration, patient scanning and image reconstruction. This presentation will outline an approach using machine data and Matlab SimEvents to evaluate tradeoffs in system design of a novel photon counting CT scanner. With the dramatic increase in scan data rates, modeling the impact on customer workflow and optimizing the data management design early in the system design process is crucial. Machine data from non-photon counting CT scanners was transformed to forecast the clinical usage of a photon counting CT scanner and the corresponding projected scan data sizes. CT scanners are slipring-based systems, which represent transmission bottlenecks for very high data rates. System requirements and design goals were defined to support clinical throughput targets. System data throughput bottlenecks pre- and post-slipring and potential design solutions and system topologies were modeled to understand impact on clinical workflow. Tradeoffs in system hardware, network topology, image generation compute resources, and data prioritization/queuing were all considered using MATLAB SimEvents design toolbox. While this project involves the design of a novel CT scanner, this type of analysis using machine data and workflow simulation may apply to many industries.

Presentation#48

Modeling Schedule Logic: Data Visualization to address Program and Systems Engineering Problems in Large Projects

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Presented on: Thursday, 08:00-08:40 HST (313C)

Keywords. Systems Engineering Digital Engineering Data visualization Schedule Project Management Primavera P6 Tom Sawyer Perspectives

Topics. 17. Sustainment (legacy systems, re-engineering, etc.); 2. Aerospace; 3.3. Decision Analysis and/or

Decision Management; 3.7. Project Planning, Project Assessment, and/or Project Control; 5.3. MBSE & Digital Engineering; 6. Defense;

Abstract. Extremely large schedules and a murky picture of work/product relationships are a common result of large projects or projects that have undergone multiple changes in direction over time. The clear understanding of the scope of work and critical relationships (both technical and programmatic workflow) can become convoluted or obscured. As a result, additional problems are realized. Specifically, with changes of staff on the project, a large schedule can mean the new staff do not have a good understanding of the program schedule and, therefore, the overall risk posture of the area of their responsibility. Also, understanding the full scope of impacts of a change to the program schedule is not easy and is often not fully comprehended. Additionally, schedule dates are often missed and schedules changed due to the perception the information in the schedule must have been incorrect. Assessment of Variance Analysis Reports become either silos of information or are missing the full assessment of the impact across the program. Ultimately, communication of the program schedule, status, and risk become more difficult. Schedule logic diagrams, or network diagrams, are often used in the planning stages to develop a schedule. The graphical depiction of the flow of work activities is a powerful tool for communication. Once a schedule has been implemented in a scheduling tool, these diagrams are typically no longer used as the schedule is updated and the diagrams no longer reflect the current program plan. Many scheduling tools can create a network diagram to visually assess the logic in the schedule. However, the capability is limited and when a schedule is large, the diagram has limited use. It becomes too complex to be meaningful. Therefore, the use of a graphical depiction of the schedule logic tends to be limited after a schedule grows large – even though the large schedule is exactly the situation where an aid to clear understanding is most needed. This research proposes that the original concept to best understanding a schedule in the planning phases – i.e., viewing the schedule logic graphically - is still a good concept and the best way to understand the relationship of the current schedule status to project workflow, risk, and change control. However, for extremely large schedules, the ability to interactively view the schedule logic based on multiple factors becomes necessary to truly comprehend the state of the program and schedule. To make the information human comprehensible, an interactive logic diagram is required to vary the levels of abstraction to support the required understanding for the question being considered. The ability to visually consider (individually or combined) the following elements in the schedule are necessary: completed tasks, in work tasks, work not started; work by Product Realization Team (PRT), work by major component, work by major program milestone, work by float duration, critical path and any number of other program specific needs. Additionally, the organization (or graphical depiction) of the data needs to be drawn in various structures to aid human understanding – and the ability to trace the schedule logic or workflow through the resulting diagrams is important. This research uses a program case study to investigate the use of this data to manage risk, change control, communications and aid program decisions. The program has multiple schedules – both design agency and production schedules – each of which contain over 11,000 activities. The schedules are implemented in Oracle's Primavera P6. This research models the schedule logic in Tom Sawyer's Perspectives data visualization software. To accomplish the modeling, the P6 schedule is exported to Microsoft Excel, simple data formatting applied with Alteryx Designer, and the resulting updated Excel file imported into Perspectives. Filters and nesting are implemented in Perspectives. Once implemented, updates can take place quickly. Monthly data updates allow comparisons to schedule changes and the ability to view that latest status of the schedule. The interactive ability, as well as the ability to create static views of data for presentations supports the communication and common understanding. The research indicates that the use of modeling schedule logic to address program and Systems Engineering problems in large projects is effective. The resulting approach is different than typical schedule network diagrams in that it is interactive and provides varying levels of abstraction. While the research was performed for projects in the aerospace and defense industry, it is applicable to any industry with large, multi-faceted projects such as education, energy, healthcare, information technology, automotive, etc. This presentation will frame the unique constraints of large projects and define the process to develop the interactive schedule logic modeling capability. Demonstrations and discussion of the types of problems to be addressed and results will be included. The presentation will conclude with observations on the difficulty of the process, the feasibility of the process to be executed by staff with limited training and the results of using the process/tool. The participant will gain understanding of a practical approach to creating visualization with common tools and the process to tackle program level problems in various program phases.

Presentation#32

MoSSEC – The common meta language supporting digital transformation

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Presented on: Tuesday, 10:00-10:40 HST (316A)

Keywords. Metadata Knowledge Interoperability Collaboration Digital Twin Digital Transformation

Topics. 17. Sustainment (legacy systems, re-engineering, etc.); 20. Industry 4.0 & Society 5.0; 3.3. Decision Analysis and/or Decision Management; 5.3. MBSE & Digital Engineering; 5.4. Modeling/Simulation/Analysis; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Digital transformations, digital threads, digital twins, the meta-verse. All of these are transitions to new ways of working that inherently build upon the exchange of modelling data. INCOSE communities lead in these developments through best practices for Systems Engineering. The use of standards in achieving interoperability in the exchange of this SE data is essential – MoSSEC is the common meta language which supports effective SE collaboration. The underlying purpose and context however of MBSE modelling, such as SysML architecture or behavior simulation models, is not conventionally evident to users that did not participate in the authoring process. MoSSEC is the ISO recognized definition and language for recording and sharing Modeling and Simulation metadata – enabling software solutions to digitally capture and share rationale, goals, assumptions, maturity levels, and limitations of their models in a common language. Contextual understanding for all stakeholders. The MoSSEC standard, ISO 10303-243:2021, is the culmination of over 12 years of collaboration between over 50 organizations across over 14 countries, co-lead by Airbus and Boeing. The speaker, Kyle Hall is the project lead for Airbus. In their role as an Airbus Data Driven System Engineer they are tasked with realizing the digital transformation and encoding of knowledge, usually lost throughout the product design lifecycle, using matured Systems Engineering methods, of which MoSSEC is key. But, how can this add direct value to your organization? What MoSSEC-compliant tools are available? How does MoSSEC complement an existing metadata ontology? Building upon INCOSE IW 2023 and NAFEMS WC 2023, this presentation will discuss; the purpose of MoSSEC; the setup of the new MoSSEC Implementation Forum; relevant MoSSEC tool implementations (used for purposes such as interoperability-collaboration and archive-retrieval) and finally, the future relationship of MoSSEC, Semantic Web ontologies and other standards for recording and exchanging product lifecycle data. MoSSEC, in principle, is simple; but immensely powerful. This is a fundamental turning point in the way businesses communicate.

Presentation#30

On Model Re-Use: Best Practices for the Application and Configuration of Model-Based Patterns

Devon Clark (Deloitte Consulting) - devclark@deloitte.com
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Presented on: Tuesday, 16:15-16:55 HST (313B)

Keywords. MBSE Models Patterns Re-Use Curation Application Configuration

Topics. 2.4. System Architecture/Design Definition; 5.2. Lean Systems Engineering; 5.3. MBSE & Digital Engineering; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Systems engineering (SE) is inherently a technical communication and knowledge management function. As SE continues to transition towards a future of data-enabled operations and model-based everything, there is a growing need to focus on best practices to achieve model reusability. Model re-use has been a selling point of MBSE for years. Likewise, model re-use has been something that has largely been something that has been realized within engineering teams rather than across organizations and enterprises. In order to achieve cross-organization model re-use, there is a need for libraries of curated models intended for re-use with instructions for how to interpret, apply, and configure that model to your specialized project. Human nature likely will lead engineering teams to gravitate towards tools, simulations, and models that they develop specifically for their own purposes rather than seeking industry best that they will have to invest effort to understand and apply. However, our hypothesis is that where organizations are able to socialize leading models, and to tailor and apply those models to their own projects, those organizations will achieve greater efficiency, consistency, and interoperability. All of which leads to greater engineering achievement. In this presentation, Deloitte will spotlight our approach to managing model-based patterns with a focus on the external modeler as consumer of the pattern. That is why our approach to management focuses on development of “How-to-apply” and “How-to-configure” instructions within the model itself, in addition to model best practices of documentation of version history and model purpose. This presentation will include a demonstration of the application of a simple pattern to a project model using these instructions to streamline the achievement of project goals as a proof of concept for the hypothesis that model re-use leads to greater efficiency and consistency.

Presentation#45

ORCUS - Cameo Plug-In for Meta-Model Compliance

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Presented on: Wednesday, 16:15-16:55 HST (316A)

Keywords. Model-Based Systems Engineering MBSE Cameo Systems Modeler Model Compliance Meta-Model Verification Validation Model Federation Interoperability SysML

Topics. 2.6. Verification/Validation; 3.8. Quality Management Process; 5.3. MBSE & Digital Engineering; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Enforcing compliance to program- or organization-defined meta-models for model-based systems engineering (MBSE) continues to be a challenge due to the standard practice of manual review for compliance and the timing of these compliance reviews after the bulk of the modeling effort has already been completed. This approach often leads to rework, which becomes a significant time and cost factor late in the model development life cycle. More likely still is that there is no complete validation of the models against the established meta-model(s) due to the amount of time and effort involved. This in turn increases the likelihood that models will be neither interoperable nor support consistent analysis, key intentions of having a shared meta-model implemented across separate models. Easing user compliance with these meta-models may address these concerns directly, decrease the overall costs of model development and review, and improve the technical and cultural adoption of MBSE. The Johns Hopkins University Applied Physics Laboratory (JHU/APL) developed a plug-in for Cameo Systems Modeler, a common MBSE modeling tool, which provides a more consistent and interactive method to comply with pre-defined Systems Modeling Language (SysML) meta-models than currently exists. This plug-in, named ORCUS (Object Recognition for Compliance, Usability, and Sustainment), provides both Active Validation to aid users as they model and a holistic project Discrete Validation, which can be used for reviews of modeling compliance. The Active Validation capability integrates into the existing Cameo user interface to provide a seamless user experience within the native Cameo environment. This helps to reduce the learning curve associated with Cameo Systems Modeler tools, as well as serve as a best-practice training tool for new users, while increasing effectiveness and efficiency for all Cameo modelers, experienced or new. The user loads user-defined meta-model(s), and ORCUS reads through the meta-model elements to find all rules defined using a set of custom ORCUS stereotypes. Afterwards, whenever an element is created or manipulated, ORCUS compares the element to all rules that apply to that element,and provides suggestions on how to comply with each of the rules outlined in the meta-model. The Discrete Validation capability produces exportable metrics that describe the state of compliance for a given model, which can be used for status reporting or model review. Discrete Validation checks all elements in a Cameo project (model) against the rules defined in the meta-model and is able to produce tabular reports within the Cameo model or as a Comma-Separated Values (CSV) spreadsheet file. ORCUS developers intend that Discrete Validation be applied to pre-existing models to establish state of compliance prior to using the Active Validation feature. However, Discrete Validation can also serve as a final verification of both new and pre-existing models to ensure compliance with all relevant meta-models. Cameo Systems Modeler has a native validation suite with some default checks of model fidelity and the capability to add additional scripted validation checks. This is sufficient for many applications of modeling standards and simple meta-model rules, but it exists separately from the reference meta-models which it is intended to represent. Consequently, this allows for the introduction of errors in interpretation and gaps between the meta-model and the validation rules. Using this form of validation can also limit the complexity of the rules being defined. ORCUS solves the first of these problems by directly using the meta-model in interpreting the rules, removing any human step in conversion from meta-model to rules. Additionally, ORCUS allows for semi-complex rulesets to enhance the utility of the meta-models and ensure useful compliance to the meta-model. While ORCUS does not ensure that the model content is correct, it does ensure that the content is correctly modeled in adherence to established modeling standards. This can decrease the labor and schedule costs associated with integrating federated models, allow for faster development of high-fidelity interoperable models, serve as an active training tool by providing modeling recommendations and helping users understand established standards, and decrease the overall maintenance costs of Cameo models.

Presentation#57

Putting the Right People on Your Project: A Quality Management Approach

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Presented on: Monday, 10:45-11:25 HST (316B)

Keywords. quality management leadership project management

Topics. 1.6. Systems Thinking; 2.1. Business or Mission Analysis; 2.3. Needs and Requirements Definition; 3.3. Decision Analysis and/or Decision Management; 3.5. Technical Leadership; 3.8. Quality Management Process;

Abstract. Everyone has the intuitive sense that people make a big difference in whether a project succeeds, meets its objectives, and finishes within its budget. Projects staffed with the best people available often succeed while equally viable projects with other team members don't. Who are the right people to put on a project? How do you recruit, interview, and hire the right people for the project or organization so that quality results are achieved? The systems engineering quality management working group (SEQM) in cooperation with the Quality Management Institute has been studying the leadership skill of choosing people and will share what we have learned through decades of combined experience. Some of the important aspects include: • Seeing the noise in the subjectivity when people evaluate other people in hiring or project staffing situations • Understanding the important qualities of person beyond simple qualifications • Recognizing and overcoming the limitations of an interview-based process • Using direct methods to learn what you need to know about a potential recruit The presenters have multiple degrees in business, psychology, and quality management.

Presentation#27

Responding to disruption: A System of Systems approach for digital transformation

Samantha Papavasiliou (James Cook University) - samantha.papavasiliou@adelaide.edu.au

Presented on: Tuesday, 16:15-16:55 HST (KALAKUA BALLROOM C)

Keywords. System of Systems Approach Digital Transformation Disruption responses User needs and expectations Best Practices

Topics. 1. Academia (curricula, course life cycle, etc.); 1.1. Complexity; 1.6. Systems Thinking; 11. Information Technology/Telecommunication; 18. Service Systems; 2.3. Needs and Requirements Definition; 3.3. Decision Analysis and/or Decision Management; 3.7. Project Planning, Project Assessment, and/or Project Control; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.);

Abstract. Responding to rapid change and disruption has become part of business as usual and day-to-day practices for organisations, businesses, and individuals around the world. This is especially relevant for digital transformation efforts, where success is impacted by considering unanticipated issues, events, users and needs. The most recent examples in Australia include the responses to COVID-19 and various natural disasters (e.g., bushfires, floods) these required rapid responses, considering a multitude of factors and differing needs of stakeholders. To respond to complexities and crisis, large public and private sector organisations had to rapidly implement policy, digital services and changes their service models (e.g., from debt collection to citizen support). Research identified that through the application of a systems of systems approach, these large organisations were able to better identify the different needs and expectations of stakeholders and users. This is especially relevant for public sector agencies, who rapidly developed digital services in lieu of face-to-face and legacy systems. What the systems approach demonstrated was how to identify the different levels of digital capabilities across users and stakeholders and the challenges and opportunities these present, along with how and where education and support would be best placed to encourage digital adoption. Digital capabilities include the skills, understanding and knowledge of digital technologies, services, and software. There are a multitude of perspectives which need to be considered, including how digital capabilities are measured, developed, and supported. As part of this session, the role of applying a systems approach to understanding diverse stakeholder needs and digital capabilities within a large Australian public sector agency will be discussed. This example will show how understanding the multidimensional needs of stakeholders and their digital capabilities, supports the success of a public sector service offer. Reviews of the application of the systems approach to the understanding diverse stakeholder needs identified potential improvements to the application, this included seeking ongoing feedback from leaders, employees, and users.

Presentation#15

REST API for Digital Thread Implementation

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Presented on: Thursday, 08:45-09:25 HST (316B)

Keywords. Digital Thread Digital Engineering Model-Based Systems Engineering REST API Key Performance Parameters

Topics. 3.6. Measurement and Metrics; 5.3. MBSE & Digital Engineering; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. The creation of a Digital Thread facilitating data exchange across individual tools and platforms is crucial to the construction and effectiveness of a Digital Engineering environment. This presentation investigates the applicability and effectiveness of a representational state transfer (REST) application programming interface (API) to stand up an effective, robust Digital Thread framework that provides authoritative data to all users. We define a Digital Thread as the digitization of connecting a point of knowledge to each location that it is referenced, used, observed, or impacted. Like the concept of model element reuse in Model Based Systems Engineering, when encountering a Digital Thread in a specific tool or visual, the value is an instance of the singular authoritative value rather than a copy. This idea can be facilitated through the implementation of a REST API that coordinates information between design and management tools, becoming the authoritative source between all data users. A Digital Thread connects points of knowledge across tools throughout the system so that a change to the authoritative value results in updates across the entire suite of contact points. This is the key to the utility of the Digital Thread – the ability to ensure that all data users agree on the selected value, and to communicate and synchronize approved changes universally, through a commonly digested data structure. Program development, from threat recognition to the fielding and operation of a system, is a long process that can see numerous adjustments to scope, requirements, and implementation. This is particularly true in the Aerospace and Defense industries, where program development timelines can stretch to well over a decade, showcased by the F-35 program, but is also applicable in other industries such as electric vehicle development in the Transportation and Automotive industry. Changes during development caused by capability improvements, evolving business goals, and other factors in flux result in a moving target that is often distinct from the solution space envisioned at the onset of development. This drives a disconnect between the Key Performance Parameters (KPPs) that the system was originally designed to meet and the real-world results that the system needs to achieve to remain viable in the present-day environment. This gap results in design rework, increased cost, and a potential to field solutions that do not adequately fulfill the evolving requirements. Digital Threads close the gap between system development and the mission by facilitating the sharing and standardization of KPPs throughout conceptualization, design, and deployment. By ensuring that KPPs are agreed upon and utilized across the system, all phases of design can integrate with shared values rather than separately. Maintaining agreement on mission-critical parameters improves the cohesion of the system as a whole and reduces the potential for misunderstanding due to a lack of communication across different stakeholders. To accomplish this, the Digital Thread must be connected to a centralized source of truth, and their associated values should be visible throughout the system in development to ensure all areas of the system are aligned with the Authoritative Source of Truth. An effective Digital Thread connects all phases of system development, guiding threat analysis, mission engineering, intelligence gathering, system design, and operations and maintenance by providing shared data and parameters. A robust Digital Thread streamlines development and enhances an organization’s ability to field effective systems by enabling all stakeholders to performed informed decision making based on the authoritative data. Depending on the system, different data formats may be appropriate to capture KPP information and change data. This presentation explores a custom datatype that can track KPP content and change data. To demonstrate a custom datatype for tracking KPPs across the system lifecycle, we employ a REST API. This REST API is used as a centralized entity that stores and provides KPP’s to authorized stakeholders within the environment it is deployed within. As such, stakeholders can query a trusted service to synchronize values to achieve a common understanding across the Digital Thread. Designed to mimic a Blockchain inspired ledger, a running change log will allow these very stakeholders to view previous values as they are constantly changing. This presentation will demonstrate a functional example of a Digital Thread implemented by REST API and identify the benefits and drawbacks of such implementation, as well as other considerations for implementing a functional Digital Thread.

Presentation#8

Revitalizing Reference Architectures through Modularity and Digital Engineering

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Presented on: Monday, 14:15-14:55 HST (316A)

Keywords. Reference Architecture Digital Engineering Modular Open Systems Approach Model Based Systems Engineering

Topics. 1.6. Systems Thinking; 11. Information Technology/Telecommunication; 3.1. Acquisition and/or Supply; 5.3. MBSE & Digital Engineering; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. There is growing interest to employ Modular Open System Approaches (MOSA) in development activities to enable faster technology refresh, cost savings/avoidance, and increased interoperability. One method for achieving consistent application of MOSA principles within and across domains is the creation of reference architectures which guide and constrain system development. While the concept of a reference architecture is not new, the concept of a digital and modular reference architecture which can be accessed and used by multiple stakeholder groups via tailored reference architecture products is something novel and unprecedented. In this work, we introduce a new method of building modular reference architectures using a model-based system engineering (MBSE) approach to capture critical system elements and relationships that define a domain trade space. Specifically, we introduce the usage of modular, reusable elements within the reference architecture itself. Reference architectures built using this method define the domain of interest via structural, behavioral, and requirements elements and the relationships between them. These elements define the system development trade space and are then used as building blocks for downstream system developments resulting in tailored architectures based on system functionality. Users and stakeholders are invited to leverage aspects of the reference architecture which are applicable and useful to their specific program and system need, while remaining in alignment with the goals and objectives of the reference architecture. An advantage of this method is that users can interact with the reference architecture without the need for software licenses or architecture expertise. The Digital Reference Architecture Source of Truth is built in Cameo Systems Modeler. However, it is not expected that users and stakeholders access the reference architecture solely via this means. Instead, a custom web-based interface (no modeling tool license required) has been developed to guide users (non-model users welcome!) though a “functionality driven design” process to tailor the superset of domain elements, requirements, and interfaces. Additionally, model validation and compliance tool plug-ins can be used to establish and document alignment of existing model-based architectures. This approach eliminates the need for superfluous documentation and instead focuses on helping the end user build and develop tailored systems aligned to reference architecture objectives and translate architecture content into actionable system artifacts. Creating and providing easily accessible reference architecture tools increases the overall usability of the reference architecture itself and ultimately increases the efficacy of the reference architecture by achieving RA goals and objectives. This presentation will describe the underlying modular reference architecture design and tools developed for user interaction. A modular reference architecture based on this method has been developed to support Position, Navigation, and Timing with others currently under development.

Presentation#61

Sources of trouble: How emergent problems blow up system complexity

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Presented on: Wednesday, 15:30-16:10 HST (313A)

Keywords. Managing complexity Model-based systems engineering Decision-making Problem solving

Topics. 1.1. Complexity; 1.6. Systems Thinking; 2.4. System Architecture/Design Definition; 3.2. Configuration Management; 3.3. Decision Analysis and/or Decision Management; 3.6. Measurement and Metrics; 8. Energy (renewable, nuclear, etc.);

Abstract. What makes a system a system? One of the most defining attributes of systems is complexity. In engineered systems, complexity play a dual role. On one hand, complex systems enable functionalities that cannot be achieved with simple systems. But on the other hand, complexity is often associated with technical risks and project failures. Only the skillful systems engineer is able to find the right balance. It should come to no surprise that the skillful systems engineer employs methods and tools to manage complexity. Model-based engineering, for example, helps to formalize large-scale systems in modelling frameworks that improve information sharing and analyses from multiple viewpoints. Design Structure Matrices (DSMs) offer compact visual representations of complex systems, and are used to identify structured patterns like modularity. Most methods would fall in the category of design information management, however they do not help us to actively reduce the complexity of a system in design. That is why we aim to develop complexity management methods for the design definition stage. Before this stage, the system design is non-existent and therefore has zero complexity. But after this stage, a design emerges with a lot of complexity. What has happened on the way? How have our design decisions led to complexity of the design? Can we find the worst-offenders, those decisions that are particularly responsible for complexity and follow-up issues? We start our presentation with a hypothesis on the growth of complexity, based on a number of factors from engineering literature. Firstly, the design process always begins with a design problem. Secondly, designers seem to have a tendency to solve problems through addition, rather than subtraction, of system elements. Thirdly, more elements and more interactions within the system inadvertently means more complexity. And finally, more complexity means that more unexpected problems may emerge in later design stages. Those emergent problems would then be solved by more additive solutions, increasing complexity once more and extending the problem-solving cycle. Our contribution is a descriptive analysis method that formalizes emergent problems, design decisions and the complexity that follows from them. The method revolves around the interplay between two models: one of the design product and one of the design process. The product model is a network of connected design elements representing functions, components, requirements etc. This representation allows the use of network metrics, making complexity a computable and traceable indicator. The process model is a set of input-output activities, where input and output are specified in terms of the product model. The input of a design activity comprises those design elements that pose a design problem, and the output comprises those elements that are added as a design solution. This paradigm leads to two core insights. Firstly, allowing design elements to be simultaneously part of problems and solutions sets the stage problem emergence: the solution of one activity that becomes a problem for another activity. Now we can arrange the design process into a hierarchy that captures those emergence relationships. The hierarchy separates root problems, i.e. those that designers cannot influence, from emergent problems that could potentially be influenced by earlier decision-making. This view should motivate designers to avoid problems by reconsidering an early decision, rather than to solve problems by adding new elements. Secondly, we define the contribution of each design activity to overall complexity by two indicators: The local complexity impact is a first order approximation that captures the incremental growth of the product model due to the output of that activity. However, this indicator does not account for follow-up problems. That is why the more holistic global complexity impact factors in the elements that were added as solutions to emergent problems. The latter indicator will increase as more problems are solved, reflecting an increasing importance of early-stage decision making. We demonstrate the method by applying it to the conceptual development of a subsystem of ITER, a first-of-a-kind nuclear fusion reactor. With a rather simple example, we show that an emergent problem can be avoided by inspecting the design hierarchy and revising an earlier decision. This leads to two alternative design products with comparable complexities. A second, more elaborate example focusses on the growth of complexity over the course of 21 design activities. We can make snapshots of the product model at different stages, and observe how more and more elements are added. Moreover, the complexity indicators highlight the responsibility of critical design decisions, even as the design process unfolds over time. With our method, we are able for the first time to retrace complexity growth to individual design activities. This will allow for greater awareness and responsibility of complexity in systems design. Our contribution is especially relevant for the development of first-of-a-kind systems, such as big-science nuclear fusion reactors. Keeping these much needed systems at a minimal complexity is essential for their effective and timely deployment.

Presentation#88

Systems Engineering Planning in a Changing World

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Presented on: Thursday, 08:45-09:25 HST (KALAKUA BALLROOM C)

Keywords. NDIA Agile Systems Engineering Program Planning

Topics. 2. Aerospace; 3.7. Project Planning, Project Assessment, and/or Project Control; 5.1. Agile Systems Engineering; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 6. Defense;

Abstract. Systems Engineering (SE) has been and is a key enabler of large contracted system procurement such as those of the US Department of Defense (DoD) ensuring that the goals, constraints, and evaluation criteria for a system are well-established and commonly understood between the customer and the contractor. As we deal with increased market challenges, competition, and change – technology, environment, missions – and the acceptance that requirements will continue to be refined well into development, SE team members become even more crucial for incorporating change, refining system intent, and clearly communicating the past, current, and desired state of the system to all the stakeholders on an ongoing basis. This changes the paradigm for the way that SE tasking has been planned, proposed, budgeted, accounted, and staffed. The Agile Planning for Systems Engineering Working Group under the National Defense Industrial Association (NDIA) Integrated Program Management Division has developed a white paper collecting lessons learned from various government partnered contracting agencies and best practices for planning SE activities for programs executing in an environment of technical complexity and potential change for the benefit of both the contractor and the government. This presentation provides an overview of the white paper, including discussion of how mature SE work needs to be at different points in program execution, how the traditional SE technical reviews change (and don’t!) in incremental product development, and how the contractor and customer mindsets must evolve to responsively deliver effective and valuable systems at the speed of relevance. The white paper provides useful guidance to those experiencing the shift to greater agility in DoD acquisition as well as anyone looking to hone their SE practice in the transition to more iterative and incremental development lifecycles.

Presentation#38

Systems Engineering Technology: Closing the MBSE Modeling Gap through Community Colleges

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Presented on: Tuesday, 11:30-12:10 HST (316A)

Keywords. Education MBSE Systems Engineering Digital Transformation Digital Engineering SysML

Topics. 1. Academia (curricula, course life cycle, etc.); 20. Industry 4.0 & Society 5.0; 5.3. MBSE & Digital Engineering; 5.9. Teaching and Training;

Abstract. The shortages in today's systems engineering workforce - sheer number of personnel, adequate skills, holistic understanding— limit the nation's ability to support digital transformation and other underpinning tenets of the fourth Industrial Revolution (Industry 4.0). Through its initiatives to identify, share and recommend digital engineering and manufacturing best practices and applications, the Institute for Digital Enterprise Advancement (IDEA) acknowledges growing industry demand for Model Based Systems Engineering (MBSE) practitioners and Systems Modeling Language (SysML) modelers. These workforce shortages have been flagged by the U.S. Department of Defense as impediments to the nation's ability to safeguard critical supply chains. Deploying a skills-based approach, IDEA offers training to create ecosystems to keep pace with Industry 4.0 guidelines, merging physical production and operations with smart digital technology and big data to create a more holistic ecosystem. Such training will support U.S. initiatives to set the pace for Society 5.0. A young, national collaboration center with pathfinder operations in Huntsville, Alabama, IDEA offers a model that can be replicated geographically. Its threefold approach to energize development of the systems engineering, model-based engineering and MBSE workforce incorporates: Systems Engineering Technology (SET) curriculum deployed through community colleges; short-term courses for upskilling existing professionals; and consultancy support for both emerging and mature industries. The IDEA Academy is our focus today and addresses the dynamic and changing nature of Industry 4.0. Community college coursework leading to an associate degree in SET and professional continuing education classes reside here. High school awareness programs are also under this umbrella. Systems Engineering Vision 2035 from INCOSE notes, "The future of systems engineering is model-based, leveraging next generation modeling, simulation, and visualization environments powered by the global digital transformation to specify, analyze, design and verify systems." Under an Other Transaction Authority (OTA) with the U.S. Department of Defense, Calhoun Community College (CCC) developed the nation's first SET program in a joint effort with IDEA, Victory Solutions, Inc., and Auburn University. This program is the model for future SET programs around the country. Systems Engineering Technicians will anchor the growing field of model-based systems engineering. The community college SET degree gives students the computer programming and database skills needed to build and maintain those models, as well as real world, hands-on experience through internships with industry partners. An apprenticeship program is a proposed next step currently under development. The SET program was specifically created for community college students to become knowledgeable in MBSE SysML using state-of-the-art Object Oriented (OO) modeling software tools. At CCC the program is based within the Computer Information Systems (CIS) department and incorporates six systems engineering/systems modeling classes in a traditional CIS associates degree curriculum. These classes include: • Introduction to Systems Engineering • Database Management for Systems Engineers • Systems Modeling I • Systems Modeling II • Systems Modeling III • Dynamic Data Visualization Applications The initial course introduces students to systems engineering principles including systems definition, development and maintenance, and the use of systems modeling and MBSE methodology. The second database management course builds on prior coursework in database design/management and further explores disparate data types, gathering data from multiple sources and transforming it for incorporation into systems engineering models. The next three courses are a systems modeling sequence focusing on the concepts and tools necessary to generate a systems model, the fundamentals of the SysML programming language and other MBSE tools and their applications and MBSE modeling skills. Practical examples using the full SysML feature set are included. This sequence of systems modeling courses have the added advantage of preparing students for the OCSMP Model Builder Fundamental and Intermediate certifications. The final

course is a capstone project with students working in teams to design, develop, document, test, evaluate and utilize a realistic, comprehensive systems model using SysML and MBSE tools. The CCC pilot SET, two-year degree program significantly exceeded the initial goal of ten students with an enrollment of 35 in the fall semester of 2020, illustrating program interest and value. During the summer of 2022, eight SET students successfully completed summer internships with four local aerospace and defense industry partners. Four interns continued employment beyond the summer. The SET program continues to grow and attract students with the 2022 fall semester enrollment of 44 students. IDEA plans to not only expand across the Alabama Community College System starting with Wallace State Community College in the fall of 2023 and Snead State Community College in the fall of 2024, but to also grow nationally. Contacts have been made and discussions are in progress to bring the SET program to community college systems in Texas, Mississippi, Tennessee, Minnesota, and the Northeast. As the SET associate degree programs expand across the nation, community college students interested in pursuing a technical major are offered an additional path to obtain an associate degree leading to rewarding, state-of-the-art technology careers. A skilled SET technician workforce will strengthen the country's global competitive advantage in diverse fields including infrastructure, pharmaceuticals, automotive, marine, consumer products, aerospace, and defense. Participants attending this presentation will gain knowledge and a better understanding of: • Utilization of systems engineering technicians to help address the skilled workforce shortage • IDEA's SET degree programs and how a SET modeler can help improve their digital engineering processes • Availability of SET interns and graduates as an additional resource to the digital transformation team • MBSE as a new tool is becoming an industry essential instrument to: o Empower systems engineering technicians and address the skilled workforce shortage o Reduce the time to bring products to market o Improve the engineering decision making process o Significantly reduce dependence on paper documentation in lieu of digital models as an Authoritative Source of Truth (ASoT) • Understand how they can help their local community colleges begin to offer the curriculum targeted to the local economy

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Presentation#47

Technological Advances and Human Performance: A Systems Engineering Approach to Reducing Human Error

Jonathan Corrado (Cryptic Vector, LLC) - corradojk@gmail.com

Presented on: Wednesday, 05:00-05:40 HST (Virtual)

Keywords. Systems Engineering Process Safety Human Error Human Performance Nuclear

Topics. 4.1. Human-Systems Integration; 4.6. System Safety; 5.5. Processes; 8. Energy (renewable, nuclear, etc.);

Abstract. Over the last several decades, companies have implemented advanced technology and increasingly removed the human from many aspects of nuclear operations. This transition has many advantages, but like any system modification, failures inevitably occur. Due to this transition, human error has resulted in several accidents at nuclear facilities in the United States. Such accidents often result in plant shutdowns and unnecessary expenses and can be problematic for people, facilities, and the environment. The research I propose to present explores whether technological complexity and change affect how operators interact in the systems of nuclear facilities, exacerbating the severity of incidents caused by human error. This research first explored the hypothesis that technological changes affecting how operators interact in the systems of nuclear facilities increase the cost of incidents caused by human error. A review of nuclear incidents in the United States from 1955 through 2021 that reached Level 3 (serious incident) or higher on the International Nuclear Events Scale was conducted. The cost of each incident at facilities that had recently undergone technological changes affecting plant operators' jobs was compared to the cost of events at facilities that had not undergone such changes. A t-test determined a statistically significant difference between the two groups, thus establishing the hypothesis. Thus, this research statistically confirmed that

complex, changing technologies impacting how operators interact within the systems of nuclear facilities increase the severity of incidents attributed to human error. Next, a follow-on study was conducted to determine the impact of incorporating new technologies into nuclear facilities. The data indicated that spending more money on upgrades increased the facility's capacity and the number of reported incidents, but that the incident severity was minor. Another aspect of the research involved surveying the context surrounding the complexity of changing technologies at nuclear facilities and the potential worsening of problems caused by human error when technological advancements concerning operator interaction with control systems were implemented. To understand the complexity surrounding human interaction with advancing technologies, the concepts of human performance and human factors were examined. Then, the impact of these concepts on the operation of nuclear facilities within the framework of advancing technology was applied. This research draws attention to the vulnerabilities caused by human error at nuclear facilities within the context of continually advancing technology and sheds insight into the impact that human performance and other human factors have on system designs and the resulting outcomes. The fundamentals of human performance and error are timeless. They remain applicable when a human is involved in any operation because all industries are interested in error reduction. The deleterious effects of human error have been studied, but not human error caused by advancing technologies in industrial settings. To combat the negative effects of advancing technologies on plant operations, this research uniquely leverages the well-established systems engineering process to bolster human performance, enhance personnel and system safety, reduce risk, and ultimately increase profits. This research has led to proposals for reducing human errors arising from advancing technology using the systems engineering process. For instance, this presentation will propose several related concepts: operator involvement in the systems engineering process; human performance integration with system operational requirements and system testing, evaluation, and validation; and procedures and training development in the systems engineering process. The isolation and bolstering of human performance improvement within the systems engineering process pose a novel approach to moderating human error associated with incorporating advanced technology in nuclear facilities. This research also proposes a method for minimizing the impact of human error throughout the life of a facility by incorporating a human performance improvement model instituting human error severity criteria, establishing a system to capture human error data, and developing a process for predicting negative behaviors before potential errors or adverse events can occur via data trending. Lastly, looking toward future systems, as new systems are designed and human roles are transformed, human error should be significantly decreased relative to predecessor systems and system stability and safety equivalently increased. This research contends that optimizing the roles of humans and machines in designing and implementing new types of automation in nuclear facility systems should involve human error reduction without ignoring the significance of human interaction within those systems.

Presentation#75

THE SCIENCE AND SYSTEMS ENGINEERING OF LAWS: RATIONALE AND GOALS

David Schrunk (Science of Laws Institute) - david.schrunk@scienceoflaws.org

Presented on: Monday, 16:15-16:55 HST (316B)

Keywords. laws lawmaking systems engineering

Topics. 1.6. Systems Thinking; 22. Social/Sociotechnical and Economic Systems; 5.4. Modeling/Simulation/Analysis;

Abstract. The laws of government, e.g., legislative statutes, are created to solve (solve, mitigate, or prevent) societal problems, and their subsequent enforcement has an effect upon the human rights, living standards, and quality of life of every person. However, laws, as a generalization, have been less than successful in their attempts to solve serious societal problems such as war, crime, homelessness, poverty, and privation, etc. To evaluate the reasons for the relative lack of success of laws and to formally establish a science of laws, the Science of Laws Institute was created in 1995. The website of the Institute (www.scienceoflaws.org) describes the principles of the science of laws, contains a journal (The Science of Laws Journal) of relevant published articles, and has a search engine that provides access to knowledge of lawmaking and of the structure and mechanics of laws. Investigations and analyses of the traditional method of lawmaking of government, as reported in the Science of Laws Journal, have disclosed that the field of lawmaking is not a science, does not rely on knowledge, and fails to observe quality standards for the creation and validation of laws. These serious defects and omissions are the major contributors to the lack of problem-solving success of laws. In 2022, SELAW, the Systems Engineering and Lawmaking Working Group (https://www.incose.org/selaw), was formed in tandem with the Science of Laws Institute to improve the lawmaking process by adapting the rigorous quality standards and methodologies of systems engineering to the creation and validation of laws. This presentation discusses the vision, research projects and goals, and findings of the science and engineering disciplines of laws and lawmaking. Since every science is a success, as measured by ever-growing bodies of knowledge and by ever-improving problem-solving technologies, it is reasonably predictable that the evolving science of laws, in the quest to create efficacious solutions to societal problems and thus improve the human condition, will be equally successful.

Presentation#35

Transforming Perimeter Cybersecurity to Zero Trust Strategy Using Model Based System Engineering

Patrick Meharg (Noblis) - patrick.meharg@noblis.org

Presented on: Wednesday, 10:00-10:40 HST (313C)

Keywords. Zero Trust Enterprise Architecture Network Security Model Based System Engineering Product Line Engineering

Topics. 17. Sustainment (legacy systems, re-engineering, etc.); 2.4. System Architecture/Design Definition; 4.7. System Security (cyber-attack, anti-tamper, etc.); 5.3. MBSE & Digital Engineering; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. The challenge DoD faces today is how to transition to a Zero Trust Architecture without impeding operations or compromising security. Applying Model Based System Engineering (MBSE) provides a formalized approach to support the transition by capturing system requirements, design, analysis, verification, and validation activities throughout the product lifecycle. The Zero Trust DoD architecture and documentation approach was chosen as the reference for the MBSE approach. The classic approach to cybersecurity is implementing a perimeter strategy that has limited value against insider threats and well-resourced adversaries. A Zero Trust (ZT) architecture approach, simply stated, means don’t trust anything, anywhere, anytime, always validate. The National Institute of Standards and Technology (NIST) defines “Zero Trust (ZT) as the term for an evolving set of cybersecurity paradigms that move defenses from static, network-based perimeters to focus on users, assets, and resources. A Zero Trust Architecture (ZTA) uses zero trust principles to plan industrial and enterprise infrastructure and workflows.” One of the primary areas where enterprises struggle trying to implement a Zero Trust strategy is simply where to start. The MBSE model(s) provide an integrated, coherent, and consistent engineering product serving as the central repository for design decisions, also known as the Authoritative Source of Truth (ASoT). The vision and goals of the Zero Trust Reference Architecture is to modernize the information enterprise to address gaps and seams, simplify the security architecture, produce consistent policy, optimize data management operations, and provide dynamic credentialing and authorization. The Zero Trust model is not a solution, it’s a means to capture and communicate concepts. It is intended to stay at a high level of abstraction defining and describing ‘what’ the Zero Trust Architecture and framework is intended to accomplish. There are seven Zero Trust pillars identified in the DoD strategy and are aligned with the common industry identification of the pillars. A pillar is a key focus area for implementation of Zero Trust controls. The seven pillars of the DoD ZT architecture include: user, device, network/environment, applications and workload, data, visibility and analytics, and automation and orchestration. The pillars form the foundation in organizing and decomposing the activities that describe the ZT model. The seven pillars are further decomposed into DoD Zero Trust capabilities. The system owners use the capabilities to guide the adoption of an enterprise solution which complies with the Zero Trust Reference Architecture and DoD Chief Information Officer (CIO) guidance. To achieve a fully secured and defended DoD Information Enterprise, all the capabilities must be satisfied. Each DoD Zero Trust capability, aligned to the seven DoD ZT pillars, are categorized as target level, target and advanced level, or advanced level. The capabilities are further broken down into execution enablers which are cross-cutting, non-technical capabilities and activities that address culture, governance, and elements of the Doctrine, Organization, Training, materiel, Leadership & Education, Personnel, Facilities, and Policy (DOTmLPF-P). The Modeling Approach A Cyber Solution Analysis Model (CSAM) is created to define the problem domain and perform black box analysis and definition to meet stakeholder expectations that is scalable and reusable across the enterprise. The re-usable CSAM model is used as a ‘template’ model allowing individual implementation strategies to be built based on the baseline set of capabilities and functions using a Product Line Engineering (PLE) approach. Starting with the Zero Trust architecture documents, the high-level baseline set of capabilities needed to implement a ZT approach is captured in Use Cases directly mapping to the Zero Trust Pillars. The Pillar Use Cases are used to create a high-level activity diagram displaying the first level activities organized by the assigned target level. These activities are further decomposed into the second level activities called the execution enablers. Relationships are created in the model linking the high-level stakeholder strategy and goals, which originate in the Zero Trust architecture

documents and policy to the lower-level functions in the system model which is used to conduct analysis for system implementation solutions. A set of stakeholder needs, captured as business requirements, are created to begin the process of documenting the strategy, tenets, and goals and objectives of ZT initiative. These stakeholder needs are further decomposed into the initial set of draft requirements used later in the process to verify compliance during implementation. The goal of the modeling activity at this point is to understand how the Zero Trust approach interacts with its environment, the main inputs and outputs, black-box functions, and quantifiable characteristics while operating in a variety of system scenarios. Digital threads are used to describe how policies and controls can be applied across users, applications, and infrastructure to reduce risk and complexity while achieving enterprise resilience. The modeling activity also supports the trade study analysis and visualize multiple approaches for ZT implementation using the model as a 'digital twin' for decision making. This provides an opportunity to explore the full ecosystem of available controls, networks, endpoints, clouds, application, and IoT used for protection. Building "as is" and a 'to be' solution model assists in identifying what current set of controls can be immediately leveraged, while creating the initial Zero Trust foundation and planning technology insertion next steps for conformance. Benefits of applying a MBSE approach include: • Creates and visualizes (using SysML diagrams) the engineering process of implementing a Zero Trust architecture across the enterprise. This provides the opportunity to strategically plan rebuilding security that meets digital transformation goals while reducing risk and overall complexity. • Provides a systematic approach to transform the enterprise to accommodate hybrid workforce, data center cloud migration and security automation. • Improves collaboration across engineering disciplines by ensuring everyone is working on the same, up-to-date information by moving away from static and disconnected document-based approaches. • Introduces the cybersecurity functions and constraints of Zero Trust earlier in the design process for analysis.

Presentation#2

Understanding the Tension Between Program Management and Systems Engineering

Mark Kaufman (MITRE) - mkaufman@mitre.org
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Presented on: Monday, 11:30-12:10 HST (316B)

Keywords. Project management Roles and responsibilities Project tension

Topics. 1.4. Systems Dynamics; 11. Information Technology/Telecommunication; 3.5. Technical Leadership; 3.7. Project Planning, Project Assessment, and/or Project Control;

Abstract. The disciplines of Program Management and Systems Engineering are inherently intertwined. To develop and deliver complex systems, all three sides of the "iron triangle" (cost, schedule, and scope) must be known, traded, and evolved in consideration of the others. When there is tension and confusion over the roles of program managers versus systems engineers, programs suffer from deadline overruns and failures. This presentation will discuss project roles performed by program managers, systems engineers, and those performed jointly. Success in these roles depends on strong collaboration. Sources of tension will be identified and ways to manage this tension discussed. This presentation will take advantage of a recently completed comparison of the PMBOK and the Systems Engineering Handbook as well as findings from the development (by the INCOSE PM - SE Working Group) of new sections recently submitted for the forthcoming release of the SE Handbook. Additionally, there are joint INCOSE/PMI initiatives resulting from a decade of working together that will be highlighted.

Presentation#53

Using Systems Engineering Tools to Support Creation of the INCOSE Systems Engineering Handbook

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Presented on: Wednesday, 13:30-14:10 HST (316A)

Keywords. handbook process tools requirements models

Topics. 5.5. Processes; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. The objective of the International Council on Systems Engineering (INCOSE) Systems Engineering Handbook is to describe the state-of-the-good-practice for Systems Engineering. It serves as the basis for the INCOSE certification examination. The handbook effort is led by an Editorial Team from across the globe (representing all three INCOSE sectors) with the support of the INCOSE Working Groups (WGs) and Subject Matter Experts (SMEs). A tailored version of the Systems Engineering process described in the handbook was used to develop the handbook. To enable this process, a requirements management tool (Jama Connect) and a system design tool (Vitech/Zuken GENESYS) were employed by the editorial team. This presentation describes the application and tailoring of these two Systems Engineering tools for use on the Fifth Edition project highlighting the key adaptations to set-up the tool, the key features used, and the benefits of usage. This presentation will present the results of these modeling efforts and highlight some of the unique challenges related to modeling process standards. Overall, the team had success using Jama Connect to capture and manage the numerous requirements for the handbook Fifth Edition. The tool created an organized structure, collaboration center, and easy to use coverage views to spot gaps in content, beyond what is possible in other documentation tools. The team also had success using Vitech/Zuken GENESYS to model the system life cycle processes within the handbook, particularly in the area of typical process inputs and outputs. The use of the model enforced necessary discipline in the identification and naming of the information items and defining the transfer of these information items between processes.

Presentation#99

Utilizing the INCOSE Services Integration Model to Optimize Value Delivery

Heidi Davidz (ManTech International Corporation) - heidi.davidz@mantech.com

Presented on: Monday, 10:00-10:40 HST (316B)

Keywords. INCOSE Services Services Value stream optimization MBSE Model-Based Systems Engineering

Topics. 18. Service Systems; 22. Social/Sociotechnical and Economic Systems; 3.5. Technical Leadership; 3.7. Project Planning, Project Assessment, and/or Project Control; 5.3. MBSE & Digital Engineering; 5.5. Processes; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. The International Council on Systems Engineering (INCOSE) Services organization has created the INCOSE Services Integration Model as a tool to manage and optimize the services provided to INCOSE members. Using a model-based approach to INCOSE Services has triggered useful conversations to remove ambiguity, document flows, provide transparency, ensure linkage to strategic priorities, and question illogical relationships. The Services function integrates content from across the INCOSE organization. Ideally, the INCOSE Systems Engineering (SE) Vision 2035, Future of Systems Engineering (FuSE) and Corporate Advisory Board (CAB) needs inform need priorities, which are addressed by INCOSE Technical Operations, whose content is delivered by INCOSE Services, with Membership Engagement providing user feedback to update the process. To provide Services at the speed of relevance, we seek to optimize value delivery, which requires better understanding of dependencies across the Services value stream. The precision required with modeling has forced deeper conversations, making the modeling effort itself useful. Also useful is the model, which is currently available in the INCOSE Online Systems Engineering Laboratory. Access is available to all INCOSE members who take advantage of the free INCOSE Online SE Lab. Other INCOSE working groups and initiatives can reference or embed this model in their own modeling activities as desired. Developed primarily within the Services team, the model is being presented at the 2023 INCOSE International Workshop for wider review and comment. In January 2023, Strategy Session #2 is “Services Value Stream Optimization” addressing “How can INCOSE more rapidly and efficiently bring value to its members?” This presentation will describe the development of the INCOSE Services Integration Model, show key diagrams and relationships, explain how 2023 INCOSE IW input advised modifications, highlight how the January 2023 strategy session ideas advised optimizations, and recommend next steps for use. As background, INCOSE Services currently includes Education and Training, Certification, Events, Community Offerings, development of new services, and governance of each. The primary objective of Services is to, “Provide value through impactful services.” This relates to all facets of systems engineering across all sectors of application. INCOSE policy “SVC-100: Services Operations Infrastructure” documents roles and responsibilities. The Services Director, who is a voting member of the INCOSE Board of Directors (BoD), leads the Services organization. The Deputy Services Director, who is a non-voting member of the BoD, supports the Services Director as needed. The Services Associate Directors are non-voting members of the BoD. The Associate Director of Certification oversees the INCOSE Certification Advisory Group (CAG) and Certification Program Manager to ensure the successful planning and execution of the INCOSE Professional Certification program. The Associate Director of Education and Training leads the INCOSE education and training activities and ensures the successful planning and execution of INCOSE education and training initiatives. The Associate Director of Events leads the INCOSE event team and ensures the successful planning and execution of INCOSE Global Events. The Services Assistant Directors are not members of the BoD. The Assistant Director of Events Portfolio Management is responsible to the Associate Director of Events to ensure consistent information across INCOSE events, establish and maintain a database of INCOSE events, and lead strategic planning for new INCOSE Global Events. The Assistant Director of Community Offerings leads and coordinates the delivery of virtual community offerings (i.e., webinars, system exchange cafés, and “Spotlight On” discussions), develops and improves specific offerings, and considers changes / new offerings as needed to ensure there are a range of virtual activities that engage the members and potential members of INCOSE with conversation and discussions about systems-related topics. The INCOSE Services Integration Model documents these roles, responsibilities, corresponding activities, and relationships to each other and to other parts of INCOSE. With systems engineering becoming more digital, advances are moving at the speed of Big Tech rather than the pace of historical aerospace and defense acquisition. For INCOSE to provide high value at the speed of relevance, we must tighten the knowledge cycle to provide timely services which help members stay on the cutting-edge as technical leaders. The INCOSE Services Integration Model helps us understand relationships and flows more transparently, to optimize the INCOSE Services value stream from “new idea” through "content delivered to members." From this presentation, the audience will understand the INCOSE Services Integration Model effort and see how they could contribute if desired.

Presentation#43

Visualizing AGILE inside the V, mixing Code-Centric and Evidenced-Based development

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Presented on: Monday, 16:15-16:55 HST (KALAKUA BALLROOM C)

Keywords. MBSE OMG RAAML ISO 26262 DevSecOps Assurance Quality Safety Cyber Security

Topics. 1.6. Systems Thinking; 2. Aerospace; 2.4. System Architecture/Design Definition; 3. Automotive; 5.3. MBSE & Digital Engineering; 6. Defense;

Abstract. In the fast moving world of Agile software development, the priority is on speed and minimizing effort spent on documentation. The code is the documentation. Maintenance of models and other forms of stakeholder documentation is seen as a waste of effort that slows down the coding of new features. Safety-critical systems necessarily require a greater degree of both transparency and accountability from the software development team. The Agile software development and functional safety communities often regard each other with suspicion and jump to the conclusion that neither has anything to learn from the other. This mutual suspicion is unfortunate. Although the nontechnical public often associates Agile development methodologies with doing things in a hurry, actually the Agile development community has developed some very sophisticated methodologies for managing project uncertainty. Applied skillfully, Agile methodologies can be very effectively applied for delivering robust, highly reliable systems in the presence of project uncertainty. Another common misconception is that the Vee model and other ISO/IEC/IEEE 15288 based engineering processes need to be applied an in inflexible, purely linear, waterfall style. Applying Agile techniques such as “Just-in-Time Requirements Elaboration” can lead to better designs, lower complexity, and better safety. On the Agile side, many teams would be well served to put less emphasis on doing things in a hurry and more emphasis on the kind of rigorous design discipline used in the safety-critical systems community. Overall throughput and quality could be improved by improving the robustness of the often informal domain driven design techniques used in DevSecOps with more robust modeling, traceability, and stakeholder communications processes. In this presentation we will present techniques for bringing these two worlds together and achieving both project resilience and the high levels of quality and accountability required for safety-critical and similar systems.

Presentation#3

Where are you on your MBSE journey

Mark Sampson (Siemens) - mark.sampson@siemens.com

Presented on: Wednesday, 10:45-11:25 HST (313A)

Keywords. MBSE MBSE implementation System integration Organization Change Management

Topics. 1. Academia (curricula, course life cycle, etc.); 2. Aerospace; 3. Automotive; 5.3. MBSE & Digital Engineering; 5.5. Processes; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.);

Abstract. Even with pockets of MBSE modeling excellence, we continue to consume half of our program schedules on system integration leaving everyone to wonder about the value of this MBSE effort. MBSE is not a tool, its collaboration with many different tools and perspectives across an organization. That means it requires a organization shift in thinking to get past Conway's law to build continuously integrated products--ie. MBSE is a journey. Any successful journey begins with knowing where you are. Once you know where you are, you can make a journey plan that includes everyone involved. The INCOSE MBSE Initiative has been working to develop a rapid MBSE Maturity test that relies on technologies currently used in an organization and developed journey advice based the current sample set. This presentation will introduce the MBSE Maturity Assessment, making predictions on where you are, and offer advice on where to start to realize the full value of integrated MBSE.

Key Reserve Paper

Key Reserve Paper#238

A Case for Systems Engineering in an Agile World and Principles for Growth

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Keywords. agile systems engineering model-based systems engineering agile software

Topics. 2. Aerospace; 5.1. Agile Systems Engineering; 5.3. MBSE; 5.7. Software-Intensive Systems; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Systems engineering enabled the development of the greatest engineering marvels of the 20th century. With the advent of the information age and software-centric systems, systems engineering as a discipline has encountered growing pains. As organizations work to adopt agile software development methods, the rigor of systems engineering work has been compromised. The linguistic relativity hypothesis suggests that the cognitive ability to engineer effective systems is developed and enhanced by the ``language'' of systems engineering. An improved understanding of what constitutes model-based systems engineering (MBSE) as opposed to systems modeling can improve MBSE outcomes. Agile systems engineering, enabled by MBSE, is the bridge that will allow the principles and processes that have been developed through decades of research and experience to be applied to benefit modern systems.

Key Reserve Paper#147

A Systems View of Career Development for Systems Engineering Leadership

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Keywords. systems engineering leadership technical leadership competencies leadership development

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

Abstract. SE leaders' career development journeys are primarily driven by their experiences that shape their capability, qualities and perspective; however, the pathways that individuals take are not only broad and varied, but also equally affected by personal life decisions and external factors. This paper describes a two-fold study that aimed to: a) provide insight into commonalities in the career journeys of SE leaders, and b) ascertain how key areas affect career development. Five key areas were explored: education, technical experience, soft skills experience, job satisfaction and work-life balance, A mixed and multi-method approach was taken, gathering data from sixty-one participants through interviews, surveys and workshopping. The study found that although there was no 'blueprint' that yields successful SE leadership, there were themes/trends that were common. An influence model was developed to highlight these trends in the form of the key areas, factors affecting them, and the interrelationships between them.

Key Reserve Paper#112

An Approach for Linking Heterogenous and Domain-Specific Models to Investigate Cabin System Variants

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Keywords. Model-based Systems Engineering Variant Modeling Aircraft Cabin

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

Abstract. This paper presents an approach to link heterogeneous and domain-specific models. The background of this research is the complete investigation and comparison of cabin system variants, where many different aspects have to be represented. These include functional requirements, safety regulations, and geometric properties (e.g. installation space). However, these cannot always be represented or validated with just one model, as different levels of detail are required. Therefore, different discipline models have to be created, which in turn increases the complexity as a whole. Furthermore, the system to be represented by the models, such as the aircraft cabin, is already complex in itself. The many dependencies among each other and subsystems make it difficult to integrate new variants or technologies (e.g. liquid hydrogen) into the existing system architecture. The approach presented here therefore shows how the data and models of the different disciplines can interact with each other in order to be able to investigate variants holistically. This is demonstrated using the design of hatrack variants for a commercial aircraft.

Key Reserve Paper#36

An Empirical Survey on the Prevalence of Technical Debt in Systems Engineering

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Keywords. Technical Debt Empirical Data Systems Engineering

Topics. 2. Aerospace; 3.3. Decision Analysis and/or Decision Management; 3.9. Risk and Opportunity Management; 5.5. Processes; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. The technical debt metaphor is used within software engineering to describe technical concessions that produce a short-term benefit but result in long-term consequences. Systems engineering is subject to these concessions yet there is a limited amount of research associating technical debt with systems engineering. This paper provides the results of an empirical survey investigating the prevalence of technical debt in systems engineering, including the occurrence of technical debt, the use of the metaphor, and the occurrence of technical debt within the systems engineering lifecycle. The results of the survey show that while technical debt is common in systems engineering and occurs throughout the lifecycle, the metaphor and terminology of technical debt is not consistently applied. These results emphasize the need to enrich the usage of the technical debt metaphor within systems engineering to enable the management of technical debt and to reduce the risk of technical bankruptcy.

Key Reserve Paper#194

Autonomica: Ontological Modeling and Analysis of Autonomous Behavior

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Keywords. Autonomy MBSE Ontology Systems Engineering Architecture Semantic Web OML openCAESAR

Topics. 14. Autonomous Systems; 2. Aerospace; 2.4. System Architecture/Design Definition; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis;

Abstract. Model-based system autonomy is a complex integration of planning of low-level command sequences from high-level goals, and execution of such command sequences to control a system. The need for autonomy has accelerated in recent years to meet the demand for more complex missions in domains like automotive, space, and defense. During system development, an understanding of the complex relationship between system autonomy and the physical environment (including hardware) is critical to support trade studies, developing concepts of operations, characterizing risk, and performing testing. This paper describes the initial results of developing Autonomica, an ontology-based method, and framework for autonomous behavior modeling and analysis. This method formalizes the State Analysis (SA) [Ingham et al, 2005] architectural pattern as a vocabulary with description logic semantics, and provides authoring viewpoints and analysis capabilities (reasoning, querying, simulation) for the SA-based architectures. The framework implements the method in an integrated workbench. Ideas are illustrated using a running example of a hypothetical mission to a small space body using an autonomous spacecraft.

Key Reserve Paper#52

Boxing Configuration Management – Configuration Change Management Meets the 4-Box Development Model

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Keywords. Configuration Management Incremental Development Systems Engineering

Topics. 2. Aerospace; 3.2. Configuration Management; 5.5. Processes;

Abstract. Systems Engineering and Configuration Management are essential ingredients in the development of complex safety-critical systems of today. However, our experience within the fighter aircraft in-dustry shows different understanding of how to best manage and control development between the Systems Engineering and Configuration Management communities. This is particularly true when a system is developed incrementally, and where there are multiple concurrent change controlled de-velopment activities. Using the 4-box development model as a basis for incremental development, the paper highlights the nature of development planning and change control. Three types of change items are identified in the paper, to capture the needs to handle both 1) long-term, static changes with a large scope to be agreed with the stakeholders, 2) short-term, dynamic changes with small scope for each development team, as well as 3) short-term, static changes with a varying scope de-pending on what is available for integration into a specific product configuration. Finally, this mod-el of handling changes is exemplified by a toy example, showing the relationships between the changes and the flexibility in handling re-planning during the long-term development. With the proposed approach, we hope to narrow the gap between the Systems Engineering and Configura-tion Management communities.

Key Reserve Paper#74

Carbon Considerations for Systems Evolution

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Keywords. Carbon Analysis Decision Making MBCD

Topics. 10. Environmental Systems & Sustainability; 17. Sustainment (legacy systems, re-engineering, etc.); 2.3. Needs and Requirements Definition; 4.4. Resilience; 5.4. Modeling/Simulation/Analysis; 7. Emergency Management Systems;

Abstract. In the early stages of systems development, Systems Engineers will typically evaluate alternatives based on performance, cost, risk, and schedule to evaluate the solution space of alternatives. While these criteria have proven to be successful, there is growing interest in the analysis of carbon costs as well to contribute to the decision making. These decision criteria are very good to help the decision maker select the best alternative within the solution space in which to develop a system concept. We offer another criterion for consideration in order to account for carbon expenditure throughout the SE lifecycle. We believe that including this dimension can influence decision makers to evaluate a richer portion of the solution space. This approach is developed and exercised with a notional example.

Key Reserve Paper#84

Descriptive Functions and the Role of Artificial Intelligence

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Keywords. Model-based systems engineering Function formulation Function modeling Artificial intelligence Recommender system

Topics. 1.6. Systems Thinking; 2.4. System Architecture/Design Definition; 3. Automotive;

Abstract. This paper describes concepts to support the application of descriptive functions using artificial in-telligence technologies. Descriptive functions are typically used in the system design phase to de-scribe and specify the system behavior. In a model-based systems engineering approach the system functions, their dependencies, and the allocation to the technical solution are typically documented in system models. Descriptive functions have a fuzziness that is beneficial in the solution finding process but also challenging in terms of development efficiency. To support development teams in formula-tion and working with descriptive functions in system design, and verification and validation phase several concepts with the use of artificial intelligence technologies are discussed.

Key Reserve Paper#167

Explainable AI and Counterfactuals for Test and Evaluation of Intelligent Engineered Systems

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Keywords. Test and evaluation of Machine Learning Explainable AI Counterfactual Testing

Topics. 14. Autonomous Systems; 2. Aerospace; 2.6. Verification/Validation; 5.11 Artificial Intelligence, Machine Learning;

Abstract. Systems Engineering (SE) based test and evaluation (T&E) approaches have proven crucial for successful realization of most modern-day complex systems and system-of-systems. The design, test, and evaluation of engineered systems with many technologically advanced and complex components hinges on well-structured integration and life cycle evolution process models, clearly defined requirements, along with controllability, observability, and stability (COS) of components that transcend to the system-level. However, integration of Deep Machine learning (ML) and artificially intelligent (AI) components invalidates some SE foundations as the deep learning (DL) algorithms are primarily data-driven with opaque decision-making constructs. As a result, the current SE T&E approaches, although necessary, have become insufficient to evaluate the adoption of Deep ML/AI methods in engineered systems. This paper proposes two new approaches—explainable AI (xAI) and counterfactual testing and evaluation (cT&E)—as addition to the SE tool set for T&E of intelligent engineered systems. A contrast of SE T&E considerations is provided based on a conceptual aircraft control system implementation as a classical controller and a DL-based reinforcement learning controller which serves as an exemplar of an intelligent engineered system.

Key Reserve Paper#75

From Requirements to Product: Digitalization of the Aircraft Design Process using MBSE, MDAO and KBE

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Keywords. Design process Digitalization and automation Model-Based Systems Engineering Multidisciplinary Design Analysis and Optimization Knowledge-Based Engineering

Topics. 2. Aerospace; 2.6. Verification/Validation; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis;

Abstract. During the aircraft conceptual design phase, many different design options need to be explored and compared in a short time frame. To speed up this process, efforts have been made in the past decades to digitalize parts of the design process, with a focus on the automation of the repetitive and non-creative tasks inherent to the iterative design process. Whilst many of the newly developed methodologies focus on specific parts of the design process, a holistic model-based design framework, incorporating the latest design technology developments, is lacking. In this paper, we present the latest version of the Design and Engineering Engine (DEE) framework, originally proposed in the early 2000s and progressively matured through the experience of several international research collaborations. The DEE enables the setup and execution of Multidisciplinary Design Analysis and Optimization (MDAO) problems for aircraft systems (full aircraft or subsystems) leveraging the automated, rule-based modeling capabilities offered by Knowledge-Based Engineering (KBE) and recent developments in the automatic formulation and integration of MDAO workflows. While the traditional MDAO process focuses on a given product architecture, the DEE allows also architectural design studies and makes use of Model-Based Systems Engineering (MBSE) principles to address the whole design process, from requirements modeling up to their automatic verification. In practice, the DEE provides a single template from which specific design framework instances can be formulated and executed, according to the user's needs. This paper describes the DEE architecture and its implementation concepts. Furthermore, it demonstrates its application to four different scenarios, ranging from a simple requirement verification study, up to the simultaneous synthesis and optimization of an aircraft system and its production process, including multiple system architecture options.

Key Reserve Paper#148

Future Trends Influencing Technical Leaders and Technical Leadership

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Keywords. Leadership Future Trends Technology Covid-19 Automated Intelligence Machine Learning Digital Engineering Model-Based Systems Engineering

Topics. 1. Academia (curricula, course life cycle, etc.); 1.1. Complexity; 22. Social/Sociotechnical and Economic Systems; 3.5. Technical Leadership; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. This paper summarizes a virtual workshop conducted on October 31, 2022, by members of Cohort 7 of the INCOSE Institute of Technical Leadership (TLI). The workshop, which built upon the global trends and influencing factors identified in INCOSE's Systems Engineering Vision 2035, considered the impacts of three key factors on technical leaders and technical leadership. These factors include: (1) the heightened societal awareness of environmental concerns and the associated demand for more environmentally friendly products, (2) the increasingly interconnected, multi-cultural, multigenerational environment work environment, and (3) the increasing capability of digital tools, techniques, and processes.

Key Reserve Paper#170

How INCOSE's Certification Program has Evolved as a System of Systems

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Keywords. System of Systems INCOSE Certification program Constituent system System of systems engineering

Topics. 1. Academia (curricula, course life cycle, etc.); 22. Social/Sociotechnical and Economic Systems; 5.10. Diversity (cultural boundaries, diverse engineering teams, training underserved groups, etc.); 5.3. MBSE; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. The INCOSE Certification program began as a subsystem of INCOSE, with only a few external entities involved. The majority of the required capabilities were carried out internally, such as testing based on the INCOSE Systems Engineering Handbook. Many capabilities have since been outsourced to independent external agencies such as psychometricians and certificate providers to gain flexibility and simplify operations. As a result, the INCOSE certification program evolved from an INCOSE subsystem to a System of Systems with component systems such as universities, exam providers, training providers, and local chapters. This paper discusses the characteristics and challenges of the INCOSE Certification program as a System of Systems, the type of System of Systems that best suits the certification program, change management of the certification program, learnings from managing the certification program as a System of Systems, the System of Systems engineering application to the certification programs, and critical problems involved in the certification program's operation and management.

Key Reserve Paper#41

MIKA: Manager for Intelligent Knowledge Access Toolkit for Engineering Knowledge Discovery and Information Retrieval

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Keywords. Machine Learning Natural Language Processing System Safety Risk analysis

Topics. 2. Aerospace; 2.6. Verification/Validation; 4.6. System Safety; 5.11 Artificial Intelligence, Machine Learning;

Abstract. Repositories of safety reports are often underutilized and only analyzed manually by trained experts, despite safety management systems requiring reports. These collections of documents contain a wealth of information from past projects and operations that could improve system safety and design. Advances in natural language processing techniques have improved information extraction and retrieval in consumer technology, biomedicine, and finance, for instance, but have not been applied to engineering documents on the same scale. To this end, the Manager for Intelligent Knowledge Access (MIKA) open-source toolkit has been developed for rapid knowledge discovery and information retrieval in safety engineering applications. The MIKA toolkit uses state-of-the-art natural language processing algorithms and allows a user to apply these methods to their own dataset. This paper describes the MIKA toolkit and its two primary capabilities, knowledge discovery and information retrieval, and demonstrates the toolkit via a case study on National Transportation Safety Board (NTSB) reports.

Key Reserve Paper#160

Moving towards a Server-Zone Vehicle Architecture with MBSE at Continental

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Keywords. MBSE Automotive Server-Zone Architecture Architecture Framework Continental IBM

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

Abstract. The automotive industry is undergoing the transition towards a revolutionary vehicle architecture concept, known as Server-Zone architecture. As a result, complexity increases exponentially and, in order to better deal with it, new development approaches like Model Based Systems Engineering (MBSE) are required. This paper focuses on how MBSE can support the migration towards a server-zone vehicle architecture, using a real-life example from Continental. Along with this example, the authors provide insights into the application of Continental's MBSE framework through the usage of IBM's Rhapsody modeling tool.

Key Reserve Paper#144

NASA Technology Readiness Level Assessment Using a Model-Based Systems Engineering Framework

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Keywords. Model Based Systems Engineering Technology Readiness Level Assessment Methodology

Topics. 3.3. Decision Analysis and/or Decision Management; 3.9. Risk and Opportunity Management; 5.3. MBSE;

Abstract. Assessing the Technology Readiness Level (TRL) of a system in support of a NASA effort is an important exercise to identify where the maturity level of the system's components and subsystems could need improvement in support of reducing the overall risk of a system not performing at an adequate level in the harsh space environment. However, the assessment process that a contractor needs to perform in support of this report is often inconsistently applied. Because this report is usually done in a document-based manner, there is little to no propagation of change throughout the system design documents, little reuse of the data once it is developed, and no single source of truth for engineers to reference. Model-Based Systems Engineering (MBSE) is an approach that has helped address these problems for other Systems Engineering-related deliverables (such as requirements specifications, system architecture, design documentation, and verification planning). In this paper, we use MBSE to create a TRL assessment methodology that a variety of different programs can tailor to use to help streamline their process, make their processes reusable, and encourage a single source of truth for their data. We first describe our approach, then describe the methodology we have developed, and finally apply this methodology to an example.

Key Reserve Paper#93

Shifting the Paradigm from Lessons Learned to Lessons Applied through Digitally Enabled Transformation

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Keywords. lessons learned lessons applied digital engineering digital transformation

Topics. 3.5. Technical Leadership; 3.9. Risk and Opportunity Management; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Lessons learned are generally documented with limited review until the next policy driven decision point. Additionally, the lessons learned are frequently documented in disparate data sources, such as individual computers. This passive, disconnected approach is an example of current processes that are desired to be overcome as an outcome of the digital transformation. Our customer defined a task to deliver proof of active lessons management, for which we selected to incorporate digital paradigm principals. To deliver the capability, we re-envisioned the passive lessons learned as active lesson applied, developed an underlying methodology, and are evolving a digital ecosystem for implementing the lessons applied methodology. This article serves to provide documentation of our lessons applied methodology and the supporting digital infrastructure.

Key Reserve Paper#219

Small satellite Extracurricular projects – Implementing a context-driven SysEng engine for improved adaptability and student agency

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Keywords. Academic Extracurricular CubeSat Small satellites Teaching Systemigrams MBSE model-centric system thinking

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;

Abstract. University student projects usually attempt to follow, and often fail to follow, industry frameworks and standards to ensure the success of their development effort. The typical student satellite project follows ESA ECSS or NASA project frameworks, prescribing document artifacts, project reviews, the project life cycle, and typical project processes. In the case of Anon Org. this was done without understanding the underlying dependencies and supporting connections between artifacts, design steps, and project phases. This paper presents a framework for increased understanding of the purpose of common design artifacts and their interdependencies by applying model-centric system thinking and systemigrams as a tool for highlighting relationships and dependencies within the SysEng discipline, thus enabling the students to complete well-informed and planned design iterations that builds a solid and coherent system understanding throughout the project lifecycle. The method is built to be adapted to the needs of the project team and can readily be used by 1st year university students with one semester of SysEng experience.

Key Reserve Paper#193

SysML Implementation of Property Based Requirements

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Keywords. MBSE SysML Requirements Requirements Management Digital Engineering

Topics. 2. Aerospace; 2.3. Needs and Requirements Definition; 2.6. Verification/Validation; 5.3. MBSE; 6. Defense;

Abstract. Text based requirements are historically used for specifications in DoD acquisition and systems engineering, along with models of various levels of fidelity. Text based requirements do not enable the comprehensive traceability and analysis necessary to successfully maintain and develop a complex system. In addition, the reliance on varied requirement interpretations along the design process causes issues in the accurate transference of intention, especially with regards to redundancy with the associated descriptive models. To mitigate these issues, a comprehensive property-based solution to the generation, linkage, analysis, and verification of requirements is proposed utilizing parametric execution within SysML. Additionally, this approach can enable a level of automation in the requirements verification process when applied with digital engineering practices. A case study shows the application of the solution with an example so that the approach can be further explained.

Key Reserve Paper#24

Systems Engineering Isn't Scary for Agile Practitioners

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Keywords. Agile Systems Engineering Comparison Relationship Terminology

Topics. 1. Academia (curricula, course life cycle, etc.); 1.5. Systems Science; 5.1. Agile Systems Engineering; 5.9. Teaching and Training; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Traditional Systems Engineering artifacts and terminology are not scary for Agile software development. They can, and should, be tailored and utilized in during the Agile development process. Many times, terminology and lack of understanding lead to Agile practitioners shying away from what are considered Traditional Systems Engineering artifacts such as requirements, architectures designs, documented interfaces, verification, gate reviews, etc. Agile already uses many of these artifacts but simply use a different terminology when referring to them. This paper helps advance the mindset that Traditional Systems Engineering artifacts are not something to avoid in Agile by providing alternative ways to describe these artifacts in an Agile world.

Key Reserve Paper#216

The Quest for an Open Digital Thread: Challenges and Practices

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Keywords. digital thread future systems engineering model analysis model version control

Topics. 2.1. Business or Mission Analysis; 2.5. System Integration; 2.6. Verification/Validation; 3.4. Information Management Process; 5.3. MBSE; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. As INCOSE also envisions in their recently published vision paper on the future of systems engi-neering (https://www.incose.org/about-systems-engineering/se-vision-2035), the future society will experience a level of interconnectedness, interrelatedness and networkedness which was not seen before. The technical reality of the realization of this vision largely depends on how we interpret and implement the notion of openness. In particular, the OpenMBEE initiative represents an in-dustrially backed research and development endeavor towards open systems engineering ecosys-tems of the future. In the OpenMBEE concept and tool portfolio, the open-source aspect of openness is emphasized. In this paper, we aim at providing a complex analysis of the organizational, con-ceptual and technical landscape of open digital engineering ecosystems along the notion of the digital thread, where different, often commercially driven engineering domains, tools and stake-holder perspectives fuse into a single, interconnected digital engineering experience. What could be the role of commercial players in, and attitude towards open digital thread ecosystems? Where do emerging initiatives and standards like SysMLv2 take the systems engineering community from this perspective? The paper provides an in-depth analysis of openness in digital engineering, as seen from a technological, organizational and techno-social perspective.

Key Reserve Paper#78

The Safety Aspect of Measuring System Trust

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Keywords. Model-Based Systems Engineering System and Software Safety Automated Metrics

Topics. 3.6. Measurement and Metrics; 4.6. System Safety; 5.3. MBSE; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. The digital transformation brings opportunities to improve how engineering data is tracked and interpreted. Safety analyses, a critical aspect of engineering, are more powerful when captured directly alongside the foundational systems models. Having these analyses integrated within the authoritative source of truth provides the team with current information and improved context. A model-based safety approach is a strong first step, but more opportunities await. The value of this data increases significantly when elevated into actionable information that decision-makers need. This paper articulates a specific approach to obtain the software safety aspect of the system trust metric for defense systems, recommends an initial structure of a system trust metric, and identifies future steps for this topic of research. Getting safety data into the digital engineering environment is the first step toward an overall system trust metric as described in the INCOSE 2035 Systems Engineering Vision.

Key Reserve Paper#143

Using model-based systems engineering to design system-based digital twins

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Keywords. Model Based Systems Engineering Digital Twin Simulation Model validation Product design

Topics. 1. Academia (curricula, course life cycle, etc.); 20. Industry 4.0 & Society 5.0; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis;

Abstract. Although the use of Model-Based Systems Engineering (MBSE) is an alternative for designing Digital Twins (DT), MBSE has a steep learning curve, and quite often companies struggle to translate its theoretical benefits to their reality. Furthermore, the challenge of determining the DT model fidelity that brings balance between simulation accuracy and development cost increases the modeling task difficulty. This paper presents the initial results from research towards facilitating the design of system-based DT, where various models are combined to obtain the desired representation of reality. The main contribution of the paper is towards the MBSE practice, where a simplified 8-step MBSE modeling approach for system-based DT is proposed. The modeling approach starts from the existing physical product and the need of a DT, and results in a simulation model that is the core of an actionable virtual twin. To shorten the MBSE learning curve, a set of guidelines is pro-posed to delimitate the Systems Modeling Language (SysML) use in Eclipse Papyrus, and a Python parser was created to convert the SysML models' information into the simulation model. The approach, guidelines and parser are analyzed through one example of application. During the example, the model creation, validation and use are illustrated.

Panel

Panel#12

As yet undecided: Does ‘engineer’ in the title limit acceptance of systems engineers?

Cecilia Haskins (NTNU - MTP and USN) - chaskins25@yahoo.com
David Long (Blue Holon) - david@blueholon.com
Tom McDermott (Stevens Institute of Technology) - tamcdermott42@gmail.com
Christopher Hoffman (Cummins Inc.) - christopher.hoffman@incose.net
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Nicole Hutchinson (Stevens Institute of Technology) - nlong@stevens.edu

Presented on: Wednesday, 15:30-16:55 HST (313C)

Keywords. soft systems systems thinking defining SE communicating about SE

Topics. 1. Academia (curricula, course life cycle, etc.); 1.5. Systems Science; 1.6. Systems Thinking; 22. Social/Sociotechnical and Economic Systems; 3.5. Technical Leadership; 5.10. Diversity (cultural boundaries, diverse engineering teams, training underserved groups, etc.);

Abstract. Does the word ‘engineering’ limit the acceptance of SE to traditional domains and product-centric efforts, meanwhile excluding soft systems practitioners and applications? The panelists and participants will share perspectives on how systems engineers can be better integrated into the broad spectrum of global challenges. Would a new discipline title better convey our ability to participate and contribute productively to fields of endeavor outside science and technology? How can we communicate the message that engineering and engineers are more flexible than implied by traditional stereotypes? This panel is made up of persons who have been examining the role and attributes of systems engineers and will offer suggestions about how their research and observations lead them to address this question. The panel will open in debate format with panelists arguing pro and con positions to establish a critical foundation before transitioning to open dialog with the audience. Audience experiences are welcome as we try to close this session with either new ideas for messaging for our current “systems engineer” brand or suggestions for a new title for soft systems engineering.

Biography

Cecilia Haskins (NTNU - MTP and USN) - chaskins25@yahoo.com

Cecilia Haskins - Cecilia is recently retired and continues in emeritus status with the Norwegian University of Science and Technology (NTNU) and the University of Southeastern Norway (USN). Her career included over 30 years as a practicing systems engineer and over 20 years educating the next generation of engineers on the importance of systems approaches. She joined INCOSE in 1993 where she held a variety of leadership and other volunteer positions, was recognized as an INCOSE Founder, and continues to be active as a mentor and author. She is a certified SE since 2004.

Position Paper

Cecilia Haskins - my position is that the profession needs a way to orient itself in the minds of the general population to sidestep the stereotypical perceptions of what engineers do, how they look at the universe, and how they can contribute to addressing the hard questions that need resolution in the near future. As the moderator, I will encourage audience feedback and creative investigation into whether there is a title that could achieve this shift in perceptions and open the door to admitting systems engineers into the mix of those looking for systemic solutions. We have the tools; we need to use them.

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

David Long is a long-standing INCOSE member, former President, and current Fellow. He was the former CEO of Vitech Corp and is an active volunteer in multiple INCOSE fora.

Position Paper

David Long has stated he could take a position on either side of this topic.

Tom McDermott (Stevens Institute of Technology) - tamcdermott42@gmail.com

Tom McDermott is well known for his many contributions to INCOSE and the SERC.

Position Paper

Tom McDermott - It is not so much the word “engineering” as the whole language that engineers use when they talk to people from other disciplines. I co-developed a training program on the use of soft systems methods in the social innovation/economic development community. There was one module related to systems-of-systems engineering that the audience really liked. However, I had to change the whole language and look & feel of my systems engineering-related applied systems thinking course to match this community. As a result, I became convinced we should have a domain at least if not shift the whole thing to “the systems approach to engineering.”
Also in my many years of experimenting and training soft systems methods, I have discovered that many engineers do not realize that soft systems tools are the same conceptual thinking tools they have used many times in their careers without thinking about it. What I have found the value of “applied systems thinking” in the engineering domain to be is understanding that there are a number of conceptualization tools that could be used and “systems thinking” is really about choosing the right one.
The core of this issue is that engineers consider a system solution as a solution, and soft systems practitioners consider a system solution as an intervention into a larger socio-economic situation. This “solve” versus “intervene” difference drives a lot of language issues.
So my position would be yes, but… it is the language engineers use not the word itself.

Christopher Hoffman (Cummins Inc.) - christopher.hoffman@incose.net

Chris Hoffman is the current INCOSE Technical Director. Certificate: System Design & Management, Systems Engineering, MIT (2012) Various electro-mechanical engineering roles, Cummins Inc. (25 years) Various leadership roles, INCOSE (11 years) Certified Systems Engineering Professional (2015). Current Main Field of Activity: Director, Engineering Information Systems Owner: I currently manage the strategy and portfolio planning of over 1300 software tools and applications that enable product design & development for Cummins Inc.

Position Paper

Chris Hoffman - position is that many SE (even in INCOSE) have non-engineering degrees and backgrounds. His position will emanate from a commercial industry point of view that 'No' engineering is not a scary word. System engineers are inclusive problem solvers, regardless of the situation.

Chris Browne (ANU) - chris.browne@anu.edu.au

Chris Brown hails from the Research School of Engineering, ANU College of Engineering and Computer Science, and is Sub Dean of the ANU College of Health and Medicine. As a systems engineer and teacher, Chris Browne's classes are centered around the innovative jigsaw classroom approach. Systems engineering is an inter-specialist engineering discipline that integrates traditional engineering specializations and Chris has created a classroom environment that provides a coherent second-year systems experience for students and was a recent recipient of an Award for Teaching Excellence.

Position Paper

Chris Brown - I am interested in this topic as I am spending more time outside of engineering and could present some views around non-engineers unconsciously doing what I would call systems engineering. There is also the view that systems engineering is not seen as 'real' engineering, and so is limited in its acceptance both by soft systems practitioners and by engineers.

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

JB is a member of the panel review committee for IS23.

Position Paper

JB has indicated that he agrees with this statement and would argue for the “yes” side.

Nicole Hutchinson (Stevens Institute of Technology) - nlong@stevens.edu

Nicole Hutchison is a Principal Investigator (PI) and research engineer at the Systems Engineering Research Center (SERC). Her primary work through the SERC has been in human capital development research. This has included the development of competency frameworks for systems engineering (the Helix project), digital engineering, and mission engineering. She is currently the Managing Editor for the SEBoK and the Lead Editor for the “Enabling Systems Engineering” section of the SEBoK. She has helped to plan and conduct exercises in Emergency Management, helped run the Louisiana Family Assistance Center following Hurricanes Katrina and Rita, and served 10 years in emergency medicine. Dr. Hutchison is an active member of INCOSE, currently serving as the Events Portfolio Manager and on the Certification Advisory Board. She holds her Certified Systems Engineering Professional (CSEP) credential.

Position Paper

Nicole Hutchinson - Yes, the word engineering does scare off a lot of folks, but it doesn’t have to if we can meet them where they live.

Panel#9

Bringing a Knife to a Gun Fight: Systems Engineering for the Modern World

David Long (Blue Holon) - david@blueholon.com
Jon Wade (University of California, San Diego) - jpwade@ucsd.edu
Duncan Kemp (Ministry of Defence) - duncan@17media.co.uk
Erika Palmer (Cornell University) - ekp48@cornell.edu

Presented on: Tuesday, 15:30-16:55 HST (316A)

Keywords. Sociotechnical Complexity Vision 2035 Social Systems Systems Thinking

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

Abstract. As a named discipline, systems engineering emerged in the 1940s and 1950s addressing large scale, long-lived, electromechanical aerospace, defense, and communication systems. Since then, we have advanced the technical and management processes, grappled with the increasing role of software, and evolved practices across diverse product lifecycles. Today we have a host of model-based tools and agile methods, but many of our processes and the underlying mindset remain grounded in the electromechanical systems of the 1950s. Systems Engineering Vision 2025 and Vision 2035 challenge us to look beyond our roots to address challenges at the product, enterprise, and societal levels. They challenge us to embrace global– human, societal, and technological megatrends as we engineer solutions for a better world. But what got us here won't get us there. To address today's problems across domains and levels of complexity requires we recognize the changing context and capabilities at our disposal. We must embrace sociotechnical, the human both in problem and solution, and corresponding methods for success. What does it take to move beyond traditional practices and properly recognize and respond across the domains reflected by Cynefin's framework of clear, complicated, complex, and chaotic? How do we embrace humans and complexity? What techniques and insights from others can we leverage and what new problems must we be alert to? How do we apply the innovation power of diverse teams and communities. It's time to recast our vision beyond the complicated and the product-centric evolving our mindset, methods, and tools for the modern world.

Biography

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

David Long has spent over 30 years helping organizations increase their systems engineering proficiency while simultaneously working to advance the state of the art. David was the founder and president of Vitech where he led development of innovative, industry-leading methods and software to engineer next-generation systems. He co-authored A Primer for Model-Based Systems Engineering and frequently delivers keynotes, tutorials, and workshops around the world. An INCOSE Fellow and Expert Systems Engineering Professional, David was the 2014/2015 president of INCOSE.

David's work with government and industry has spanned product, service, and enterprise systems engineering as well as mission engineering. He has worked both in the problem domain to better characterize and understand wicked problems as well as the solution domain to advance capabilities, often with a very agile mindset. As a coach in the INCOSE Technical Leadership Institute, he helps current and future leaders apply the Cynefin framework better matching approach to problems clear, complicated, complex, and chaotic.

Position Paper

The path to success does not lie in blindly clinging to the past. Nor does it lie in carelessly discarding it. To embrace the future, we must both understand our past and the foundations it provides as well as a changing context to inform our journey to the future.

Good systems engineering is fit for purpose addressing the transdisciplinary needs of the team coming together to properly understand the problem and characterize the solution. While the aerospace, defense, and communication opportunities of the 1950s and 1960s were unprecedented, the complexity and pace of change of both problem and solution was relatively low. The resulting technical and management processes matched that need and remain useful in Cynefin's clear and complicated domains.

However, the more audacious problems we face today – ranging from advanced products to grand challenges and sustainable design goals – tend to fall into the complex, if not chaotic, domain. We have greater appreciation for the interconnected nature of our environment and our impact on that environment. The technologies with which we build – both cyber and human – imbue our solutions with both capability and complexity. Our design teams and supply chains span the world crossing domain, organizational, language, and cultural boundaries bringing with it both the power of diversity when properly harnessed, and the dangers when not. And our stakeholders demand shorter cycle times as we respond to, or preferably anticipate, their needs.

To deliver the requisite technical and business value, we must know when we are in the complicated domain where the relationship between cause and effect can be known a priori versus the complex domain where we must probe, sense, and respond. As we engineer, influence, and lead, we must look beyond classical technical boundaries to enlarge our toolkit, diversify teams to enhance innovation, and embrace learning approaches in both the problem and solution domain. We must return to our roots as both socio and technical, systemic and systematic, systems and engineering.

Jon Wade (University of California, San Diego) - jpwade@ucsd.edu

Jon Wade, Ph.D., is a professor of practice at the Jacobs School of Engineering at the University of California, San Diego where he is the director of Convergent Systems Engineering and the executive director of the Institute for Supply Chain Excellence and Innovation. Dr. Wade's focus is on developing research and education to provide ethically sustainable solutions to critical, complex societal problems. Previously, Dr. Wade was the chief technology officer of the Systems Engineering Research Center, executive vice president of Engineering at International Game Technology, senior director of Enterprise Server Development at Sun Microsystems, and director of Advanced System Development at Thinking Machines Corporation. Dr. Wade received his S.B., S.M., E.E. and Ph.D. degrees in electrical engineering and computer science from the Massachusetts Institute of Technology. Dr. Wade is an INCOSE Fellow.

Position Paper

SE has evolved from complicated mechanical systems to complex networked, software intensive ones. At its birth, SE developed hardware technology that people used to accomplish various tasks. Even in these systems when SE considers the software, the primary decision makers are people, and thus someone else's responsibility. The human operators, usage, and mission context are someone else's problem. SE's are responsible for the HSI, 'Human System Interface' as though the humans exist outside of the system. One could argue that this kept the system complicated, rather than complex, which enabled engineers to use a familiar set of tools and techniques to develop the system. Complexity was to be avoided.

There are numerous factors changing this equation. First, our systems are becoming far more complex and are getting much more closely integrated into the overall mission, so engineering them requires more operational knowledge. Second, the rapidity of updates and deployment necessitates closer cooperation. Third, the instrumentation of the operational system as a testbed has resulted in the merging of development and operations. All of these factors are driving DevOps, and expansion of SE's context. However, the technical/operational walls can still exist, despite the operational failures.

What really breaks this paradigm of a technological dividing line is the increasing use of AI/ML to replace/augment human interactions. What was once human error is not encoded in technology with the result that the engineers and SE's are liable. No longer can SE's turf off the human side of the system to other organizations, but rather they have to own it. Ethics have far greater meaning. This is the new context for systems engineering.

Was the mission of the space shuttle so much greater than that of an Apollo lunar landing? Clearly, technology took on a far greater share of the 'intelligence' of the system, but from a system's perspective, the change is not so great. Once we as SE's look at the entire system, we will see that the total intelligence of the system may not have changed so dramatically, but rather its factoring and distribution is dynamically changing. The static boundaries that worked in the past are no longer effective as the dividing line becomes fluid.

What does recontextualization look like? It is redrawing the picture moving the humans from outside the system to inside. It is the difference between systems thinking (thinking from systems), vs. traditional SE (thinking about systems). At its birth, SE was about creating technology that was built to do something, to Act on the world, and people were the actors who controlled it. SE has been so focused on the 'A' in the OODA loop, it has lost sight that it is responsible for 'OOD' as well.

What does the world look like when SE considers and takes responsibility for the whole system? It involves putting the entire operational OODA-loop into the system context and removing the notion of a 'Human-System Interface'. Let's get on with it!

Duncan Kemp (Ministry of Defence) - 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, where he leads the DE&S internal consultancy.

Duncan has over thirty-years' experience of developing safe and effective socio-technical systems, in: air Defence, submarine combat systems, operational and business information services and railways. 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 IET and INCOSE Fellow. He was one of the authors of the SE Vision 2025, the INCOSE UK Capability SE Guide and the INCOSE UK Agile SE guide. He has presented over 20 peer reviewed papers at INCOSE international symposia and INCOSE UK conferences. He was the co-author of the INCOSE UK Agile SE guide and the INCOSE Capability SE guide. 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

Reading INCOSE Vision 2035 presents a sense of deja-vu. Socio-technical systems engineering is not the future of SE in 2035. It is the history of SE from the 1900s to the 1960s. The earliest implementations of SE were socio-technical systems.

The first modern battleship, the Air Defence System that won the battle of Britain and the Apollo programme were complex socio-technical systems. Whilst enabled by technical innovations, they were a fusion of new technology, processes, organisations and people. As Systems Engineering matured it progressively narrowed to the design of product systems. Whilst this has undoubtably improved our ability to deliver increasingly complicated products, this has taken the focus away from building effective socio-technical systems.

Despite this, there is a small core of systems engineers who have remained focused on Socio-Technical SE over the last 50 years. SEs working for Asset Owner Operators do not have the luxury of pushing the people out of their system of interest. Whilst small in number, they have had to remain focused on the fuzzy-front end and messy in-service phases so critical to delivering effective socio-technical systems. One of the key measures of success for a good socio-technical SE is their ability to create clear, unambiguous and stable requirements for the product systems engineer to deliver against. We have built a body of knowledge of what works and what doesn't. We have underlying theory, methods, processes and tools.

Where the practitioners have boldly gone, the academics have feared to tread. To systems engineers comfortable with complicated system, socio-technical systems seem to be an anarchic, confused and un-designable space. This is assumed to be a sign that socio-technical systems engineering is a weak and immature discipline. It is not. It is actually a sign that most (if not all) socio-technical systems are complex adaptive systems. Socio-technical SE is not a subset of Product SE. Product SE is a subset of socio-technical SE.

One of the key motivations behind publishing the INCOSE UK Capability SE guide was to provide a high level overview of socio-technical SE for academics to teach against. The reception to the guide has been interesting. To those familiar with Complex systems the response had tended to be 'of course'. Those who have only delivered complicated systems feel deeply disappointed. The design paradigm is different, leaders need to focus on different issues, models are used differently. Socio-technical SE feels like a different country. They do things differently there.

Erika Palmer (Cornell University) - ekp48@cornell.edu

Dr. Erika Palmer is a Senior Lecturer in the Systems Engineering Program at Cornell University, where her research and teaching focuses on sociotechnical systems. She founded the Systems and Society Research Lab (SSRL) at Cornell, which brings together systems engineers and social scientists to develop new modeling and simulation methods for evaluating sociotechnical and policy systems. Dr. Palmer is the founding chair of the Social Systems Working Group and the incoming Deputy Technical Director of the International Council for Systems Engineering (INCOSE).

Position Paper

As detailed in INCOSE Vision 2035, the next generation of systems engineers will need to support the sociotechnical application of systems engineering. How can we best enable this?

I argue that all systems engineering is sociotechnical as you cannot engineer anything without people, and all engineering artifacts affect society is some way. However, sociotechnical systems have only recently been in focus at INCOSE. Momentum for sociotechnical systems has been growing over several years now in the systems engineering community, and now more formally with INCOSE Vision 2035. INCOSE as an organization does not have a large academic community compared to its government and industry representation. However, those working on sociotechnical system methodology for systems engineering at INCOSE are much more academic (for example, in the Social Systems Working Group).

For those that consider sociotechnical systems in industry and government, there has not been a motivation to develop sociotechnical system methods adequate enough for general systems engineering practice, at least not under the heading of "sociotechnical systems", which is why there has been no lasting impact on systems engineering methods. The systems engineering community needs a more robust arsenal, and we need a state of the practice for sociotechnical systems. If methods do not become standardized (either formally or as accepted best practice), then it is lost to history – just another isolated, historical case study. We can build however from the areas of systems engineering that attempt to embrace the complexity of sociotechnical systems in order to develop a state of the practice by combining it with the current state of the art in academia.

With the lighthouse that is INCOSE Vision 2035, INCOSE is at least theoretically a space that is

transdisciplinary and inclusive, so let’s start looking beyond traditional systems engineering academic spaces because there are a lot of innovative system tools for social systems being used in other disciplines. There are robust modeling methods (e.g., systems dynamics modeling, agent based modeling and discrete event simulation) for policy system analysis in many different domains that can easily be put in a systems engineering context. The lowest hanging fruit is for critical infrastructure, as sociotechnical system modeling and simulation as a tool for analysis is well-established in this domain (even if not using the term “sociotechnical system”).
How do we build from this towards a state of the practice for sociotechnical systems? How can industry, government and academia work together to build systems engineers a better toolkit? There are tools available in academia, so how do we integrate what academia is already doing for sociotechnical systems into systems engineering practice? We can make use of existing system tools and methods (while developing new) to embrace the complexity of social systems that weave through the lifecycle of systems engineering practice. The systems engineering community agrees that transdisciplinarity is important and necessary. But what is lacking is how this is practically done? This question has been asked before, and we must build upon our answers: how can INCOSE foster this?

Panel#7

Contrasting and Comparing Agile Systems Engineering and Agile Software Engineering

Rick Dove (Unaffiliated) - dove@parshift.com
Duncan Kemp (Ministry of Defense) - duncan.kemp735@mod.gov.uk
Kerry Lunney (Thales Group) - kjlunney@tpg.com.au
Robin Yeman (Unaffiliated) - robinyeman@gmail.com
Keith Willett (US DoD) - kwillett@ctntechnologies.com

Presented on: Monday, 15:30-16:55 HST (313B)

Keywords. agile systems engineering agile software engineering agile engineering principles

Topics. 2. Aerospace; 3. Automotive; 5.1. Agile Systems Engineering; 6. Defense;

Abstract. Agile engineering, of any kind, is a principle-based method for designing, building, sustaining, and evolving purpose-fulfilling creations when knowledge is uncertain and operational environments are dynamic. Principles are abstractions for what needs to be accomplished and why, without constraints or directions on how. How those abstractions manifest operationally depends upon the engineering context. Single-domain software engineering is different than multi-domain systems engineering. Panelists will offer their views on selected agility-enabling principles with considerations for fitting them differently in Agile Systems Engineering and Agile Software Engineering.

Biography

Rick Dove (Unaffiliated) - dove@parshift.com

Rick Dove is an unaffiliated independent operator, specializing in systems security and agile systems research, engineering, and project management. He chairs the INCOSE working groups for Agile Systems and Systems Engineering, and for Systems Security Engineering; and leads both the Security and Agility projects for INCOSE’s initiative on the Future of Systems Engineering (FuSE). He is an INCOSE Fellow, and author of Response Ability, the Language, Structure, and Culture of the Agile Enterprise.

Position Paper

Rick Dove: Agile systems engineering and agile software engineering share operational principles that provide engineering agility; but they have very different operational environments and objectives which influence how these principles manifest. Rick will discuss certain aspects of these differences from the provocative summary below:
Principle Software Engineering Systems Engineering
Modularity Standard interface Proprietary interface
Increments & Iterations Tight Loose
Situational Awareness Introspective Extrospective
Decision Making Simple Complicated
Teaming Homogeneous Heterogeneous
Knowledge Management Code libraries PLM
Continuous Integration Common platforms Proprietary platforms
OpsCon Do Agile Be agile

Duncan Kemp (Ministry of Defense) - duncan.kemp735@mod.gov.uk

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 is also leading the implementation of Digital Engineering transformation on MOD. 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 led one of the earliest Agile software development teams in MOD to build collaborative working environments at the turn of the century. He has also led, and supported, a range of initiatives to reduce the time to Market for products. More recently Duncan used agile principles to grow the MOD internal technical consultancy capability. 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. He was the co-author of the INCOSE UK Agile SE guide. 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

Duncan Kemp: To most stakeholders Systems Engineering is seen as slow, methodical and cumbersome. Agile software development is the opposite – responsive, effective and efficient. Based upon these facts the case for a more Agile approach to systems engineering is compelling, The proponents of Agile SE are the enlightened pioneers, the opponents luddites standing in the way of progress. This simple narrative is, however, at best simplistic and at worst fundamentally flawed. Duncan will explore:
• The diverse definitions of what people call Agile SE, from a true evolutionary approaches, through fast and lean conventional approaches to snake oil.
• Why Agile Software Engineering actually works. He will explain how open architectures, high quality user feedback and rigorous continuous integration testing enables agile software development.
• Why systems with their long manufacturing timescales, difficult modification and upgrade cycles and need to meet high integrity safety requirements counter the underlying assumptions behind Agile Software.
Finally Duncan will provide an overview of what is needed to ensure that complicated cyber-physical systems can be effectively developed using an Agile approach.

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

Kerry Lunney has extensive experience developing and delivering large system solutions. She has worked in various industries including ICT, Gaming, Transport, Aerospace and Defence. 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 holding 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. She recently contributed to the authorship of the new text on “Emerging Trends in SE Leadership”.

Position Paper

Kerry Lunney: Applying an agile approach to engineering systems is not without its challenges. Considerations such as long lead times, interlacing different system elements at different stages of their life cycles, safety and cybersecurity factors, the collaboration with end users and customers, to name a few, can be quite a balancing act. Likewise, the idea of one size fits all when applying an agile approach to systems is ludicrous. Even considering applying only one set of adapted processes supporting an agile approach on a large systems project can be problematic. The adoption of a tool or a methodology reporting to provide an organisation with an agile approach, is not what provides agility. However, an agile approach sets expectations that can be addressed through better handling of change at the system level through adaptation. This takes into consideration the dimension of time wrt change. To effectively address change, we must master the aspect of situational awareness. Situational awareness focuses on knowing what is happening at a particular time, location and event, allowing better informed decisions to be made. Individuals and organisations can anticipate and act accordingly – whether in response to positive feedback (opportunity) or negative feedback (threat). With an agile approach to Systems Engineering we can address this “constant change”.
As part of the panel “Contrasting & Comparing Agile Systems Engineering & Agile Software Engineering” I will present and discuss the importance and challenges of adaptation at the system level pivotal to applying Agile Systems Engineering, but less so for Agile Software Engineering. I will introduce how situational awareness is key to enhancing how we carry out agility in our work in Systems Engineering. This will include –

- Strengthening an agile approach utilising situation awareness in the feedback loop for replanning increments of work and capability offering;
- Rebalancing and setting customer expectations, and the shift of power between supplier and customer;
- Boosting the digital transformation perspective with the right people accessing the right information at the right time through increased situational awareness cycles.

Through this panel discussion I will also highlight why success in applying Agile Systems Engineering is harder to implement and even harder to demonstrate the benefits, in comparison to Agile Software Engineering, because of the importance and challenges of adaptation at the system level.

Robin Yeman (Unaffiliated) - robinyeman@gmail.com

Robin Yeman is currently publishing her first book in what she has coined “Industrial DevOps” which is scheduled to be released in 2023. Robin’s expertise spans over twenty-five years as a Senior Technology Fellow at Lockheed Martin. Her specialty is software engineering with focus on Digital Engineering, DevSecOps, and Agile building large complex solutions across multiple domains from submarines to satellites. She advocates for continuous learning with multiple certifications including SAFe Fellow, SPCT, CEC, PMP, PMI-ACP, and CSEP. She is a Systems Engineering PhD candidate at Colorado State researching best practices to deliver complex safety critical solutions using Agile and DevSecOps. Robin has led several efforts in Agile program execution and continues to lend her expertise on the development of Safety Critical Systems using Digital Engineering, DevSecOps, and Agile techniques and processes on management, schedule, cost, and technical performance. She provides mentoring, guidance, coaching support, and conducts training classes for engineering and management teams and customers on Digital Engineering, DevSecOps and Agile tools, process, and methodologies.

Position Paper

Robin Yeman: Many people equate Agile methods applicable to only software development. However Agile is an iterative and incremental lifecycle just as Waterfall is a phase-gate lifecycle. Both Agile and Waterfall lifecycles should be utilized to deliver outcomes across the entire value stream which includes systems engineering, hardware engineering, and software engineering. While these groups engage in different types of activities the same concepts apply to all domains.
I will discuss where Agile should be utilized in conjunction with the Stacey Matrix. The Stacey Matrix, developed by Ralph Stacey, is a contingency-based approach to decision making. A decision is based upon two variables: Certainty (Cause and Effect of Decision) Agreement (Extent of Agreement among

Stakeholders).
Agile Methods should be applied to solution problems where there is uncertainty in either requirements or technology. I would argue this applies to the majority of large complex safety-critical cyber-physical systems. When delivering complicated and complex systems teams should all be aligned to a single lifecycle across the valuestream which is inclusive of Systems, Software, and Hardware Engineering.

Keith Willett (US DoD) - kwillett@ctntechnologies.com

Keith Willett is a senior systems engineer for the U.S. Department of Defense with over 35 years of experience in technology as an educator, practitioner, and innovator. He has degrees in computer science, mathematics, business, cybersecurity, and systems engineering and takes a transdisciplinary approach to problem definition and solution development. Keith is an active member of INCOSE as a co-chair for the Systems Security and Agile Systems & Agile Systems Engineering Working Groups; and projects related to the Future of Systems Engineering (FuSE), an INCOSE-led multiorganizational collaboration to strategize and develop ideas for the future of systems engineering. Keith recently contributed to three books by Springer Publishing, 1) The Handbook of Security Science, 2) Disruption, Ideation, and Innovation for Defense and Security, and the 3) Handbook of Foresight, Strategy, and Futures Studies for Defense and Security. Keith's contributions include chapters on Aligning Security with General Systems Theory, Systems Thinking and Security, Security Modeling and Simulation, Quantum Computing – Unraveling the Hype, and Total War, among others.

Position Paper

Keith Willett: The primary goal of any system is value-delivery. That which constitutes 'value' is non-static; stakeholders change what they want. Threats, natural or contrived, jeopardize the system's ability to provide value-delivery. Integrating agility into a system provides the conditions of the possibility for the system to remain relevant to stakeholders and viable when encountering threats.
Agility overlaps with resilience. Resistance attempts to avoid or withstand loss; resilience attempts to recover from a loss. Recovery from a loss may return the system to its original state, return to the previous state, or change to a new state. Returning to the original state may be a reboot or a replacement-in-kind. Returning to the previous state may invoke fault-tolerance or back out a recent system change. Recovery to a new state implies the ability for dynamic adaptation; i.e., the system is agile.
Risk has two sides: a negative side (potential loss) and a positive side (potential gain). A lack of change may not result in a loss but may miss out on optimal returns; i.e., a lack of change may incur an opportunity cost. Agility helps to minimize opportunity costs by providing continual dynamic change for optimizing system relevance to stakeholders. Agility as part of resilience addresses loss recovery. Agility, as distinct from resilience, addresses potential gain. Agility may be proactive, anticipate a stakeholder need, and adapt accordingly, thus providing continual optimum value-delivery.
The system may have assisted agility or autonomous agility. Assisted agility involves human intervention. Autonomous agility is when the system performs governance, adjudication, decision, and action for dynamic change without human intervention. The introduction of systems as software platforms and artificial intelligence facilitates autonomous agility.
The principles of agile software development do not adequately transfer to the concepts of operational agility, hard-system production (non-software), product and service agility, and personnel agility. The latter requires new agility principles and engineering approaches to integrate the ability for continual dynamic change. Let's start with the principle of composition.
Composition uses a set of modules to produce a solution (product) or result (service). Rather than develop solutions, we develop modules and then compose solutions using modules. We are constrained by the permutations of the modules we have; however, we can always add a module to increase solution variations. Modules may take the form of discrete low-level actions or components. Modules may take the form of a complete sequence of events with a specific purpose (playbooks). Substituting a fixed sequence of events is very fast but has low flexibility. The ad hoc composition of a new approach is highly flexible but slower. Both are approaches to agility; each has tradeoffs.
Conclusion: What we're looking for is continual dynamic adaptation (agility) in systems, where a system can be a person, group of people, operations, workflow, process, product, or service. Existing disciplines like DevOps and product line engineering provide clues for engineering agility. There is much more to discover for agile-systems as a superset of agile software development.

How can you help your area become a Smart City? Connect with the INCOSE Smart Cities Initiative

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Presented on: Tuesday, 10:00-12:10 HST (316B)

Keywords. Smart Cities Initiative Social Systems MBSE Architecture

Topics. 1.6. Systems Thinking; 12. Infrastructure (construction, maintenance, etc.); 2.4. System Architecture/Design Definition; 20. Industry 4.0 & Society 5.0; 5. City Planning (smart cities, urban planning, etc.); 5.3. MBSE & Digital Engineering;

Abstract. The INCOSE Smart Cities initiative has been working diligently for 3 years. We are ready to broaden our reach and engage more INCOSE members through knowledge sharing and participation. Attendees will learn about the Initiative’s completed and on-going efforts for the Reference Framework, IEC Collaboration, and Smart City solution modeling. A recent publication of the Smart City Definition, Metrics, and Framework provides the foundation for our human-centric approach to Smart Cities. This approach provides a formal lens through which municipalities can evaluated their current systems and identify key next steps toward being a ‘Smart City’ that meets the needs of its human residents. The Initiative members have also collaborated with the IEC Smart Cities team developing a Reference Architecture. Our partnership has supported the infusion of systems thinking and the human centered approach to this typically tech-heavy commission. Finally, with a clear definition of a smart city, our MBSE and other modeling efforts have taken flight. The Initiative has selected a use case of homelessness to model. The specific views, situations, and resources for this master use case are wide and varied. We are welcoming modelers of all competence to join our efforts by contributing their modeling skills.

Biography

Jennnifer Russell (Garver) - JLRussell@GarverUSA.com

Jennifer Russell, EISE, CSEP is the Program and Management Support Leader on Garver's Water team. Over the past 25 years, she honed her West Point leadership motto of being a "Leader of Character." From strategic planning to tactical logistics, Jennifer has invested in public service and infrastructure. The domains of her experience are a testament to the portability of her skill set and include water systems, software systems, high-speed rail, transit systems, highway systems, and multi-modal connectivity. Currently, Jennifer is the Chair of the INCOSE Smart Cities Initiative, and has been the Outreach Director for the Transportation Working Group. At the International Symposia, Jennifer has presented several papers, on a panel, and lead several Roundtables. Jennifer holds a B.S. in Engineering Psychology from the United States Military Academy and an M.S. (2003) and Engineer Degree (2007) in Industrial and Systems Engineering from the University of Southern California.

Position Paper

Moderator and Initiative Chair, Jennifer Russell – Will set the stage for the Smart City discussion, why INCOSE is involved and who can and should contribute to the initiative. Will lead the Members into discussion and will host the questions for members within each of the discussion topics.

Jargalsaikhan Dugar (TUS Solution) - jargalsaikhan@gundinvest.mn

Mr. Jargalsaikhan earned his B.S. degree in mining economics from the Moscow School of Mines, had specialized training at the Colorado School of Mines. Before entering the private sector in 2005, he held senior leadership positions in the Mineral Resources Authority, the Ministry of Heavy Industry, and the Ministry of Trade and Industry. His current focus is aimed at creating system engineered management tools and developing digital transformation solutions for social systems, and green projects such as redevelopment of underdeveloped areas in Ulaanbaatar, the capital city of Mongolia. Mr. Jargalsaikhan is an Honorary Professor at the University of Science and Technology of Mongolia, Chairman of Gund Investment LLC, Founding Chairman of the Young Researchers Support Foundation, and a Board Member of the Business Council of Mongolia

Position Paper

Panelist, Jargal Dugar - As one of the main authors of “Smart City Definition, Metrics, and Framework,” he’ll be discussing the use cases of INCOSE-TUS reference model and next practical steps of implementation.

Marcel van de Ven (Heijmans N.V.) - mtfmvandeven@gmail.com

Marcel van de Ven MSc, CSEP graduated from the department of Mechanical Engineering of the Technical University of Eindhoven in 1993 as a Master of Science (MSc). He had a career at Movares in railway infrastructure and developed his skills in Systems Engineering when he was a senior engineering consultant for catenary, track and signaling systems. He was responsible for the development, engineering and commissioning of the phase lock systems and voltage lock systems for the Dutch railway Betuweroute. In 2011 he started his Systems Engineering career in civil systems at Croon Elektrotechniek in tunneling systems and complex buildings. He was a systems architect for the refurbishment of the tunnels in the Dutch A15 highway and the Westerscheldetunnel. In 2016 he became responsible for Systems Engineering in the department Buildings Technology at Heijmans N.V. He was the Senior Consultant for the application of Systems Engineering for several complex buildings, court houses, hospitals and also the European Medicines Agency. He is also skilled in contract management, risk management and general process management. Marcel is co-chair for the Infrastructure Working Group and Smart Cities Initiative. He is the chair of the Dutch Model Based Systems Engineering Working Group.

Position Paper

Panelist, Marcel van de Ven – Co-chair for the Smart Cities Initiative and Infrastructure Working Group. Will discuss connections and opportunities for collaboration with other WGs like Transportation, Infrastructure, Critical Infrastructure, in current work. And targeted future collaboration with MBSE groups, such as regional-Model Based Systems Engineering WGs, academic partners, and professional modelers interested in contributing to the development of an INCOSE Smart Cities model. Will also discuss Smart Cities efforts from the viewpoint of contractors as large contractors are developing smart infrastructure by integrating the systems of sub-contractors into one large system e.g. smart buildings.

Rael Kopace (Robotic Research, LLC) - Rael.kopace@incose.net

Rael Kopace, CSEP is the director of Systems Engineering at Robotic Research LLC, a leading provider in autonomy and robotic technology in the ground vehicles space. He has over 13 years of scientific and engineering experience across multiple industries. Rael started his career in the medical field working in biomedical engineering and imaging physics space at the National Institutes of Health. In 2013 he joined Northrop Grumman Corporation where he provided systems engineering and safety engineering services to various defense clients. In 2018 Rael accepted a Systems Engineering specialist role with Deloitte Consulting, LLP to provide consulting services to various US Federal Clients, supporting their digital transformation efforts to strengthen their overall systems engineering capabilities in the face of the industry 4.0 challenges. Rael is a co-chair of the Smart Cities Initiative and contributes to multiple working groups. He has a Bachelor of Science Degree in Physics and Mathematics from University of Maryland – College Park, a Master of Science Degree in Systems Engineering from George Washington University, a Space Systems Master Certificate from the Naval Postgraduate School and training in Medical Physics from Duke University and the Foundation for Advanced Education in Sciences (FAES) at NIH.

Position Paper

Panelist, Rael Kopace – Co-chair for the Smart Cities initiative. Leading the collaborative effort with IEC in the development of a Smart Cities Reference Architecture. Will look to discuss the collaborative relationship with IEC and the development efforts on the Smart Cities Reference Architecture.

Panel#15

Methods of Resilience Engineering

Ken Cureton (University of Southern California) - cureton@usc.edu
Scott Jackson - jackson@burnhamsystems.net
Bill Scheibe - Bill.Scheible@incose.net
Ivan Taylor - ivan@policydynamics.ca
Mark Winstead - mark@markwinstead.net

Presented on: Thursday, 02:00-04:10 HST (Virtual)

Keywords. Resilient Systems Resilience to Adversity Adaptive Response Agility Anticipation of Adversity Avoid Adversity Constrain Propagation Continuity of Operation Disaggregation Evolution Graceful Degradation Integrity Prepare for Adversity Prevent Adversity Re-architect for Adversity Redeploy after Adversity Robustness Situational Awareness Tolerance of Adversity Transform System Behavior Understand Adversity

Topics. 1.1. Complexity; 12. Infrastructure (construction, maintenance, etc.); 2.4. System Architecture/Design Definition; 20. Industry 4.0 & Society 5.0; 4.4. Resilience; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Resilience is the ability of the system to provide required capability when facing adversity. The fundamental objectives of resilience are avoiding, withstanding, and recovering from adversity in cyber-physical, organizational, and conceptual systems. This panel examines best-practices and advances in the state-of-the-art for: * Resilience Requirements over the life-cycle of a system or system-of-systems * Patterns of Resilience Requirements, Techniques, and Architectural considerations * Resilience Metrics and Measurement methods * Resilience Modeling and Simulation * Resilience Tools * Resilience in System State Considerations * Resilience and Agile Systems Engineering * Resilience Engineering relationship to other Quality Characteristics (Affordability, Agility, Human Systems Integration, Interoperability, Logistics/Supportability, Manufacturing/Producibility, Reliability/Availability/Maintainability, Sustainability/Disposability, System Safety, System Security) * Resilience Engineering and Risks/Issues/Opportunities

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Panel#5

Roundtable explores how security joins performance and safety as foundational systems design perspectives.

Rick Dove (Unaffiliated) - dove@parshift.com
Dawn Beyer (Lockheed Martin) - dawn.m.beyer@lmco.com
Tom McDermott (Stevens Institute of Technology) - tmcdermo@stevens.edu
Mark Winstead (Mitre) - mwinstead@mitre.org

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Presented on: Monday, 13:30-14:55 HST (313C)

Keywords. systems security security competency system design

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

Abstract. INCOSE's Vision 2035, on page 37, posits that "Cyber-security will be as foundational a perspective in systems design as system performance and safety are today." No argument is heard against the value of this; but how will it come to pass? Is this wishful thinking or feasible outcome? This roundtable will explore the what, why, and how of this expectation.

Biography

Rick Dove (Unaffiliated) - dove@parshift.com

Rick Dove is an unaffiliated independent operator, specializing in systems security and agile systems research, engineering, and project management. He chairs the INCOSE working groups for Systems Security Engineering and for Agile Systems and Systems Engineering; and leads both the Security and Agility projects for INCOSE's initiative on the Future of Systems Engineering (FuSE). He is an INCOSE Fellow, and author of Response Ability, the Language, Structure, and Culture of the Agile Enterprise.

Position Paper

Rick Dove: In systems engineering performance and safety are front burner objectives; a system short on either is not viable. But a system that can perform safely but not reliably isn't viable either. As stakeholders we know the systems we build or acquire are targets for attack, so we engage security-development specialists and certification procedures intended to harden and verify reliability expectations. But reliability is fragile and illusive when stakeholders are misaligned on security needs and have offloaded the responsibility for security outcomes.

Outcome-relevant stakeholders are those who can directly affect or be affected by system security. Virtually none of them are subject matter experts in system security – they are customers, users, and developers; they are systems engineers responsible for system coherence; and they are managers of all sorts that control decision making and work priorities.

Though they can't speak with technical expertise, all stakeholders can elucidate, or validate when prompted, what they cannot afford to lose, and what they can tolerate as partial or temporary loss. Loss may be in system functionality, in system assets, or in assets the system can affect. Identifying intolerable loss requires neither knowledge of vulnerabilities that can cause the loss, nor knowledge of how to protect against the loss – common sense is required, not security expertise.

To achieve security as a broadly embraced systems foundational perspective we need understandable and meaningful security capabilities that stakeholders can articulate, support, and relate to with personal feeling as both necessary and useful.

Security is more than a collection of technologies and specialists, it is a mission that needs an aligned team of stakeholders. Stakeholders who are misaligned compromise and degrade the objectives of those who are aligned.

Stakeholders who are aligned appreciate the needs of others, share their needs and priorities with others, seek non-conflicting understandings of collective needs, and will revamp personal requirements that would impair the security needs of others even if they don't feel those same needs.

Systems engineering has responsibility for identifying system design requirements. Discovering, expressing, and aligning system security design requirements as loss-driven, needs oriented capabilities does not require technical security expertise and serves as a focal point for stakeholder alignment. This avoids the issue of scarce security expertise and defines a viable approach for security joining performance and safety as foundational systems design perspectives.

Dawn Beyer (Lockheed Martin) - dawn.m.beyer@lmco.com

Dr. Dawn Beyer is a Lockheed Martin (LM) Senior Fellow. She led the development and implementation of the LM Cyber Resiliency Level® (CRL®) framework as a standard way to measure cyber resiliency maturity. Dr. Beyer recently led the development of the 2022 LM Cyber Defense Technology Strategy. She is currently

leading the independent research and development project CyCADA™--Cyber intelligence Capabilities for Autonomous Detection & defeat of Attacks, an end-to-end cyber ecosystem of cyber resiliency capabilities.
Dr. Beyer is a strategic leader in LM and Industry. At LM, Dr. Beyer founded and was the first Chair of the LM Women's Fellows Network with the goal to attract, develop, and retain women in top talent initiatives. She also engages in industry exchanges and is on the Board of Governors with the Women in Cybersecurity organization.
Dr. Beyer is a recipient of the Nova Southeastern University (NSU) Distinguished Alumni Achievement Award for the College of Engineering and Computing. She was recognized by SC Magazine as a "Women in Security: PowerPlayer" in cybersecurity.
Dr. Beyer earned her Ph.D., M.S., and B.S. in Information Systems. She maintains the following certifications: PMI's PMP®, (ISC)2's CISSP® and CSSLP®, ISACA's CISM®, and Six Sigma Black Belt.

Position Paper

Dr. Dawn Beyer: Cybersecurity should already be foundational in systems design as system performance and safety are today. We have processes, practices, and tools to achieve this. However, there aren't enough cybersecurity subject matter experts to fill the demand. Skills shortage not only makes recruitment and retention harder; but also, leads to employee burnout and an increase in voluntary attrition. Therefore, in order for cybersecurity to successfully be as foundational in systems design as system performance and safety are today, cybersecurity should be everyone's responsibility, like safety. In addition to workforce challenges is the deficiency in risk awareness and management. Most organizations and programs don't continuously identify, assess, and mitigate security risks. Stakeholders need assistance with prioritizing risks and selecting courses of action based on their risk tolerance. Decision makers need assistance with understanding how their investments mitigate risk and increase cyber resiliency.

Tom McDermott (Stevens Institute of Technology) - tmcdermo@stevens.edu

Tom McDermott is the Chief Technology Officer of the Systems Engineering Research Center (SERC) at Stevens Institute of Technology in Hoboken, NJ. With the SERC he develops new research strategies and is leading research on digital transformation, education, security, and artificial intelligence applications. Mr. McDermott also teaches system architecture concepts, systems thinking and decision making, and engineering leadership. He provides executive level consulting as a systems engineering and organizational strategy expert, applying systems approaches to enterprise planning. He currently serves on the Board of Directors of the International Council on Systems Engineering (INCOSE).

Position Paper

Tom Mcdermott: INCOSE's Vision 2035, posits that "Cyber-security will be as foundational a perspective in systems design as system performance and safety are today." Systems are increasingly composed of heterogeneous elements, both cyber and physical in nature. While this coupling can produce capabilities beyond those achievable before, it also makes these systems vulnerable to classes of threats previously not relevant for many physical control and computational systems. What is unique to cybersecurity in systems design is the notion of sentient external threats. While natural threats may loosely be addressed via measures of reliability or integrity, sentient threats (i.e., security) are external to the system in question. What is not unique is the system functions we define to counter these, they can be reused to equally produce security, safety, integrity, and similar outcomes. The discipline of cybersecurity has for too long tried to just prevent these threats from entering the system. Systems engineering must stand up to provide holistic understanding and modeling of the threat behaviors within the system, and the system's response, which is generally referred to as cyber resilience. Cybersecurity in this vision and perhaps security in general are too narrowly focused terms. A comprehensive approach involves many non-functional requirements: security, safety, integrity, maintainability, assurance, etc. All of these must be linked in an analytical framework to determine if a system is protected to some level of acceptable risk versus cost. Likewise, the approach can and should draw on multiple specialty disciplines including security, safety, reliability, integrity, maintainability and assurance.
Current research conducted by the Systems Engineering Research Center (SERC) is directly in support of this vision. The research applies a systems engineering approach to the concepts of cyber resilience in operational settings of a system. Cyber resilience may be achieved through any number of implementable techniques that provide capabilities to respond to threats. These techniques may be represented as design patterns, each contextually relevant to a given threat type, and are ideally reusable from one system to another. Security is realized by incorporating these design patterns into the system, thereby generating an adapted system architecture with new or improved, threat-specific capabilities. The set of selected security design patterns form the security architecture.
The SERC's System Aware Security work has explored the representation of both system behaviors and threat

behaviors in formal MBSE representations, specifically in SysML. Unlike system assurance, which by its nature requires a complete system design, and cybersecurity, which treats a system as a black box, the system resilience approach offers the ability to analyze cyber threats and system design protections early in and throughout the systems engineering process. Because we define in terms of system behaviors, it is possible to reason about systems resilience in terms of system functions in advance of a design. In other words, across the full SE lifecycle. A principal focus of the SERC has been the development of methods and tools that support functional system design for cyber resilience in cyber physical systems. The objective of these efforts was to develop and transition an end-to-end systems engineering methodology intended to close the loop between mission level resilience analysis and system development activities using digital engineering and MBSE oriented processes. They have been developed in a research setting but are now being applied into new defense-related systems and industrial control environments.
So yes, it will come to pass if the SE community stops treating concepts like security, safety, reliability, etc. as independent specialty disciplines and takes advantage of MBSE to integrate these across the SE process. The SERC has demonstrated the methods and is beginning to apply them widely.

Mark Winstead (Mitre) - mwinstead@mitre.org

Mark Winstead is Systems Security Chief Engineer within The MITRE Corporation's Systems Engineering (SE) Innovation Center. He had over twenty-five years' STEM experience before joining MITRE in 2014, including stints as a crypto-mathematician, software engineer, systems architect, and systems engineer as well as occasionally working systems security engineering (SSE). Past employers include defense contractors, an EPA contractor, a Facebook-like start-up, a semi-conductor manufacturer of security protocol acceleration solutions, and a network performance management solutions company. At MITRE, Mark has worked/works with various sponsors, helping programs with security engineering and teaming on integrating security into systems engineering for acquisitions and program offices. Recently, he has worked on advancing the practice, working on Department of Defense SSE standardization and co-authoring NIST SP 800-160 V1R1 Engineering Trustworthy Secure Systems, a publication intended to advance systems engineering in developing trustworthy systems for contested operational environments. He has also worked with MITRE internal training center on developing materials in SSE and has taught SSE tutorials at INCOSE IS and conferences. Soon in his spare time, he will be writing a book for systems engineer about their role in security. A graduate of the Virginia (PhD, Mathematics) and Florida State (BS), Mark resides in Colorado Springs, CO.

Position Paper

Mark Winstead: Historically, cybersecurity has the tendency to be bottoms-up – how can a malicious threat find and exploit vulnerabilities, and what effect they can generate as a result. Cybersecurity is practiced by specialists using their own language and jargon, not as a general competency of other fields nor sufficient cross-pollinating with other fields. Insufficient focus has occurred for a systems-driven top-down thinking.
To be a foundational perspective in systems design like performance and safety, systems engineering's cybersecurity perspective needs to be systems-driven, top-down perspective. Moreover, the perspective needs to align to performance and safety in ways enabling more transdisciplinary and relate better to all stakeholders.
Achieving these are not exclusive of one another.
Safety is often defined in terms of avoiding loss or endangerment of human life or limb or the environment. NIST SP 800-160 Volume 1 Revision 1 expresses security in terms of loss by defining security as freedom from the conditions that can cause loss of assets with unacceptable consequences. By approaching security from a loss/consequences/effects approach to security including cybersecurity, I believe doors open for new transdisciplinary thinking not just with safety but reliability and other loss concerned disciplines as well.
This loss thinking approach opens the aperture for a top-down approach and to relating to stakeholders. Systems engineering begins with stakeholder needs – a problem needs addressing. The need itself may be dealing with loss itself, but more commonly, in expanding the need statement derivative needs related to loss are identified – a capability needs to be delivered without unacceptable degradations (a form of loss), the users of the solution need to be free of harm (a loss avoided), etc. As the solution moves to realization, new derived needs are identified, such as the need for integrity of system data (no loss of integrity). The stakeholder's real need is not with the adversity itself but the effect or loss the adversity may trigger or create.
Furthermore, such a perspective should be less focused by reacting to known or possible specific threat actions, but more focused on assurance (sufficient grounds for confidence) in the face of adversity. The need is to think about ensuring delivery of the desired system capability despite failure that may occur, where the failure may be a reliability shortfall, operator error, or malicious activity (any reliability shortfall may be a result of malicious activity). Systems engineering perspective needs to be driven by "when things go wrong" first, as for complex systems and intelligent adversaries no realistic bound exists on "why".
This assurance needs to be driven by two capabilities the systems engineer should focus to, capabilities core for any system to control loss and loss effects. One is complete mediation, that any interaction, behavior, and

outcome is authorized following documented intent; the other is system control, that system interactions, behaviors, and outcomes are only what is intended. Complete mediation and system control are intended as enabling capabilities to meet stakeholder needs – ensuring the system delivers the performance capability needed within stakeholder other needs such as operating safely.

Panel#19

Scars from the battlefield – Lessons from Technical Leadership

Natalie Davila-Rendon (Lockheed Martin) - nataliedavila_ee@yahoo.com
Amy Thompson (University of Connecticut) - amy.2.thompson@uconn.edu
Leema Kerkinni (Eli Lilly) - leema.kerkinni@lilly.com
Chris Schreiber (Lockheed Martin) - chris.schreiber@lmco.com
Carla Sayan (Raytheon Intelligence and Space) - carlasayan07@hotmail.com

Presented on: Wednesday, 15:30-16:55 HST (316B)

Keywords. Management Technical Leadership Academia Medical Devices Defense

Topics. 1. Academia (curricula, course life cycle, etc.); 1.6. Systems Thinking; 3.5. Technical Leadership; 4. Biomed/Healthcare/Social Services; 5.9. Teaching and Training; 6. Defense;

Abstract. The concepts of Management and Leadership have been overly used and are constantly used interchangeably. The incorrect use of these concepts creates deep scars, but how do we learn to heal them? Exploring the definition's perceptions and deeper meanings, this panel will showcase real stories from different points of view and industries including Defense, Academia, and Medical Devices. We will explore with our panelists their journey in Technical Leadership and will learn its definition. The audience will leave the session with a better understanding of the concepts, differences, and practical applications in the real world.

Biography

Natalie Davila-Rendon (Lockheed Martin) - nataliedavila_ee@yahoo.com
She has a technical background in Electrical and Systems Engineering. She has a wide range of experience in the engineering field which includes test equipment, operations, and systems engineering. She has developed her leadership skills by holding different leadership positions in professional organizations like Toastmasters, American Institute of Aeronautics and Astronautics (AIAA), Society of Hispanic Professional Engineers (SHPE), Institute of Electrical and Electronics Engineers (IEEE) and is a member of International Council on Systems Engineering (INCOSE). Currently she is in the SHPE National Board of Directors.

Position Paper

The eternal discussion of management vs leadership is not an easy one. The concept of Technical leadership is the closest combination of leaders that have application in technical areas of the industry. Mostly I have seen that organizations call their "managers" or refer to them as "leaders". Some of them are leaders but not all of them. Leadership is not a title, is a mind set that anyone can implement in their life, community and workplace. Manager is a title in which an individual distributes tasks but this does not imply that the individual demonstrates all the skills associated with leadership. Through practice, effort and constant improvement managers could be come leaders of their teams.

Amy Thompson (University of Connecticut) - amy.2.thompson@uconn.edu

Dr. Amy Thompson joined the University of Connecticut in 2017 as an Associate Professor-In-Residence of Systems Engineering and as the Associate Director for the Pratt & Whitney Institute for Advanced Systems Engineering. She currently teaches systems engineering courses and coordinates the graduate programs in Advanced Systems Engineering for the Institute. Prior to joining UConn, she received her B.S. in Industrial Engineering, M.S. in Manufacturing Engineering, and Ph.D. in Industrial and Systems Engineering from the University of Rhode Island and she coordinated the undergraduate Systems Engineering program for six years at the University of New Haven. Her current research portfolio includes the application of MBSE for the design and optimization of complex systems, model-based fault detection and diagnostics (FDD) for HVAC systems; design of smart manufacturing systems and facilities; supply chain design; and systems engineering education. Prior to graduate studies, she worked in industry for 10+ years as a process engineering and was responsible for managing production maintenance, manufacturing process and facility improvements, and new process and facility scale-up. She also owned and managed an energy management and operations consulting company for three years prior to joining UConn. Dr. Thompson received the U.S. EPA Environment Merit Award for Region 1 (2017).

Position Paper

Amy provides the point of view of Academia as its representative in the panel. The Management perspective is seen during the research and distribution of tasks for research purposes. Sometimes due to the type of work performed at universities there is not an establish “team” and the individual is the “leader”. Is up to the individual to become the manager and leader of its project. During research several hats are used but the interactions with students that proves to be the most successful are the ones in which the “hat” of a leader is used. An interesting discussion is what academia teach on technical leadership versus what individuals encounter in the real world. Discrepancies on definitions of management vs leadership could lead to a change on how academia approaches this topic.

Leema Kerkinni (Eli Lilly) - leema.kerkinni@lilly.com

Leema Kerkinni is a Principal Systems Engineer, currently developing medical devices in the connected drug delivery space at Eli Lilly and Company. She has experience as the Systems Engineering lead for the device and System of Systems development on various injection-based platforms, ranging from capsules to autoinjectors to large volume delivery. Leema is a 2022 graduate of INCOSE’s Technical Leadership Institute. Previously, she worked as a Project Manager at DaVita Clinical Research. She holds a MS in Systems Engineering from the University of St. Thomas (St. Paul, Minnesota) and a BS in Neurobiology and English from the University of Wisconsin-Madison.

Position Paper

When considering leadership and management, both are critical to enable a well-functioning enterprise, and the various sub-organizations contained within it (i.e. departments, programs, functional teams, project teams, etc). However, the roles that leadership and management play are vastly different, and are highly impacted by how the individuals fulfilling their roles understand them, especially in the context of a company’s mission and goals. While management is tied to the coordination and progress of development, leadership has the task of providing the vision that contextualizes managerial goals. The complexity of this distinction is based on the complexity of the enterprise, itself. As a technical leader, it is critical to understand the larger vision in order to define and deliver the right type of work. Understanding the relationships between larger goals and coordinated activities is critical. For example, working at a pharmaceutical company as a systems engineer in the medical device division requires awareness of the expectations that senior leadership has on milestones that are expected to be hit. There is a distinct difference between leadership and management that one must acknowledge and be mindful of in order to successfully deliver on programs.

Chris Schreiber (Lockheed Martin) - chris.schreiber@lmco.com

Carla Sayan is an Associate Director for Systems Engineering at Raytheon Intelligence and Space (RI&S) Business Unit. She received her doctorate in Electrical and Computer Engineering from the University of Arizona, a master’s degree in systems engineering from the University of Arizona and a bachelor’s degree in industrial and systems engineering from the University of Texas at Arlington. In her time at Raytheon, Carla held various System of System Architecture, R&D and leadership roles within key defense programs and proprietary business portfolios leading 25 direct reports and 41 indirect reports which solve complex national security challenges by developing smarter defense systems. This includes recruitment and retention establishing university and industry partnerships to support front end of the business and systems of systems architecture technical strategies. Carla is supporting the future of defense technology on many fronts. She is an active technology leader and passionate about building the gap between fundamentally academic research and applied engineering product development. She works with business leaders in the digital and agile transformation for a franchise level program establishing relationships with department managers on people management, project and program management for a large team of engineers supporting radar, cyber, advanced technologies and missile defense programs.

Position Paper

Carla brings her point of view from the Aerospace and Defense industry on Technical Leadership. Carla has built a reputation and credibility in her community for championing an inclusive diverse organization and culture. Raytheon has a low number of female engineers and an even lower number of women in technical fields at the highest pay grades. To respond to this need Carla funded the Raytheon Women in Engineering Science and Technology (RWEST) mentoring program. Programs like RWEST demonstrate that leadership can be taught and implemented successfully in corporations. Programs like this one provide return on investment to the corporation and employee satisfaction that support technical leadership as a business goal.

Carla Sayan (Raytheon Intelligence and Space) - carlasayan07@hotmail.com

Chris Schreiber is a Director for Lockheed Martin Space with responsibility as the Chief Engineer for Space's IT and Digital Enablement organization. For the past 15 years Chris has been focused on developing and deploying Model-Based Engineering practices, training, and infrastructure at Space Systems. He has led many Model-Based Engineering and Systems Engineering pilots, IRADs and implementations, including Systems Engineering efforts for Lockheed Martin's Digital Tapestry Initiative. Chris has 20+ years of experience in a variety of industries ranging from Management Consulting to Manufacturing to Aerospace. Chris is active in several industry associations as a member of INCOSE and OMG, vice-chair for the National Defense Industrial Association (NDIA) Systems Engineering Division, the joint OSD/INCOSE/NDIA Digital Engineering Information Exchange Working Group (DEIXWG) and works on development efforts for SysML 2.0. He also serves as a Corporate Advisory Board member for Englewood Public Schools' STEM initiative.

Position Paper

From my perspective technical leadership is a key component in an organization that values innovation and excellence. Working from the definition that management is oversight and responsibility for the execution of work or business within a group, and leadership as providing the framework for a group to succeed, I would say that management is necessary for leadership, but not sufficient. Good leaders are mainly good managers, but the converse isn't necessarily true. In my experience, leadership (especially in the technical arena) requires a set of skills and capabilities not necessarily found in good managers: strategic understanding, change management, risk and opportunity management, systems thinking. Good managers can understand the decomposition of work and are able to manage its execution successfully. Good Technical Leaders can establish a vision for what a group needs to do and then translate it into a form that their team can understand and internalize as their mission. They're able to understand the broader perspective of what needs to be accomplished, understand the tradeoffs in play to accomplish it, and manage the team to perform. It's half technical expertise and vision, and half coaching, influence and emotional intelligence. In my opinion, technical leadership can be taught to a certain point, but it requires a level of introspection and personal continued focus and growth to be effective. Cultivating technical leaders is also difficult. One's technical expertise is usually the initial gate to becoming a technical leader, but more often than not, technical people struggle to learn the non-technical aspects of good leadership. The great technical leaders I've experience over my career have a few characteristics. They're obviously extremely technically competent. They are servant-leaders and adept at establishing teams that self-direct with great communication. They have emotional intelligence that helps drive decision-making and team building. They establish open lines of communication built on trust. They are fierce defenders of their team and encourage internally the team to drive accountability for the whole system or mission. The best seem to lead without leading.

Panel#11

The Future of Decision Analysis

Frank Salvatore (SAIC) - Frank.salvatore@saic.com
Gregory Parnell (University of Arkansas) - gparnell@uark.edu
Devon Clark (Deloitte Consulting) - devclark@deloitte.com
Robert Kenley (Purdue University) - kenley@purdue.edu
Dan Hettema (Department of Defense) - jarsmith@deloitte.com

Presented on: Tuesday, 13:30-14:55 HST (313A)

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

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

Abstract. The future of Systems Engineering (SE) is model-based! SE provides methods and tools to mature the design of complex systems and systems of systems (SoS) designs. And due to the complexity of the systems themselves, or the processes and environments in which those systems must operate, one method stands out as the most critical—Decision Analysis. So, what does the model-based future of SE mean for Decision Analysis? The SE Vision 2035 projects a future where enterprises rely on quantitative decision making techniques enabled by greater automation. It also projects a transformation of model-based practices to a state where “a family of unified, integrated MBSE-Systems Modeling and Simulation frameworks exist.” Finally, INCOSE Vision 2035 recommends a focus on reuse through development patterns and reuse patterns. The INCOSE Decision Analysis Working Group is committed to this working towards a ‘first-of-its-kind’ reusable model pattern—a Decision Analysis Data Model—which will provide working Systems Engineers with work aids, reusable constraints and data models, and instructions on Decision Analysis process, all of which will provide an accelerator and the basis of decision specialization and tailoring. This panel will explore the art of the possible around model-based decision analysis, as well as what a future portfolio of INCOSE provided process models as digital assets might entail. The outcomes of this panel will inform the development of the INCOSE DAWG Decision Analysis Data Model to pioneer the future of reusable model patterns that can produce better engineering decisions while accelerating the execution of engineering activities.

Biography

Frank Salvatore (SAIC) - Frank.salvatore@saic.com

Frank Salvatore is a Senior Digital/Systems Engineer at SAIC. Frank has more than 30 years of experience supporting the development of DoD policy, guidance, strategy as well as development of Smart Munitions, GPS, and Software Programmable Radios. Frank is an Expert Systems Engineering Professional (ESEP), an Object Management Group (OMG) Certified Systems Modeling Professional (OCSMP), and a Six Sigma Green Belt. Frank is an active member of the International Council on Systems Engineering (INCOSE). He is a chairperson of the Decision Analysis Working Group and the Digital Engineering Information Exchange Working Group, and is a past chapter president.

Position Paper

Frank Salvatore – Industry - Engineering Support – As engineering practice becomes more digitalized, it is essential to establish a foundational data model that parallels the defined process. Decision Analysis is an important practice that all engineering disciplines perform. A challenge faced by engineers when conducting decision analysis, trade studies is with finding the data, being able to share the data, and managing the data.

Every trade I have ever been involved in has had to establish its own constructs for how it will go about doing the work. There is a fair degree of set up time and learning every time that could be mitigated if a core Decision Management Data Model (DADM) was established and followed. As a chair for the Decision Analysis Working Group this idea was discussed at the 2022 International Workshop and it was decided that it would be value added to have such a data model. Our efforts to develop this data model product needs to be shared so that other SE processes work toward similar outcomes.

Gregory Parnell (University of Arkansas) - gparnell@uark.edu

Dr. Gregory S. Parnell is a Professor of Practice in the Department of Industrial Engineering at the University of Arkansas and Director, System Design and Analytics Laboratory (SyDL), and Director of the M.S. in Operations Management and M.S. In Engineering Management programs. He was lead editor of Decision Making for Systems Engineering and Management, (2nd Ed, 2011), lead author of the Handbook of Decision Analysis, Wiley Operations Research/ Management Science Series (2013), and editor of Trade-off Analytics: Creating and Exploring the System Tradespace, (2017). He previously taught at the West Point, the U.S. Air Force Academy, the Virginia Commonwealth University, and the Air Force Institute of Technology. He has a Ph.D. from Stanford University. He is a retired Air Force Colonel.

Position Paper

Dr. Gregory S. Parnell – Academia – The adoption of MBSE will continue to grow with the increased use of Digital Engineering. There will be continued development of new MBSE tools and use across all organization functions. Future MBSE tools will need an integrated platform to enable performance modeling at different resolutions, value models, life cycle cost models, and schedule models that show tradespace feasibility, uncertainty, and risk. These tools will also provide affordability analysis, economic analyses, and other trade-off analyses throughout the enterprise with results updated automatically for each requirement and/or design change.

Devon Clark (Deloitte Consulting) - devclark@deloitte.com

Devon Clark is a Systems Engineer with 23+ years of experience in Systems Engineering, Integration, and Test. He holds a Bachelors degree in Physics from Georgia Tech and a Masters degree in Systems Engineering from the Naval Postgraduate School. Devon began his career engineering Surface Warfare and Command and Control systems for Naval Sea Systems Command (NAVSEA) before he transitioned to Consulting in 2018, where he specializes in Digital Government Transformation, including the application of Model-Based Systems Engineering (MBSE), Data Architecture and Modeling, and Model-Driven Decision Making. Devon is also an avid karaoke-er.

Position Paper

Devon Clark – Industry – Consulting – As a member of a Consulting firm whose government services prioritize domain awareness over product design, Devon’s position represents a focus on using data and models to make better decisions at an enterprise (e.g., cross portfolio) level. Devon’s position is also informed by 18 years of government service leading the engineering of Navy systems, where decision processes were often heuristic and/or post hoc. That is why Devon’s position focuses on making decision-making processes more accessible and useful through the use of models to drive efficiency through re-use, open systems, and knowledge management.

Robert Kenley (Purdue University) - kenley@purdue.edu

Dr. Kenley is a Professor of Engineering Practice in Purdue’s School of Industrial Engineering, where has been developing courses and curricula to support the educational objectives of the Purdue Systems Collaboratory. He has over 30 years’ experience in industry, academia, and government as a practitioner, consultant, and researcher in systems engineering. He has published papers on systems requirements, technology readiness assessment and forecasting, Bayes nets, applied meteorology, the impacts of nuclear power plants on employment, model-based systems engineering, and agent-based modeling for systems of systems. He is an expert system engineering professional (ESEP), and a Fellow of INCOSE.

Position Paper

Dr. Kenley – Academia – As INCOSE Pioneer John Warfield used to say to participants in workshops that he ran, “We provide you a process that you are to follow. Your creativity and ideas are reflected in the content that you are providing within the process not in reinventing the process.” Warfield was insistent on this, because quality of the outcomes and the efficiency in producing outcomes was directly linked to following a process that demanded collection of the needed information in support quality decision-making. With the increased use of Digital Engineering, we have an opportunity to capture decision making processes and the attendant data requirements to establish repeatable, reliable, and consistent enterprise approaches to ensure quality decision making.

Dan Hettema (Department of Defense) - jarsmith@deloitte.com

Dan Hettema currently serves as the Director of Digital Engineering, Modeling and Simulation within the Office of the Under Secretary of Defense for Research and Engineering. He oversees DoD-wide strategy, policy, and coordination in digital engineering and promote the advancement of digital practices in defense acquisition. Dan brings together experience in systems and digital engineering, in both industry and government service, and has supported a variety of customers including Navy, Joint Staff, NNSA, and the Intelligence Community, and held multiple leadership roles in INCOSE.

Position Paper

Dan Hettema – Government – As the Director of Digital Engineering, Modeling and Simulation within the Office of the Under Secretary of Defense for Research and Engineering, Dan oversees DoD-wide strategy, policy, and coordination in digital engineering and can speak to the DoD’s perspective on digital transformation.

Panel#10

Utilizing Model and Data Governance to Enhance Digital Engineering Execution

Ryan Noguchi (The Aerospace Corporation) - ryan.a.noguchi@aero.org
Heidi Davidz (ManTech International Corporation) - Heidi.Davidz@mantech.com
Misak Zetilyan (The Aerospace Corporation) - misak.zetilyan@aero.org
Sarah Scheithauer (Georgia Tech Research Institute (GTRI)) - sarah.scheithauer@gtri.gatech.edu
Douglas Orellana (Mantech International Corporation) - Douglas.Orellana@mantech.com

Presented on: Monday, 15:30-16:55 HST (313A)

Keywords. MBSE model based systems engineering governance model governance MBSE governance DE governance data governance digital engineering DE

Topics. 2. Aerospace; 3.8. Quality Management Process; 5.3. MBSE & Digital Engineering; 5.5. Processes; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. This session will describe key elements of the governance problem for Digital Engineering (DE) and solution approaches. Governance lessons learned will be shared. Participants will gain better understanding of data and model governance challenges, along with practical ideas on how to implement governance to improve organizational DE execution for enhanced program outcomes.

Biography

Ryan Noguchi (The Aerospace Corporation) - ryan.a.noguchi@aero.org

Ryan A. Noguchi is Principal Engineer in the Architecture & Design Subdivision at The Aerospace Corporation. He is responsible for developing and applying disciplined system architecting methods, processes, tools, and models for a diverse set of government agencies and internal R&D projects. He has led multiple system, system of systems, and enterprise modeling pilot projects and advises government enterprise management organizations and system acquisition programs to guide their establishment of disciplined model-based systems engineering and digital engineering capabilities. He is an Object Management Group (OMG) Certified Systems Modeling Professional (OCSMP) SysML Model Builder—Advanced. He has a B.S.E. in Mechanical and Aerospace Engineering from Princeton University and a M.S. in Mechanical Engineering from the University of California, Berkeley.

Position Paper

MBSE has been growing in adoption but has largely been pursued in individual silos with little formal or disciplined governance. This has led to a fragmentation of the community in terms of MBSE process, methods, and models. Some governance is needed to improve the value that can be achieved by individual programs adopting MBSE, and more importantly, the value that can be achieved by portfolios of programs adopting MBSE within an enterprise. While the community has largely been in an epoch of exploration with regard to MBSE, we need to collaborate to achieve greater consensus on best practices and standards to achieve greater value and longetivity from MBSE.

Heidi Davidz (ManTech International Corporation) - Heidi.Davidz@mantech.com

Dr. Heidi Davidz is an Intelligent Systems Engineering Subject Matter Expert at ManTech International Corporation where she works to modernize SE practice using model-based, computational technologies. She is co-author of the ManTech Model Governance Guide which has been used on multiple programs for model and data governance to enhance Digital Engineering execution. She serves as the International Council on Systems Engineering (INCOSE) Deputy Services Director. Previously at Dynetics, she was a Senior Principal Aerospace Engineer for the Human Landing System. At Aerojet Rocketdyne, roles included the Digital Engineering and Model-Based Systems Engineering Lead, SE Discipline Lead, Chief Process SE, and other positions in SE and Test. She earned a Ph.D. in Engineering Systems from the Massachusetts Institute of Technology, a M.S. in Aerospace Engineering from the University of Cincinnati, and a B.S. in Mechanical Engineering from The Ohio State University.

Position Paper

In the field of data science, data governance is key to ensuring data quality. Likewise in systems engineering, governance is key to ensure high quality of models and data. As DE and MBSE are employed, increased connectivity and complexity can quickly result in out-of-control situations. Robust model and data governance organizes the DE ecosystem to execute efficiently and reduce the cost of confusion, churn, and rework. Governance can address scope for what models/data are in the program DE ecosystem, roles for who needs to interact with those models/data, purpose of why models/data are needed for the mission, process for how what actions happen when, and location of where models/data reside in the infrastructure. An overview of the problem space, an introduction of data governance applied to DE/MBSE, and lessons learned from practical application of a model governance guide will be discussed.

Misak Zetilyan (The Aerospace Corporation) - misak.zetilyan@aero.org

Misak Zetilyan is a Senior Project Lead at the Aerospace Corporation, specializing in Digital Engineering Transformation. He has experience in software and hardware design, process improvement, and quality management. He has led the development of software and hardware for satellites, military and commercial aircraft, as well as implantable biomedical devices.

Position Paper

Model-Based Systems Engineering models enable Digital Engineering Transformation and support engineering activities throughout the lifecycle. Some organizations have responded by defining a DE implementation plan that addresses their own DE strategy. However, the lack of a common set of best practices guidance that addresses model management including governance has created an “ad-hoc” approach. This lack of shared best practices, guidance, and standards leads to inconsistencies in defining or applying DE management across organizations. The need to identify best practices for consistency, quality, security, and interoperability is needed to build trust in data and models.

Sarah Scheithauer (Georgia Tech Research Institute (GTRI)) - sarah.scheithauer@gtri.gatech.edu

Sarah Scheithauer is a Model Based Systems Engineering (MBSE) Research Engineer at Georgia Tech Research Institute (GTRI) with 10+ years of experience in Systems Engineering, with a focus on the application of MBSE and Digital Engineering (DE) for the majority of her career. Sarah earned her B.S. and M.S. in Electrical Engineering from Ohio University and started her career with Boeing Defense thereafter, where she established core Systems Engineering principles as a Requirements Management Engineer for the CH-47 Chinook. Additionally, Sarah held several lead roles in and facilitated the planning and execution of the transition to Digital Engineering for many Boeing programs. In her current position at GTRI, Sarah continues to learn about how MBSE and DE (as the encompassing application of MBSE) is being implemented across the DoD, and strives to use her experience to continuously improve DE implementation on real-world acquisition programs in the rapidly changing environment of DE.

Position Paper

Approaching the transition to Digital Engineering (DE) can be overwhelming and intimidating. As an MBSE/DE white hat advisor to the Government in her role with GTRI, Sarah is passionate about simplifying this process by teaching and applying DE in phases, such that the customer can truly understand the digital transformation and the nuances associated with it. Beyond the educational piece, another key aspect in acceptance of this cultural shift is being able to define achievable goals and provide visual and tangible results along the way. Sarah was first introduced to “model governance” in the midst of supporting the Army’s Optionally Manned Fighting Vehicle (OMFV) program. While model governance provides countless benefits throughout the DE transition lifecycle, it has been an especially useful tool for capturing the DE implementation execution into achievable steps, helping the program identify and rectify crucial gaps in the process, and producing quantifiable metrics for communicating progress and success. The DoD and supporting organizations are at a cross roads with DE, and it is more important than ever to work together on the common goal(s) of this transition, and share and collaborate on resources such as model governance that can contribute to the DoD’s success in the complex world of DE. As a panelist, Sarah will speak to her experiences on applying model governance to the OMFV program, and lessons learned that model governance introduced including the significance of ontologies (i.e. MBE vs. MBSE vs. DE) and scoping your model governance plan appropriately.

Douglas Orellana (Mantech International Corporation) - Douglas.Orellana@mantech.com

With over a decade of experience in organizational transformation, systems engineering, and technology integration, Dr. Douglas Orellana, is responsible for ManTech’s digital transformation and modernization of systems engineering and developing the next generation solutions powered by advanced computing, modeling and simulation, automation, and artificial intelligence. Prior to ManTech, he held numerous positions with increasing authority within system engineering organizations at Northrop Grumman and SAIC, spanning the systems lifecycle. Dr. Orellana earned his B.S. in Electrical Engineering and M.S. in Systems Engineering from Johns Hopkins University, and his Doctorate in Astronautical Engineering from the University of Southern California.

Position Paper

As the amount of information exponentially grows, there is a high risk of falling back into the abyss of information silos that is consistent with Document Intensive Systems Engineering. We have to ensure data within the digital ecosystem is enabled to reach all stakeholders to enhance decisions with better understanding of why that data exists and any metadata that can better characterize the data in use. Data Governance becomes a clear requirement for building digital ecosystems to reduce data paralysis and the creation of dark data. Developing Data Governance through a systematic approach allows organizations to fully understand the lifecycle of data in use, why the data is being created, and how data is used intra-organization and inter-organizations.

Tutorial

Tutorial#25

Agile, Industrial DevOps, and Organizing for Flow

Suzette Johnson (Northrop Grumman) - suzette.johnson5@gmail.com
Robin Yeman (Project & Team) - robinyeman@gmail.com

Presented on: Saturday, 08:00-12:00 HST (316A)

Keywords. Agile Industrial DevOps Continuous Improvement Value delivery

Topics. 1.6. Systems Thinking; 11. Information Technology/Telecommunication; 2. Aerospace; 2.3. Needs and Requirements Definition; 3. Automotive; 5.1. Agile Systems Engineering; 5.7. Software-Intensive Systems; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.);

Abstract. This workshop provides an introduction to Industrial DevOps and the concepts around creating a delivery pipeline to improve flow and delivery of value to users. Following a discussion on the Industrial DevOps principles and delivery pipeline, participants work in small teams to build and deliver products while receiving payment for their deliveries into production. The goal is to organize around value delivery in the shortest sustain lead time. This activity emphasizes the organizational structure and the required collaboration across functional areas for achieving a single piece flow delivery option. In this workshop participants use an iterative approach to build products (fun toys) as defined by the needs of business team. The business team defines the value of each feature which helps teams to understand the priorities and return on investment. Working with the Product Owner, each team creates a plan to deliver as much value as possible each iteration while collaborating with the Security Team, Infrastructure Team, other teams, and their Release Manager to know when they can deliver. As the team makes deliveries, they begin encounter disruptions, vulnerabilities, and challenges around security and operations. Teams apply a continuous improvement mindset through the use of retrospectives to continuously evolve the team structure for improved collaboration, feedback, and flow. The participants will conclude with a discussion on the implications and application of these principles in the engineering and development of cyber-physical environments.

Tutorial#26

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

Ali Raz (George Mason University) - araz@gmu.edu
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Presented on: Saturday, 08:00-17:00 HST (313A)

Keywords. Artificial Intelligence Systems Engineering Machine Learning Intelligent Systems

Topics. 14. Autonomous Systems; 2. Aerospace; 2.4. System Architecture/Design Definition; 5.11 Artificial Intelligence, Machine Learning;

Abstract. Deep Neural Networks have become the most powerful software development technique in recent years, leapfrogging other more established, but increasingly obsolete, artificial intelligence 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. It will also introduce emerging concepts of explainable AI as applied for systems level test and evaluation.

Tutorial#21

Basic SysML modeling with Automated Validation Support

Michael Vinarcik (INCOSE Michigan Chapter) - michael_vinarcik@msn.com
Chris Swickline (SAIC) - chris.r.swickline@saic.com

Presented on: Saturday, 08:00-12:00 HST (316B)

Keywords. SysML MBSE Validation

Topics. 2.4. System Architecture/Design Definition; 2.6. Verification/Validation; 5.9. Teaching and Training;

Abstract. INCOSE's Vision 2035 envisions that "Systems architecting methods are well established and ... provide a single, consistent, unambiguous, system representation." Achieving that goal requires competent use of digital engineering tools to ensure that abstract and concrete concepts (from stakeholder needs to specific design attributes) are properly identified and transformed into appropriate digital elements, properties, and relationships. This tutorial will focus on the use of automated validation techniques to create descriptive architectures of a system and demonstrate how model quality is improved through their use. Traceability, behavioral/structural integrity and consistency, "garbage collection," and completeness will be explored. This tutorial is intended for novice-to-intermediate modelers; it will include access to a modeling ecosystem for the duration of the International Symposium.

Tutorial#20

Developing Verification Requirements to Assure Project Success

Mark Powell (Attwater Consulting) - mark.powell@attwaterconsulting.com

Presented on: Sunday, 08:00-12:00 HST (316A)

Keywords. Verification Requirements Validation

Topics. 2. Aerospace; 3.3. Decision Analysis and/or Decision Management; 3.7. Project Planning, Project Assessment, and/or Project Control; 3.8. Quality Management Process; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. A well thought out and planned set of verification requirements can make all the difference between a happy customer and a dissatisfied customer. If you cannot provide confidence to the customer that you met their requirements, you won’t have a happy customer. Yet few projects these days invest much effort in developing good verification requirements. Quite often, verification requirements are treated as an afterthought to the performance requirements. But, if we produce the verification requirements concurrently with the performance requirements, the verification requirements can expose problems in the performance requirements they are intended to verify. Of course, this not only leads to better verification requirements, but to better performance requirements, which leads to a happy customer. Why is it then that most requirements training courses just gloss over the development of verification requirements? Verification requirements are actually very different from the requirements they support. While they share the same syntax and basic requirements writing rules as performance requirements, you usually need many verification requirements to properly verify that a single performance requirement is satisfied. This tutorial will enlighten both the new SE as well as the grizzled veteran who needs a refresher about how to properly develop good verification requirements. We will go through a number of real world examples of good and bad verification requirements, and how they contributed to success and failure. We will establish the philosophical foundation for writing verification requirements, and present a simple process for developing verification requirements for broad classes of performance and functional requirements.

Tutorial#34

Digital Engineering Basics

Frank Salvatore (SAIC) - frank.salvatore@saic.com
Darryl Howell (Powell Consulting Group) - darryl.howell@pcgconsults.com

Presented on: Saturday, 13:30-17:00 HST (316A)

Keywords. Digital Engineering Digital Thread Digital Twin Digital Artifact Authoritative Source of Truth Digital Engineering Ecosystem Model Based Systems Engineering Modeling Simulation Model Management Digital Engineering Strategy

Topics. 11. Information Technology/Telecommunication; 20. Industry 4.0 & Society 5.0; 3.7. Project Planning, Project Assessment, and/or Project Control; 5.9. Teaching and Training; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. The Digital Engineering Basics tutorial describes foundational terms and concepts for Digital Engineering. Attendees will become familiar with Digital Engineering methods that support product development activities to include: the development and delivery of training and other areas of acquisition and product support. This tutorial will identify the need for Verification, Validation and Credibility (VV&C) in models in ensuring that engineering models meet the needs of their users; and curation for models to be trusted for use and reuse. This tutorial will describe the characteristics and associated challenges of Digital Engineering use in: Test and Evaluation, Autonomy, Mission Engineering, Research and Development/Acquisition and Manufacturing. It will also show the key role Digital Engineering has in developing capabilities that support Training and other operational Missions. The tutorial will identify accessible DoD Digital Engineering information resources and explain the role of the Office of the Under Secretary of Defense for Research and Engineering (OUSD (R&E)) Digital Engineering, Modeling and Simulation Directorate. As an outcome of this tutorial, the learner should be able to understand the DoD Digital Engineering Strategy and further their understanding of key terms and concepts and how they are being applied. The tutorial will aid learners in driving digital engineer principles and practices into digital transformation initiatives within their own home organizations.

Tutorial#27

Digital threads with the Open Services for Lifecycle Collaboration (OSLC)

Eran Gery (IBM) - eran.gery@il.ibm.com
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Jad El-Khoury (KTH Royal Institute of Technology) - jad@kth.se

Presented on: Sunday, 13:30-17:00 HST (316B)

Keywords. Digital engineering Digital threads Digital engineering information exchange OSLC Linked data Engineering Lifecycle Management Model Based Engineering MBSE

Topics. 2. Aerospace; 3. Automotive; 3.2. Configuration Management; 5.3. MBSE & Digital Engineering; 6. Defense;

Abstract. Open services for lifecycle collaboration (OSLC) is an open standard that supports lifecycle integration across modeling and other engineering domain tools. OSLC is also referenced by INCOSE Vision 2035 as a technology that may support the systems engineering digital transformation. It is also featured by the upcoming SysML v2.0 submission. OSLC is an actively evolving standard managed as an OASIS open project. While there are engineering data exchange standards such as STEP, they all focus on offline data exchange while OSLC is the only architecture that enables online collaborative digital integration across systems engineering domain tools. OSLC is based on the semantic web stack and is based on the linked data architecture, and is based on a service oriented architecture. In this tutorial we will teach the OSLC specification and how it supports digital lifecycle use cases. As part of that, we will discuss the use-cases that guided the design of OSLC, after we provide an overview of some of the semantic web technologies. The core of the tutorial provides a tour of the different OSLC specification areas with examples of how they are used in the context of digital threads use cases in heterogeneous environments.

Tutorial#14

Engineering Assured Trustworthy Secure Systems

Mark Winstead (The MITRE Corporation) - mwinstead@mitre.org
Michael McEvilley (The MITRE Corporation) - mcevilley@mitre.org
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Presented on: Sunday, 08:00-17:00 HST (313B)

Keywords. Systems Security Engineering Assurance Trustworthy Systems Loss Driven Engineering System Design Trustworthy Secure Systems Secure and Resilient Systems Secure Design

Topics. 12. Infrastructure (construction, maintenance, etc.); 2.3. Needs and Requirements Definition; 2.4. System Architecture/Design Definition; 3. Automotive; 4.6. System Safety; 6. Defense;

Abstract. Security should be as foundational a perspective as system performance and safety (INCOSE SE Vision 2035), as engineering of systems cannot assume benign environments for development, operations, maintenance, and support. Systems engineering must think and execute to properly employ principles, concepts, and methods to coordinate, orchestrate, and direct the activities to deliver assured trustworthy secure systems in and for contested environments. This tutorial overviews the needed security proficiency elements for systems engineering with alignment to many of the concepts of INCOSE's security in the future of systems engineering efforts (INCOSE Insight June 2022). Meeting stakeholder needs within constraints of cost, schedule, and performance must include meeting the security protection needs derived from those stakeholder needs. Systems Security Engineering (SSE) activities address loss concerns associated with the system-of-interest throughout its lifecycle, considering potential adversities. This includes developing an inherently assured trustworthy secure design that 1) avoids loss from occurring, 2) minimizes effects of loss that does occur and 3) is intrinsically easier to analyze for vulnerabilities and hazards during upgrades. The tutorial presents a principled strategic approach towards the design of an intrinsically assured trustworthy design. This approach aids in realizing an intrinsically trustworthy secure system to help in prioritizations, reduce workload, and mitigate concerns of “unknowns” with assurance and thus producing trustworthiness in the system. This approach contrasts with widespread tactical risk-based approaches. This tutorial targets the experienced systems engineer who is a novice in Systems Security Engineering as a specialty discipline of systems engineering.

Tutorial#23

Federating System-of-Systems models with Automated Validation Support

Michael Vinarcik (INCOSE Michigan Chapter) - michael_vinarcik@msn.com
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Presented on: Saturday, 13:30-17:00 HST (316B)

Keywords. SysML Validation Federation

Topics. 17. Sustainment (legacy systems, re-engineering, etc.); 2. Aerospace; 5.3. MBSE & Digital Engineering; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 5.9. Teaching and Training; 6. Defense;

Abstract. INCOSE's Vision 2035 expects that "Systems of systems are designed with a family of unified modeling approaches. Common SoS style guides, patterns, and methodologies are practiced...Model-based verification of SoS's are realized...Systems engineers design-in assumed SoS reuse within an anticipated larger SoS solution." Some aspects of this anticipated future are possible today within existing system modeling tools. This tutorial will show how model federation can be used to support automated validation of interface and behavioral consistency between multiple system models. Techniques to federate models, curate shared reusable libraries, and include legacy and/or nonconformant models will be demonstrated. Students will also be taught how to identify potential disconnects and construct customized automated validation rules to support the integrity of the federated models. We also explore mirroring content in UAF and SysML models to avoid entanglement while maintaining consistency through validation. This tutorial is intended for intermediate-to-advanced modelers; it will include access to a modeling ecosystem for the duration of the International Symposium.

Tutorial#5

Leveraging Decision Patterns to Power Digital Engineering

John Fitch (Decision Driven Solution) - johnafitch@gmail.com
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Presented on: Saturday, 08:00-17:00 HST (313B)

Keywords. decision analysis decision management trade study decision patterns digital thread traceability

Topics. 3.3. Decision Analysis and/or Decision Management; 5.3. MBSE & Digital Engineering;

Abstract. Decisions are the integrative mechanism of Systems Engineering – the thinking process that translates a problem into a solution design. Each decision represents a fundamental question/issue that demands an answer/solution. Decisions follow patterns based on the type of problem being addressed, e.g., enterprise strategy/design, capability/process design, system/product design or service design. Leveraging such patterns can accelerate the solution design process, increase the value delivered to stakeholders and reduce the risk of project failure. This tutorial will teach you how to: 1. Frame a problem/project as a Decision Breakdown Structure (DBS) based on proven decision patterns. 2. Use the DBS as a management, innovation, and evaluation framework to focus project resources on the highest-value decisions. 3. Capture the essential information needed to make a decision with confidence, to preserve decision rationale and to communicate this rationale to stakeholders. 4. Manage the consequences (e.g., derived requirements) associated with each decision and enable a seamless handoff between decision-making and other systems engineering processes. 5. Maintain and visualize a decision-centric digital thread to enable agility in the face of evolving requirements or solution technologies. 6. Identify organizational roadblocks to the use of decision patterns Your introduction to these concepts and skills will be reinforced by hands-on workshops that address a mix of case studies and your real-world project decisions.

Tutorial#7

Model-Based Cyber-Physical Systems Engineering: The James Webb Space Telescope as a Case in Point

Dov Dori (Technion, Israel Institute of Technology) - dori@mit.edu

Presented on: Sunday, 08:00-17:00 HST (313C)

Keywords. cyber-physical systems model-based systems engineering James Web Space Telescope - JWST

Topics. 1.2. Cybernetics; 14. Autonomous Systems; 2. Aerospace; 2.4. System Architecture/Design Definition; 22. Social/Sociotechnical and Economic Systems; 5.3. MBSE & Digital Engineering; 5.4. Modeling/Simulation/Analysis;

Abstract. Cyber-physical systems (CPSs) are complex ensembles of hardware and software components that together function to deliver value. The CPS software parts get and process signals from the environment, and they use them to controls the hardware to achieve the goals which these systems were designed to achieve. While physical objects in the system follow the laws of nature, informatical objects—the software parts of the system—are bound by a totally different set of rules. Due to the intimate and intertwined relations between these two kinds of components within CPSs, a language and methodology to model these systems as a basis for their system engineering must accommodate these two disparate paradigms under the same hood and be able to explicitly express how the hardware and software parts interact. A magnificent feat of science-based engineering for the sake of promoting human scientific knowledge, The James Webb Space Telescope (JWST) is perhaps the ultimate example of a CPS. Designed primarily to conduct infrared astronomy, JWST is the largest optical telescope in space, and its high infrared resolution and sensitivity allow it to view early, distant, or faint objects that its predecessor, the Hubble Space Telescope, could not detect. JWST enables a broad range of investigations across astronomy and cosmology, including observation of the first stars and the formation of the first galaxies, and detailed atmospheric characterization of potentially habitable exoplanets. This tutorial introduces the new domain of Model-Based Cyber-Physical Systems Engineering (MBCPSE) using Object-Process Methodology (OPM) ISO 19450 with JWST as a case in point. OPM is especially suitable to cope with the challenges that MBCPSE poses, as it provides for modeling both physical and informatical objects and processes in the same single kind of diagram—Object-Process Diagram (OPD). The model is a hierarchically organized set of OPDs whose root OPD—the system's top-level view—specifies the CPS's main process and transformed object(s)—the system's function—along with the beneficiary group and the value they reap from this function. Every OPD elaborates on its predecessor by refining a subset of the things in it. Each graphical construct is translated automatically by OPM modeling software, OPCloud, into a sentence in Object-Process Language (OPL)—a subset of English, such that the graphical and textual modalities complement each other. I will present the structure and behavior of JWST as a means to introduce the basic OPM building blocks—objects and processes, and how they relate to each other via structural and procedural links to express the CPS structure and behavior. The focus on JWST as the running example makes the tutorial timely, inspiring and exciting, as attendees learn about both Model-Based Cyber-Physical Systems Engineering with OPM and how JWST is built and operates to achieve the magnificent images and the new insights into the early universe, star formation, and exoplanets. The focus on JWST as the running example makes the tutorial inspiring and exciting, as attendees learn about both Model-Based Cyber-Physical Systems Engineering with OPM and how JWST is built and operates to achieve the magnificent images and the new insights into the early universe, star formation, and exoplanets.

Tutorial#9

Practical Systems Engineering: Principles and Methods for Success

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

Presented on: Saturday, 08:00-17:00 HST (313C)

Keywords. Fundamentals Requirements analysis Systems architecture MBSE Digital Engineering

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

Abstract. “I know how to draw the diagrams” … “we’ve defined our requirements” … “I applied the processes” … “we have selected a tool” … “it’s all checklists, documents, and overhead.” Systems engineering is a rich practice leveraging an evolving set of processes, methods, and tools to address problems complicated and complex. With this richness, it is easy to become lost in nuance, details, and disconnected processes. In reality, the path to systems engineering success lies in perspective, the big picture, and integration. This tutorial demonstrates a practical approach to foundational principles and methods of systems engineering within a framework for overall project success. We focus on both understanding the problem and defining the solution as we address requirements, behavior, architecture, and V&V. Rather than treating these in isolation, the fundamentals are positioned within a flexible systems engineering framework suitable for system development tasks across the complexity spectrum. Our focus will be on eliciting the right requirements, understanding the problem and solution, enhancing communication amongst the design team and the stakeholders, and satisfying the system need, all underpinned by a model-based approach. Through discussions of the fundamental concepts integrated with sample exercises, we will maintain our focus upon the true deliverables – the system itself and overall project success. Note: This proposal is for a one-day tutorial. The tutorial can be extended to a two-day workshop where the fundamental scope remains the same, and concepts are addressed to a greater depth (while still maintaining a focus on fundamentals) as attendees work a sample problem threaded throughout. The tutorial can also be scaled down to a half-day session with a reduced outline focused on the introduction and practical walkthrough though this option is not preferred.

Tutorial#22

Quantitative Risk Assessment

Mark Powell (Attwater Consulting) - mark.powell@attwaterconsulting.com

Presented on: Sunday, 13:30-17:00 HST (316A)

Keywords. Quantitative Risk Assessment Risk Management Statistics

Topics. 2. Aerospace; 3.3. Decision Analysis and/or Decision Management; 3.6. Measurement and Metrics; 3.9. Risk and Opportunity Management; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Risk Management is rarely practiced or taught with anything other than qualitative risk assessments. There is a good reason for this; up until recently, for the real world problems faced by Systems Engineers, quantitative risk assessments have been generally impossible. The classical statistical processes we normally use force us to ignore some types of data, and in many cases the math just does not work. Well, what is so special about a Quantitative Risk Assessment in the first place? Quantitative risk assessments infer statistically from the available data and information the full uncertainty distribution for a risk – they are a mathematical process that produces numbers, not qualitative statements like “severe with low likelihood.” The result: a very good numerical understanding of the risk, as well as all of its sensitivities. New methods have been developed in Europe in the 1990’s that do not force us to ignore any data in a risk assessment, and make it possible to always produce a quantitative risk assessment. Further, these methods allow a Systems Engineer to avoid making assumptions when some part of the problem is unknown. This tutorial explains in detail the concepts of quantitative risk assessment to practicing Systems Engineers who want to expand their Systems Engineering skills. We will review how quantitative risk assessments fit into the Risk Management process. The new methods from Europe will be introduced by solving some real world problems that were previously considered impossible to solve quantitatively.

Tutorial#13

System Safety Engineering

Meaghan Oneil (System Design and Strategy Ltd) - meaghan.oneil@gmail.com
Duncan Kemp (Ministry of Defence) - duncan@17media.co.uk

Presented on: Sunday, 08:00-17:00 HST (313A)

Keywords. System Safety STPA CAST STAMP Socio-technical systems

Topics. 14. Autonomous Systems; 3. Automotive; 4. Biomed/Healthcare/Social Services; 4.1. Human-Systems Integration; 4.6. System Safety; 5.12 Automation;

Abstract. This tutorial will provide an overview of modern System Safety Engineering. This highly interactive tutorial will include: 1. Basic Systems thinking and systems engineering concepts as they apply to Systems Safety 2. Safety Engineering basics, including what constitutes acceptably safe in different industries and countries 3. Different approaches to engineer safe systems 4. Organisational safety and mental models 5. Safety culture and leadership styles 6. Practitioner’s introduction to STAMP including CAST and STPA The tutorial will include a range of real-world examples and will include a case study based upon the 737 MAX aircraft. This session will cover all of the material included in the significantly updated System Safety section of the INCOSE handbook. The STAMP introduction will include examples as well as insights on best practices gathered from over 10 years of application.

Tutorial#3

Systems Engineering MBSE implementation in your organization

Mark Sampson (Siemens) - mark.sampson@siemens.com

Presented on: Sunday, 08:00-12:00 HST (316B)

Keywords. MBSE Model Based Systems Engineering MBSE ROI Organization Change Organization transformation

Topics. 1.1. Complexity; 1.6. Systems Thinking; 11. Information Technology/Telecommunication; 2. Aerospace; 2.4. System Architecture/Design Definition; 2.5. System Integration; 22. Social/Sociotechnical and Economic Systems; 5.3. MBSE & Digital Engineering;

Abstract. We are long past the arguments of whether MBSE is required to handle todays complex product combinations of software, electronics, mechanics, et al. The question is what and where to implement it to get the fastest return for your MBSE investment. Given these complex products are designed/built inside complex organization structures and processes it follows that implementing MBSE is yet another complex system requiring systems engineering to implement MBSE in your organization. This half-day course/workshop applies Systems Engineering (SE) processes, techniques, and tools/methods to choosing and implementing Model-Based Systems Engineering in an organization—doing two things at the same time—learning about available MBSE tools/techniques to help organizations compete and applying systems engineering processes to successfully deploy/leverage tools to your organization. You will leave this tutorial with the tools you need to plan and start your own MBSE journey in your organization.

Tutorial#8

Understanding and Applying the INCOSE SE Handbook Fifth Edition

David Walden (Sysnovation, LLC) - Dave@sysnovation.com

Presented on: Sunday, 08:00-17:00 HST (316C)

Keywords. handbook; process; best practices; INCOSE

Topics. 5.5. Processes; 9. Enterprise SE (organization, policies, knowledge, etc.)

Abstract. The objective of the International Council on Systems Engineering (INCOSE) Systems Engineering Handbook (SEH) is to describe the state-of-the-good-practice for Systems Engineering (SE). It also serves as the basis for the INCOSE certification examination. The Fifth Edition of the INCOSE SEH is being released in conjunction with the 2023 INCOSE International Symposium.The objective of this one-day tutorial is to provide a top-level overview of the latest edition of the SEH and explain how it can be used to plan, manage, and realize complex systems within the context of demanding business constraints. Participants are introduced to key SE terminology, concepts, and principles in the handbook. The participants will complete several team-based exercises to solidify the concepts being presented. Each student will receive a complete set of lecture notes and an annotated bibliography, but will not be provided a copy of the handbook.Note: this tutorial is an overview of the handbook and does not include the level of detail typically presented in an INCOSE Systems Engineering Professional (SEP) preparation course.

INCOSE Content

INCOSE Content#425

Architecture: Bringing Form to Function

Mark Wilson (Strategy Bridge International) - mwilson@strategybridge.com

Presented on: Monday, 03:30-04:10 HST (Virtual)

Keywords. Architecture

Topics. SE fundamentals;

Abstract. The cost of any system is largely determined by early technical decisions, especially the choices of solution concept and architecture. “Architecting” is the process of translating requirements into a viable solution. Architecture decisions address strategy, purpose, and structure: how system elements and components will interact with each other and other systems. This presentation provides an overview of architecture terminology and concepts, emphasizing the critical role of architecture in solution success.

Biography

Mark Wilson (Strategy Bridge International) - mwilson@strategybridge.com

Mark A. Wilson is CEO of Strategy Bridge International, Inc., a company that helps clients think strategically to improve their bottom-line results. Mr. Wilson served more than 25 years in the U.S. Navy and retired as a Captain (O-6). He has worked with Aerospace, Defense, Telecommunications, and U.S. Federal Government organizations, helping teams choose organizational strategies, plan and execute major programs, allocate resources, and select preferred concepts and solutions in trade studies. He regularly conducts training seminars on systems engineering, project management, strategic thinking, and effective decision-making. He is certified as an Expert Systems Engineering Professional (ESEP - INCOSE) and earned a B.S. from the U.S. Naval Academy and M.S. from the U.S. Naval Postgraduate School.

INCOSE Content#412

Architecture: More than a Floor Plan

Jim Armstrong (INCOSE) - jimarmstrong29@aol.com

Presented on: Monday, 11:30-12:10 HST (316C)

Keywords. Architecture

Topics. SE fundamentals;

Abstract. This presentation will cover the essentials of systems architecture as a key engineering element of the systems engineering discipline. Specific topics covered that everyone should be knowledgeable of include:Physical and Functional Architectures: What they are, how to define and model them, and the critical points to address in developing both.Hardware and Software Architectures: How they differ and how they are integrated to be a systemInterfaces and Integration: What the significant aspects are of physical and functional interfaces and how they affect systems integration including Systems of SystemsAnalyzing Architectures: What analysis techniques are valuable during architecture development to avoid later disasters and to provide early verification and validation of the final product. Architecture’s Relationship to the Rest of Systems Engineering: How architecture relates to requirements, integration, verification, validation, risk management, and MBSE.References: Some places to go for further information.While time does not permit a complete discussion of these topics, the attendee will have an understanding of the most important elements of architecture and have a roadmap for further learning.

Biography

Jim Armstrong (INCOSE) - jimarmstrong29@aol.com

Jim Armstrong has practiced systems engineering for 56 years in various roles including chief engineer, test, deployment, configuration management, and program manager. For the last 35 years he taught, consulted, and appraised systems engineering in industry and government. Jim has regularly presented papers at the International Symposium and served on the author teams of several of the systems engineering standards and models. He has a BS in Mechanical Engineering from Rensselaer Polytechnic Institute, an MS in Systems Management from the University of Southern California, and a PhD in Systems Engineering from Stevens Institute of Technology. He has an INCOSE Expert Systems Engineering Professional certification.

Avoiding Stupidity is Easier than Seeking Brilliance

Ad Sparrius (Ad Sparrius Systems Engineering and Management) - ad_sparr@iafrica.com

Presented on: Monday, 06:30-07:10 HST (Virtual)

Keywords. Tailoring SE/Fitting to the Problem; Organization; Lifecycle

Topics. SE fundamentals;

Abstract. The title appears to assert that not doing stupid things provides similar results as using the most advanced engineering techniques. There is no evidence to support that assertion. It is a common disease to know the correct approach, but to nevertheless foolishly neglect it. Avoiding stupidity eliminates that.What is application? What is tailoring? Why are they needed? Where and when should they be used? The context of tailoring is the project life cycle. Tailoring is not a license to do nothing!First determine whether a particular standard is applicable, and second adapt it to fulfill the requirements of that life cycle stage—add, change or delete the standard's content.

Biography

Ad Sparrius (Ad Sparrius Systems Engineering and Management) - ad_sparr@iafrica.com

Ad Sparrius has been awarded four degrees—B Sc B Eng (University of Stellenbosch), MSEE (University of California, Berkeley), and MBL (University of South Africa), and is professor extraordinarius at UNISA's Graduate School for Business Leadership. Ad got involved in system engineering during the late 1970s and has been passionate about that discipline ever since. Ad has been the Technical Chair of INCOSE South Africa's 2012, 2013, 2015, 2016, 2017 and 2018 conferences, and has been instrumental in elevating that conference to a new level of distinction. He has been recognized as an INCOSE Fellow.

INCOSE Content#421

Building Program Archetypes for Digital Engineering

David Long - david.long@incose.net
Nicole Hutchison - nlong@stevens.edu

Presented on: Thursday, 11:00-11:20 HST (KALAKUA BALLROOM C)

Topics. MBSE Lightning round

Abstract. In the US Department of Defense (DoD), evidence across the Services and industry affirms digital transformation is critical for program success in an environment of increasing global challenges, dynamic threats, rapidly evolving technologies, and increasing life expectancy of systems currently in operation (Zimmerman et al., 2019). The DoD is not alone in this experience. Whether engaged in aerospace or transport, energy or medical devices, organizations recognize that they must harness the potential of digital transformation not only in the practice of systems engineering but across the greater engineering and product lifecycle. We as systems engineers must update our concepts, methods, and workflows taking full advantage of the digital power of computation, visualization, and communication as we develop, deploy, and sustain capabilities.While the desire and drive to digitally transform are real, so are the challenges programs and organizations face in this journey. For some, this is the challenge of starting a program in a digital way. For many others, it is a challenge of taking the approaches and processes currently being used and updating them and their staff to take advantage of digital approaches. Though many organizations are working to create reference models and best practices, digital transformation is often hindered by the workforce's understanding of how to tailor it to fit the program's needs.There is no one-size-fits-all answer to this challenge. While the theoretical ideal would have every organization and program custom develop a fit-for-purpose environment and ecosystem, such an approach is not practical. In reality, by focusing on a select set of considerations, we can quickly reduce the solution space to a limited number of archetypes. A few considerations include the type of acquisition (e.g. a major capability, a prototyping approach, software-intensive, etc.); the risk profile of the program; the novelty of the technology in play; and the balance of the acquisition in terms of fidelity versus abstraction of data. These archetypes provide a solid starting point that can then be further tailored, as desired. We will discuss the most frequent archetypes and the different "flavors" of digital engineering that are most commonly required based on archetype, including common templates, considerations for environment, etc.

INCOSE Content#414

Closing of the INCOSE IS2023 Hackaton

Presented on: Thursday, 11:00-12:00 HST (Virtual)

INCOSE Content#426

Get yourself Tested!

Paul Davies (thesystemsengineer.uk) - paul@thesystemsengineer.uk

Presented on: Monday, 05:00-05:40 HST (Virtual)

Keywords. Integration; Verification & Validation

Topics. SE fundamentals;

Abstract. A presentation on the fundamentals of Integration, Verification and Validation by Paul DaviesThe talk will start with some key concepts and terms, based partly on the INCOSE Systems Engineering Handbook and partly on the recent ‘Don’t Panic!’ guide to system testing, written by the presenter and published by the INCOSE UK Chapter. A description of common problems follows, with diagnosis of root causes and beneficial practices to correct them. After a brief discussion of requirements and their relationship to proper testing, some best practices in planning and sequencing a good strategy are presented. Finally, a SysML model of building the evidence base towards acceptance will be shown, for those inclined towards MBSE.Some concluding remarks will cover the benefits of getting involved in integration, verification and validation activities early in one’s career, and some suggested further reading for those keen to learn more about best practices.

Biography

Paul Davies (thesystemsengineer.uk) - paul@thesystemsengineer.uk

Paul Davies is semi-retired, and was previously the Discipline Manager for Systems Engineering at Network Rail Infrastructure Projects. In that role he was responsible for promoting improvements in process and in practitioner competence in all aspects of systems engineering. Prior to this, he worked for Thales UK, with nearly thirty years’ experience in SE research, innovations management, SE functional leadership, and project engineering management. Over a succession of challenging projects with challenging customers, many empirical lessons on system integration and testing were learned, which are distilled here.
Paul is a Chartered Engineer, a Certified Systems Engineering Professional, a Past President of the UK Chapter of INCOSE, and has been a popular presenter and tutorial lead at many INCOSE events.

INCOSE Content#420

INCOSE Systems Engineering Laboratory Status

Heidi Davidz (ManTech) - heidi.davidz@incose.net

Presented on: Thursday, 10:40-11:00 HST (KALAKUA BALLROOM C)

Topics. MBSE Lightning round

Abstract. The INCOSE Systems Engineering Lab (SE Lab for short) is a computing environment (or set of environments) where INCOSE members can use real, full versions of systems engineering tools for non-commercial INCOSE purposes, for learning, and for INCOSE projects, at no cost to the member or to INCOSE. Tool Providers participate to gain exposure for their products, and for modest promotional consideration and acknowledgement for their contribution of product availability. Products in the SE Lab may be used in combination, such as a requirements management tool from one Tool Provider in combination with a SysML modeling tool from another, as enabled by integrations provided by the Tool Providers, or by a third-party integration provider. During this presentation, an update on the SE Lab will be provided and future enhancements will be described. Integration with other INCOSE offerings will be described, including integration with the SE Tools Database, the INCOSE Professional Development Portal and the INCOSE Mentoring Service.

INCOSE Content#427

Let’s talk machine! – The Digital Transformation of Systems Engineering

Tim Weilkiens (oose) - Tim.Weilkiens@oose.de

Presented on: Monday, 05:45-06:25 HST (Virtual)

Keywords. MBSE; Digital Engineering

Topics. SE fundamentals;

Abstract. Around 30 years ago, we probably would have called scanning paper digitalization. But what is it today, when almost everything is digital and artificial intelligence is an increasingly important part of engineering teams? We will cover the difference between digitization, digitalization, and digital transformation and how MBSE relates to it. The talk will focus on the practical aspects of these concepts in systems engineering, illustrated by clear and easy-to-understand examples. Although digitization is a multi-faceted topic, we will highlight selected key aspects that are essential to grasp while avoiding high-level, abstract discussions which are already well covered by many other publications.

Biography

Tim Weilkiens (oose) - Tim.Weilkiens@oose.de

Tim is a member of the executive board of the German consulting company oose, an MBSE coach, and an active member of the OMG and INCOSE communities. He has written sections of the initial SysML specification and is a lead developer of the SysML v2 specification.
As a coach, he has advised many companies in different domains. His insights into their challenges are one source of his experience that he shares. Tim is a co-host of the MBSE podcast.

INCOSE Content#407

Making Sense of Alphabet Soup: MBSE and DE

David Long (Blue Holon) - david.long@incose.net

Presented on: Monday, 13:30-14:10 HST (316C)

Keywords. MBSE; Digital Engineering

Topics. SE fundamentals;

Abstract. Model-based systems engineering (MBSE) … model-based engineering (MBE) … digital thread and digital twin (DT) … digital engineering (DE) … digital transformation (yet another DT). There is an explosion of concepts and the corresponding acronym soup as we apply the power of digital to systems engineering and the greater engineering lifecycle. What are the various concepts? How do they interrelate? What do they mean for me, my organization, and the greater practice? How do I adopt and apply the right practices? We will move beyond the marketing, myth, and misconception to a practical understanding of what digital transformation means for systems engineering, the fundamentals we need to know, and the value we expect to achieve.

Biography

David Long (Blue Holon) - david.long@incose.net

David has spent over 30 years helping organizations assess, adopt, and deploy methods to increase their systems engineering proficiency while simultaneously working to advance the state of the art. David founded and led Vitech where he developed innovative, industry-leading methods and software to engineer next-generation systems. Today, he is the Chief Engineer for Digital Engineering at the Systems Engineering Research Center working to coordinate and advance their digital portfolio. He co-authored A Primer for Model-Based Systems Engineering and frequently delivers keynotes and workshops around the world.
An INCOSE Fellow and Expert Systems Engineering Professional, David was the 2014/2015 President of INCOSE. David currently serves as INCOSE’s Director for Strategic Integration and as a coach in INCOSE's Technical Leadership Institute.

INCOSE Content#430

New Spaces, New Places: How SEs Influence and Impact in Our Changing Times

Donna Rhodes (Massachusetts Institute of Technology (MIT)) - rhodes@mit.edu

Presented on: Monday, 16:15-16:55 HST (316C)

Keywords. The Why, What, and Value of SE – How to position SE to various audiences and stakeholders

Topics. SE fundamentals;

Abstract. As we approach the next new quarter century, systems engineers increasingly find themselves stepping into new spaces and new places, as contrasted with where we traditionally work. In this talk I would like to share some perspectives on how I think about systems engineers in these changing times. Using a quadrant map with axes of impact and influence, four distinct spaces where systems engineering provides unique value will be described. The nature and motivation for systems engineering work in these four spaces will be discussed and a case will be made for why it is essential to think of the value of systems engineering as contextual. Some specific examples will be shared to describe how various systems engineering methods and tools are being applied respective to specific new places in the four spaces. We'll explore some of the tensions and opportunities experienced by a systems engineer in a new space. And, we'll consider how specific places – even while somewhat new to us – are essentially familiar at the core. An imperative we face is to find cogent ways to communicate the value we can bring as a systems practitioner within new spaces and new places. As a traveler through all four quadrants in my research and practice, I hope to share some insights that may help inform the spaces and places you might explore in your own systems engineering journey.

Biography

Donna Rhodes (Massachusetts Institute of Technology (MIT)) - rhodes@mit.edu

Dr. Donna H. Rhodes is a principal research scientist in the Sociotechnical Systems Research Center at Massachusetts Institute of Technology, and director of the MIT Systems Engineering Advancement Research Initiative (SEAri). She is principal investigator for numerous sponsored research projects on innovative approaches for enterprise transformation under the digital paradigm, human-model interaction, model curation, and model-centric decision making and trust. Her research involves international collaboration and engagement with industry, government and academic partners across a variety of sectors in engineering and manufacturing. She teaches graduate courses, professional courses and executive courses, and has advised over 120 graduate students and authored over 150 publications. Previously, Dr. Rhodes held senior leadership positions at IBM, Lockheed Martin, and Lucent. She is a Past President and Fellow of the International Council on Systems Engineering (INCOSE). Her contributions in the systems field have been recognized by numerous publication awards, INCOSE Founders Award, IBM Outstanding Innovation Award and Lockheed Martin NOVA Award. She received her M.S and Ph.D. in Systems Science from T.J. Watson School of Engineering at Binghamton University.

INCOSE Content#419

Next-generation MBSE: Model as the cyber-physical system driver

Dov Dori (Technion) - dori@technion.ac.il

Presented on: Thursday, 10:20-10:40 HST (KALAKUA BALLROOM C)

Topics. MBSE Lightning round

Abstract. The current MBSE paradigm calls for modeling systems in general, and of cyber-physical systems (CPSs) in particular, throughout their lifecycle based on textually expressed requirements. Treating the evolving model serves as the ultimate source of truth and point of reference for all the system stakeholders. However, the system is developed separately from the model, and its software components are implemented using a traditional software engineering approach.The paradigm-shifted next-generation MBSE comprises three components: (1) automated model-from-requirements construction, (2) model-as-operating-system, and (3) round-trip engineering. Constructing the model from textual requirements will be increasingly automated using language models based on deep-learning AI technology. The model shall serve not just as a reference for building the system-to-be as a separate entity. Rather, the intelligent, cyber part of the CPS shall materialize from the model through automatically generated low-code or no-code software. The resulting code-from-model shall serve as the driver, or "operating system" that controls the CPS, eliminating the need for manual coding of the CPS software. Finally, round-trip engineering shall ensure that any update to the model will be reflected in the software and vice-versa.While this disruptive approach to systems development and lifecycle management might seem like a "pie in the sky," using Object-Process Methodology that extends the current OPM ISO 19450:2015 and capitalizing on recent advances in generative language models, proofs of concept for the three components of next-generation MBSE already exist at different stages of maturity. They demonstrate that this paradigm is not a distant dream but a viable approach that our community should vigorously explore if systems engineering is to remain relevant and ready to tackle the expectations and complexities of next-generation systems.

INCOSE Content#423

Proposing an MBSE Minimal Viable Product for Missions of all Risk Levels

Regan Bullister (LMCO) - regan.bullister@lmco.com

Presented on: Thursday, 11:40-12:00 HST (KALAKUA BALLROOM C)

Topics. MBSE Lightning round

Abstract. The aerospace industry has had a noticeable shift in the past ten years. Large space programs such as Hubble, Apollo, and the International Space Station, inspired this generation's engineers, but now industry has swayed in favor of fast, cheap, and easy. The commercialization of launch services has allowed for several small spacecraft to enter orbit for the same (or cheaper) cost than one large and exquisite spacecraft, thus driving innovations like SpaceX's Starlink constellation. In response to this shift, the Aerospace Corporation released its Mission Risk Posture Assessment Process Description (ATR-2015-03151), which is now considered the gold standard for mission assurance in the aerospace industry. This framework very cleverly outlines expectations in 50 "technical focus areas", such as requirements definition, electrical design, and command & data handling for each of the four classes of missions. These mission classes are defined as A, B, C, and D, where Class A is considered an ultra-critical, high-cost mission, such as GPS or GOES weather satellites, and Class D is considered least critical, low cost, possibly R&D or experimental spacecraft. In other industries, a Class A program may be considered a high TRL, high profit product, while a Class D program may be considered a prototype. The framework has been a fantastic tool for ensuring spacecraft are engineered to an appropriate level of maturity, but there is one noticeable flaw: there is no standard for Model Based Systems Engineering.Clearly this is a problem. Many companies have tried to compensate by creating a blanket Digital Program Policy, but we believe a one size fits all MBSE or Digital Engineering policy does more to hurt small Class C/D programs than help them. Class C/D programs don't need the same level of model traceability and fidelity as Class A/B programs, and they typically don't have the headcount of engineering staff to support it. In this presentation, we will be proposing an MBSE Minimal Viable Product for each of the mission risk levels. This framework will outline required content and the engineering required to create that content. The model content will be more complete for a Class A/B program than a Class C/D program.

INCOSE Content#418

Put an end to my MBSE frustration. Please

Kyle Hall (Airbus) - kyle.hall@airbus.com

Presented on: Thursday, 10:00-10:20 HST (KALAKUA BALLROOM C)

Topics. MBSE Lightning round

Abstract. Engineering companies working on complex products don’t have the tools to effectively manage studies across organisations and domains; we are losing valuable knowledge and wasting money and time.I have been a systems engineer for close to 30 years. I have found huge frustration in watching highly trained engineers painstakingly collecting data inputs from multiple sources for input into their methods and completely failing to record them. Or their methods. Or indeed very much at all to provide any context for what they were doing.It doesn’t have to be like that.MoSSEC stands for Modelling and Simulation information in a collaborative Systems Engineering Context.In 2021 the MoSSEC project became ISO 10303-243, an approved part of the ISO 10303 STEP engineering standards family. Problem solved!

INCOSE Content#416

Smart Cities – Middle East-Asia (MEA)-based systems thinking in Smart Cities

Frank Sheehan

Presented on: Tuesday, 06:10-07:10 HST (Virtual)

INCOSE Content#415

Smart Cities – US-based systems thinking in Smart Cities

Sarah Fustine (Pioneer Partners)
Herb Sih (Pioneer Partners)

Presented on: Tuesday, 05:00-06:00 HST (Virtual)

INCOSE Content#422

Strategies to Accelerate MBSE Adoption in SE Practices: Results of the Systems Engineering - Modernization Study

Tom McDermott (Stevens University) - tamcdermott42@gmail.com

Presented on: Thursday, 11:20-11:40 HST (KALAKUA BALLROOM C)

Topics. MBSE Lightning round

Abstract. According to the United States Undersecretary of Defense for Research and Engineering (OUSD R&E), “Digital engineering is an integrated digital approach using authoritative sources of system data and models as a continuum throughout the development and life of a system. Digital engineering updates traditional systems engineering practices to take advantage of computational technology, modeling, analytics, and data sciences.” From the very beginning, there was a recognition of the impact Digital Engineering (DE) will have on Systems Engineering (SE). For the past two years, the Systems Engineering Research Center (SERC) and OUSD R&E have conducted research into the causal factors that are delaying the full implementation of DE into DOD SE practices and workflows. The research team conducted three formal workshops including an INCOSE Strategy Session with government, industry and academia to gain insights. In addition, the team had a number of individual discussions with experts and program offices led by the sponsor. These activities generated a number of statements that informed a more comprehensive set of SE Modernization pain points from various participant and ongoing implementation strategies maturing at the program and Service level. The resulting integration framework organizes these into an Ishikawa (fishbone) diagram. The goal of the Systems Engineering Modernization effort is to build “Seamless and efficient digital flows from data to decision artifacts and from decision artifacts back to data.” The pain points led to development of a set of roadmaps for SE Modernization in the DoD engineering and acquisition processes. These roadmaps have been generalized to the larger SE community and will be presented in this talk, including ontologies and semantic integration for pervasive data and model driven program management and engineering process integration, improved collaboration around digital artifacts, reference implementations and common patterns for DE ecosystems, managing a fully digital and agile SE lifecycle, and building workforce and culture. The presentation will summarize these roadmaps and offer insight on how digital SE might drive the future of SE.

INCOSE Content#410

Systems Thinking 101

Stuart Burge (Burge Hughes Walsh Limited) - SBurge@burgehugheswalsh.co.uk

Presented on: Monday, 02:00-02:40 HST (Virtual)

Keywords. Systems Thinking

Topics. SE fundamentals;

Abstract. Systems Thinking is the foundation of Systems Engineering. Being a good systems engineer is predicated on the ability to “systems think”. Most humans, however, are not natural systems thinkers. Our brains are wired to make us object-oriented, an evolutionary necessity. Consequently, we categorize and organize things according to what they are rather than what they do. In contrast, Systems Thinking is a world of purpose, context, interconnectivity and behavior. It asks, “what is to be done?” rather than “how it is done?”. We must work hard to use Systems Thinking, but the benefits can be outstanding – it’s a different way of viewing the world. This does not mean we cannot do “Systems Thinking”, but it is a skill we must acquire through understanding and practice. This session aims to give a brief glimpse of what we have to do to become systems thinkers.

Biography

Stuart Burge (Burge Hughes Walsh Limited) - SBurge@burgehugheswalsh.co.uk

Dr Stuart Burge owns Burge Hughes Walsh Limited (BHW), an established training and consultancy since 2000. His area of expertise is Systems Thinking and Systems Engineering. He has worked with many companies delivering Systems Engineering and Systems Thinking training and providing project support to live design teams. BHW’s client base is now over 100 companies and organizations. These include defense companies like BAE Systems, Rolls-Royce, MBDA, [dstl], QinetiQ, Northrop Grumman, General Dynamics and ST Kinetics. There is a growing customer base in the automotive industry with Cooper Rubber, Visteon, Ricardo, Jaguar-Land Rover and Dyson, and in the energy/power market with GE Oil & Gas, Baker Hughes, Vestas, Petronas and LG. In recent years we have become the preferred supplier of training and deployment support in the medical devices industry to Abbott, Blatchford, Waters Corporation, BD, Elekta and Renishaw. BHW supports several start-up companies, including Vertical Aerospace, Aero Gearbox International, Electroflight, Hanwha-Phasor and Ultaleap.

INCOSE Content#406

Tales of Tails, Cobras, Cats and Models

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

Presented on: Monday, 10:00-10:40 HST (316C)

Keywords. Systems Thinking

Topics. SE fundamentals;

Abstract. "Systems Engineering is a transdisciplinary and integrative approach to enable the successful realization, use, and retirement of engineered systems, using systems principles and concepts, and scientific, technological, and management methods" (INCOSE). This introductory presentation, broadly structured into three parts, will focus on some of these “systems principles and concepts” that underpin the understanding of systems and the engineering of systems, enabling the efficient and effective transformation of complex concepts into safe, secure, and sustainable capabilities. Part 1 is a motivational introduction on the importance (“why”) of systems thinking through a series of real-life systems stories and of systems archetypes. Part 2 shifts focus onto “what” is systems thinking, leveraging the Iceberg metaphor as a system thinking tool, and highlighting two key questions that systems engineers seek to answer (“did we build the system right?”, and “did we build the right system?”). Part 3 elaborates on the “how” of systems thinking from two key perspectives – outlining a “systems framework” model for how we may better understand a system, and a “systems process” model on how systems engineers enable the understanding and transformation of complex concepts into tangible, safe, secure, and sustainable capabilities.

Biography

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

JB is a passionate Systems professional and current president of INCOSE's Australian chapter (SESA). He contributes to the advancement of Systems Thinking, Systems Engineering and Modelling & Simulation locally, regionally, and globally. He has a BE (Aerospace Engineering), a BSc (Computer Science), a Master’s in Systems Engineering and is a current PhD candidate working on the systems engineering and assurance of AI-Intensive systems. He is a past member of the Board of Simulation Australasia and was recognised in 2021 as the recipient of the “Ray Page Lifetime Achievement Award” for an outstanding contribution to the advancement of Modelling and Simulation.

TBD title

Olivier 'Oli' de Weck (Massachusetts Institute of Technology (MIT)) - deweck@mit.edu

Presented on: Monday, 14:15-14:55 HST (316C)

Keywords. Systems of Systems

Topics. SE fundamentals;

Biography

Olivier 'Oli' de Weck (Massachusetts Institute of Technology (MIT)) - deweck@mit.edu

Olivier de Weck is the Apollo Program Professor of Astronautics and Engineering Systems at the Massachusetts Institute of Technology (MIT). He earned degrees in Industrial Engineering from ETH Zurich (dipl. Ing. ‘93) and Aerospace Systems from MIT (SM ’99, PhD ’01) where he is the faculty director of the Engineering Systems Laboratory (http://systems.mit.edu) His main research is in Systems Engineering with a focus on how complex technological systems are designed and optimized and how they evolve over time. He has authored or co-authored over 400 publications for which he has been recognized with twelve best paper awards since 2004. He is a Fellow of INCOSE and AIAA and served as Editor-in-Chief for the journal Systems Engineering from 2013-2018. He is a former Senior Vice President of Technology Planning and Roadmapping at Airbus where he was responsible for roadmapping a $1-billion R&D portfolio for the world’s largest aircraft manufacturer. His most recent book on Technology Roadmapping and Development was published by Springer-Nature in 2022. His passion is to improve life on our home planet Earth through research and education in design and systems engineering, while paving the way for humanity’s future off-world settlements.

INCOSE Content#429

Tea, Pie, and Other Ingredients to Build Competency and Have a Successful Systems Engineering Career

Lori Zipes (US Navy, NSWC Crane) - lorizipes@gmail.com

Presented on: Monday, 15:30-16:10 HST (316C)

Keywords. SE Competencies giving early careers the bigger picture

Topics. SE fundamentals;

Abstract. How many Systems Engineers do you know? How similar are their jobs? As a “meta discipline” Systems Engineering competency requires an unusual mix of knowledge and skills. This presentation will first place SE in the context of traditional engineering disciplines. We will explain what is meant when SEs are described as having “T” shaped knowledge or “pi” shaped knowledge. Several references will be used to show how an SE can have roles that require a variety of competencies and discuss ways to build those competencies. We will describe how the domain and complexity of the systems of interest can affect the type and depth of knowledge needed to be a competent systems engineer. Finally, we will review some example positions you might encounter in your career and suggest ways to prepare yourself to take on those roles with confidence.

Biography

Lori Zipes (US Navy, NSWC Crane) - lorizipes@gmail.com

Ms. Lori Zipes is currently serving as Co-Chair of the INCOSE Competency Working Group as well as Assistant Director for Technical Information. An ESEP since 2016, she was a primary author on the INCOSE Systems Engineering Competency Framework published in 2018, and the Systems Engineering Competency Assessment Guide recently published by Wiley.
Educated at MIT, Ms. Zipes has a BS and MS in Ocean Engineering, as well as a second MS degree in Systems Engineering from the Naval Postgraduate School. Ms. Zipes is the Command Chief Engineer for Naval Surface Warfare Center Crane, a US Navy research and development base. Her current position is an enjoyable culmination of a 30+ year career as an engineer for the Navy, always striving to raise the bar on systems engineering knowledge and capabilities.

INCOSE Content#413

the Kickoff of the INCOSE IS2023 Hackaton

Presented on: Tuesday, 02:00-04:10 HST (Virtual)

Abstract. The workshops goal is to begin a new thread of activity in the Systems Engineering Community focusing on the next-generation use of technology and open practices in the world of Digital Engineering.The workshop will make use of the INCOSE SE Lab resources and the new INCOSE Virtual presence set ups.The goals of the first workshop will be to:understand the basics of collaborative systems engineeringUnderstand the basics of sharing models through innersource and opensource practicesUnderstand the communications of hybrid engineering workDraft Schedule of EventsDay 1 - July 18th - workshop introduction and kick offOverview of Virtual Collaboration CapabilitiesOverview of resources in SE Lab infrastructure and set upIncluding OpenMBEE provided resources for Open Source presentation by Saulius on building and sharing SysML ModelsDemo meeting - July 20th - folks demo their buildsRemote facilities available during the entire Symposium

INCOSE Content#424

The Pragmatic Requirements for Requirements

Hazel Woodcock (Costain) - Hazel.Woodcock@scsrailways.co.uk

Presented on: Monday, 02:45-03:25 HST (Virtual)

Keywords. Requirements

Topics. SE fundamentals;

Abstract. Have Agile and MBSE killed the need for requirements? What is a requirement? Where do they come from? What are they used for? … so many questions. In this presentation we will look at the pragmatic requirements for requirements, and answer some of those questions. This presentation will also summarise the language used in requirements management, the different types of requirement and why it matters. The purist, academic, approach is rarely the right thing for your project, but when you move away from 'best' practice, you still need to retain good practice. From capture, through validation, decomposition, allocation, implementation, and verification, pragmatism is key to delivering value to your project in all phases of requirements management.

Biography

Hazel Woodcock (Costain) - Hazel.Woodcock@scsrailways.co.uk

Hazel Woodcock is Head of Systems Engineering for HS2 London Tunnels Main Works Civils Programme and is Chief Systems Engineer for Costain. With over 30 years of Systems Engineering experience across multiple industries including having worked as a requirements engineer and then internationally as a Systems Engineering consultant, Hazel has seen requirements managed and mismanaged in many different ways. Hazel was the 13th ESEP certified in the UK and her application showed a significant portion of her time was spent on Requirements Engineering. Hazel currently holds a leadership role in a large infrastructure programme where she enjoys sharing her expertise as well as coaching and mentoring others in her team.

INCOSE Content#411

What is the Point of Requirements?

Tami Katz (INCOSE Requirements Working Group) - Tami.Katz@incose.net

Presented on: Monday, 10:45-11:25 HST (316C)

Keywords. Requirements

Topics. SE fundamentals;

Abstract. So much effort during system development is spent on generating and managing requirements. Why is this useful, and what is the point? Some systems engineers believe that "requirements are no longer necessary"; if so, what is the alternate approach? This presentation will address the fundamentals of what requirements are, what they are not, and the value they can provide to a system when implemented properly. The presenter will highlight where requirements come from, different methods of communication and enforcement, and introduce the concepts of needs, verification and validation in association with system requirements.

Biography

Tami Katz (INCOSE Requirements Working Group) - Tami.Katz@incose.net

Dr. Tami Katz is a Staff Consultant at Ball Aerospace, located in Colorado, USA. Dr. Katz is certified as an International Council on Systems Engineering (INCOSE) Expert Systems Engineering Professional (ESEP) and has a Doctorate of Philosophy in Systems Engineering from Colorado State University.
Dr. Katz is active in the INCOSE community, serving as the chair of the INCOSE Requirements Working Group and Assistant Director of Technical Operations for Process Enablers.
During her career, Dr. Katz has worked in systems and test engineering of space vehicles, performing a range of activities from design, requirements development, verification, validation, test, and technical leadership. Over the last several years, Dr. Katz has performed extensive research into techniques towards optimizing the requirements management process, publishing multiple papers, and is a contributing author of the INCOSE Needs and Requirements Manual.