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Keynote - Plenary

Keynote - Plenary#2

Biomimicry - A Bioinspired approach to Systems Thinking

Prashant Dhawan (Co-Founder, Biomimicry India)

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Presented on: Tuesday, 08:00-09:25 in Grand Cypress Ballroom DEF

Keywords. keynote

Abstract. The systems that exist in living nature have evolved over a period of 3.8 billion years under operating conditions, limits and boundaries that apply to all that exists on our planet including the human species. If we look at nature's systems, for example an ancient forest, we find there is zero waste, zero pollution and nothing akin to a crisis of 'unemployment' in the billions of plant and animal species. At the current time, humanity is grappling with problems of pollution, waste, endemic poverty, unemployment and an impending ecological disaster. It appears that these are unintended consequences and indicators that the human systems are far from perfect and misaligned to the ecological health of the planet. Evidence from living nature suggests that systems in nature are among the most time tested solutions that we can learn from and have a lot to offer in terms of ideas that can change our world for the better. But how do we translate the systems and processes that work so well in living nature into usable solutions for our problems? Can and should everything in nature be mimicked? And that is where biomimicry comes into the picture. The talk introduces 'Biomimicry' - a multidisciplinary and systems based approach, that helps us look at nature, not just as a source of raw materials, but as a source of ideas and solutions/advanced technologies. Biomimicry has now made available a formal structure and methodology to learn from nature. Biomimicry is relevant and applicable across sectors and at various scales, whether it be learning from additive zero waste manufacturing in nature, selforganisation, self-healing, self-assembly to urban scale systems/smart cities that mimic forest ecosystems. The talk will also include a few examples and case studies of biomimicry based projects and design explorations from the workshops conducted by the speaker (in India).

Biography

Prashant Dhawan (Co-Founder, Biomimicry India)

Prashant Dhawan is the Co-founder of the Biomimicry India Network. He holds a degree in MS (Master of Science) in Biomimicry from the Arizona State University, U.S.A and Biomimicry Professional Certification from Biomimicry 3.8, USA. He also holds a degree in Architecture from SPA Delhi, and an MBA from ISB Hyderabad. Prashant has conducted Biomimicry workshops and talks in various forums and educational institutes which include IIT Gandhinagar, Centre for Environmental Planning and Technology University (CEPT University in Ahmadabad), NIT (Trichy), NID (Bangalore, Vijayawada & Kurukshetra), NIFT (Hyderabad & Delhi), Ahmedabad University, RVCA, BMSCE, BMSIT and Shristi school of Art, Design and Technology (Bangalore) amongst others. He has also conducted Biomimicry workshops for corporates and these include a full day workshop for senior executives of Mahindra & Mahindra (Mumbai) and Axis Bank. Prashant prefers to call himself an amateur researcher of issues related to sustainable happiness.

Interdisciplinary Systems Engineering inspired by da Vinci

Dr Wanda Austin (President, University of Southern California)

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Presented on: Monday, 08:00-09:25 in Grand Cypress Ballroom DEF

Keywords. keynote

Abstract. Throughout history, humans have always had a desire to use technology to extend their reach, solve problems and explore the universe. As systems engineers we accomplish impossible tasks that are helping to solve the most complex global problems including leadership.

Biography

Dr Wanda Austin (President, University of Southern California)

Dr. Austin is the former president and chief executive officer of The Aerospace Corporation, a leading architect for the nation's national security space programs. The Aerospace Corporation has nearly 4,000 employees and annual revenues of more than \$850 million. She assumed this position on January 1, 2008 and retired from this position 2016. She is internationally recognized for her work in satellite and payload system acquisition, systems engineering, and system simulation. Austin served on President Obama's Review of Human Spaceflight Plans Committee in 2009, and in 2010 was appointed to the Defense Science Board. Austin is a fellow of the AIAA, and is a member of the Defense Science Board, the National Academy of Engineering, the International Academy of Astronautics, and the American Academy of Arts and Sciences. She also serves on the Board of Directors of the Space Foundation, and on the Board of Trustees for the University of Southern California and the National Geographic Society. Among her numerous awards and citations, are the National Intelligence Medallion for Meritorious Service, the Air Force Scroll of Achievement, and the National Reconnaissance Office Gold Medal. In 2010 she received the AIAA von Braun Award for Excellence in Space Program Management, and is a recipient of the 2012 Horatio Alger Award and the 2012 NDIA Peter B. Teets Industry Award. Austin is committed to inspiring the next generation to study the STEM disciplines and to make science and engineering preferred career choices. Under her guidance, the corporation has undertaken a number of initiatives in support of this goal, including participation in MathCounts, US FIRST Robotics, and Change the Equation. Austin was among the first CEOs to commit to Change the Equation.

The Underway Global Unmanned Systems and Robotics Revolution

Grant Begley (CEO, Rocket Crafters)

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Presented on: Thursday, 13:30-14:55 in Grand Cypress Ballroom DEF

Keywords. keynote

Abstract. Grant will revisit and update his 2014 INCOSE keynote and associated forecasts. During Grant's 2014 INCOSE keynote, he forecast that unmanned systems and robotics will become ubiquitous to our everyday lives. He asserted to INCOSE participants their professional opportunity and responsibility to significantly contribute to the underway global unmanned systems and robotics revolution. Unmanned systems and robotics are rapidly expanding across ground, maritime, airborne and space systems providing a superb opportunity for systems engineers to provide a better world through a systems approach. Systems Engineers contributions, implemented responsibly and ethically, will provide new capabilities at a systems level for the benefit of humankind.

Biography

Grant Begley (CEO, Rocket Crafters)

Grant Begley is an aerospace, unmanned systems and robotics leader, manager and consultant enabling next generation capabilities. An accomplished initiator, developer and implementer of strategic planning, change management, and resource development to achieve compelling products, dramatic future capabilities and enterprise successes. Mr. Begley is a public speaker, author and moderator and participant of expert panels, on the Global Robotics Revolution. Mr. Begley was Corporate Senior Vice President for Alion Science and Technology, developing and implementing the \$1B annual revenue Business Development Enterprise, including unmanned systems, ahead of schedule. Prior to Alion, Mr. Begley served as Pentagon Senior Advisor to the Office of the Under Secretary of Defense, for Unmanned Systems, advising on critical issues and leading development of DoD's 2011 Unmanned Systems Roadmap. Mr. Begley's career includes Defense Industry leadership positions for the development of advanced capabilities with Raytheon and Lockheed Martin where he initiated and led cross-corporation unmanned systems and robotics successes. Mr. Begley served in the United States Navy for 26 years, to include operational assignments flying fighter aircraft, designated Top Gun, followed by acquisition assignments for the development and management of next generation manned and unmanned aircraft systems, weapon systems and joint executive acquisition assignments. Mr. Begley holds master's degrees in Aerospace and Aeronautic Engineering from the Naval Post-Graduate School and a bachelor's degree in General Engineering from the U.S. Naval Academy.

To the Stars. The Sky Is No Longer the Limit

Capt. Winston Scott (Director, Environmental, Tectonics Corporation)

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Presented on: Wednesday, 08:00-09:25 in Grand Cypress Ballroom DEF

Keywords. keynote

Abstract. Winston Scott's journey to the stars as a NASA astronaut is a testament to the power of perseverance and vision. Raised in Miami, Scott's largely segregated education provided little access to resources but his own determination, combined with the dedication of his family and his teachers, set him on an inspiring path of achievement. Scott's work in space is now regarded as a case study in leadership and expert communications, qualities most clearly exhibited in the much-publicized manual capture of the Spartan satellite in the 1997 Columbia mission. Join Scott as he thrills the audience with expert descriptions and actual footage of his experiences in space. Join him as he takes the audience to the stars!

Biography

Capt. Winston Scott (Director, Environmental, Tectonics Corporation)

Mr. Scott is a retired U. S. Navy Captain and former NASA Astronaut and currently serves as Dean of the College of Aeronautics of the Florida Institute of Technology. His professional experience includes significant industry and academic positions as well as a 27-year career in the U. S. Navy. During his Navy career, Mr. Scott accumulated more than 5,000 hours of flight time in 20 different military and civilian aircraft and more than 200 shipboard landings. Mr. Scott was selected by NASA for their Astronaut program in March 1992. He served on two space shuttle missions, logging more than 24 days in space including three spacewalks totaling over 19 hours. Mr. Scott's civilian experience includes serving as the Vice President for Student Affairs for Florida State University, an Associate Dean and Adjunct Instructor position at FSU College of Engineering, Executive Director of the Florida Space Authority, and as Vice President and Deputy General Manager of the engineering and science contract group for Jacobs Engineering in Houston, Texas. Mr. Scott holds a B.A. in Music from Florida State University, a M.S. in aeronautical engineering from the U.S. Naval Postgraduate School, and honorary doctorates from Florida Atlantic University and Michigan State University. Mr. Scott belongs to the American Institute of Aeronautics & Astronautics, Aircraft Owners and Pilots Association, Experimental Aircraft Association, and Bronze Eagles Association of Texas. Since 2003, Mr. Scott has served as a director of Gulf Power Company, a subsidiary of The Southern Company, a public company which is traded on NYSE. Mr. Scott also serves as a Director for a non-profit entity (the Astronaut Memorial Fund).

Paper

Paper#23

12 principles for SE leaders

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Presented on: Wednesday, 10:00-10:40 in Grand Cypress Ballroom GH

Keywords. Systems Engineering;Leadership;#Management;Enterprise;Capability;Cynefin;Obeng;Culture

Abstract. Successful Systems Engineering (SE) leadership requires the fusion of systems engineering and leadership. This paper explores some of the practical elements of building a systems engineering team.

This paper describes the lessons from the authors real world experience in: making the case for SE, selecting the right approach to deliver SE, selecting and aligning SE processes to the wider business, establishing the right culture and growing an effective SE team.

Finally we have identified key 12 key principles to follow when building an effective SE Capability.

Paper#113

A Concept for Set-based Design of Verification Strategies

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Presented on: Tuesday, 10:45-11:25 in Grand Cypress Ballroom A

Keywords. verification;set-based design;acquisition;contracting

Abstract. In current practice, a verification strategy is defined at the beginning of an acquisition program and is agreed upon by customer and contractor at contract signature. Hence, the resources necessary to execute verification activities at various stages of the system development are allocated and committed at the beginning, when a small amount of knowledge about the system is available. However, contractually committing to a fixed verification strategy at the beginning of an acquisition program fundamentally leads to suboptimal acquisition performance. Essentially, the uncertain nature of system development will make verification activities that were not previously planned necessary, and will make some of the planned ones unnecessary. In order to cope with these challenges, this paper presents an approach to apply set-based design to the design of verification activities to enable the execution of dynamic contracts for verification strategies, ultimately resulting in more valuable verification strategies than current practice.

Paper#100

A Model-Based V&V Test Strategy Based on Emerging System Modeling Techniques

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Presented on: Wednesday, 16:15-16:55 in Grand Cypress Ballroom I

Keywords. Model-Based Systems Engineering;MBSE;SysML;RFLP;System Modeling;Verification & Validation;Automated Testing

Abstract. This paper describes a two-stage, model-based verification and validation (V&V) approach to capturing technical baselines and managing engineering changes for systems by leveraging SysML-based system modeling techniques, standard-based execution and simulation environment, and by establishing RFLP-T architecture traceability. With application on a real project – Virtual Factory™ – this paper demonstrates how to apply model-based testing to requirement and functionality verification early in the design phase by using standard-based model execution and how to develop automated system testing by reusing and expanding the test cases to interface with external and manual-based test procedures during the final system test phase.

A practical study on how proactive quality approach can improve system development process to ensure system-effectiveness and -performance

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Presented on: Tuesday, 16:15-16:55 in Grand Cypress Ballroom A

Keywords. Quality;proactive quality approach;Quality Management;Systems engineering;Water treatment;case study

Abstract. This paper investigates how a proactive quality approach can aid in improving the systems development process for a young company in the water cleaning industry. The paper conducts a case study on an existing water cleaning system that has gone through this process to investigate the possible effects of an improved system development process. Additional data complement the gap analysis such as survey in the company, analysis of time sheets, water samples from the system, customer- and employee-interviews, work sessions with employees and observations. Our results show that the company lacks emphasis on activities related to systems engineering. We observed that forty-nine percent of hours spent in the operational life of the case system related to non-conformances of customer requirements. In conclusion, a proactive quality approach, with focus on the familiar tools that are easy to implement, could reduce non-conformances in system operations and improve system performance.

A Roadmap for Advancing the State of the Practice of Model Based Systems Engineering for Government Acquisition

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Presented on: Wednesday, 13:30-14:10 in Grand Cypress Ballroom I

Keywords. MBSE;Model Base Systems Engineering;Government Acquisition

Abstract. Model-Based Systems Engineering (MBSE) is an emerging paradigm for improving the practice of systems engineering, in which integrated sets of digital system models serve as the focal point for knowledge management, technical communication, and data interchange. Adoption of MBSE by Government prime contractors has grown significantly, often motivated by the drive for improved efficiency from the commercial elements of their businesses. Interest in adopting MBSE on the Government side of that interface has also grown, motivated not only by desire for improved efficiency but also by the need for a better approach for managing the complexity of those Government mission enterprises. This roadmap was created as an initial attempt at establishing a shared vision to drive discussions among the Government acquisition community—and the associated community of supporting contractors—to drive investment and collaboration to improve the state of the practice of MBSE within this community.

A strategic asset planning decision analysis: An integrated system dynamics and multi-criteria decision-making method

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Presented on: Wednesday, 15:30-16:10 in Grand Cypress Ballroom B

Keywords. system dynamics; multicriteria decision making; multicriteria decision analysis; mixed methods; asset planning; asset management

Abstract. Asset planning is complex and dynamic, where the decision maker is often faced with the challenge of making decisions now about dynamic aspects. This paper is a part of an ongoing study to develop decision-support methods and tools to support asset planning. This paper's objective is to demonstrate an integrated approach for combining System Dynamics (SD) and Multi-criteria Decision Making (MCDM). To support our design approach, we use a multi-method design framework, from the wider Operations Research/Management Science (OR/MS) literature, as a theoretical lens to synthesize literature. To apply and test our approach, we use as a test case the classic asset replacement problem from the asset management literature. The test case is applied in a real-life decision support project for fleet planning in a military organization. Our results showcase the value of using SD methods and MCDM, both independently and integrated, to support asset planning.

Paper#21

A Subjective Toolbox for Sociotechnical Systems

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Presented on: Tuesday, 10:45-11:25 in Grand Cypress Ballroom I

Keywords. Sociotechnical systems;Integral theory;Subjective toolbox;Design thinking;Culture;Empathy;Heuristics;Storytelling;Beauty;Judgment

Abstract. One of the recent developments in systems engineering has been to expand its focus to sociotechnical systems. New disciplines and new frameworks have been proposed in response to this expansion. For example, Soft Systems Methodology was developed as a way to apply systems engineering approaches to solve softer management and business problems. In addition, the Engineering Systems movement set a research agenda to focus on complex sociotechnical systems, including the nontraditional system lifecycle properties (i.e. the “ilities”), sociotechnical complexity, and system architecture. In this paper, it is argued that these new disciplines and frameworks will have a limited impact because they have a limited viewpoint: they only make use of objective perspectives. It is proposed that an Integral approach, which makes use of both subjective and objective perspectives, can have a greater impact on the discipline of systems engineering in the development of sociotechnical systems.

Paper#17

A System Dynamics Model for Systems Security Engineering Analysis of Internet Service Provider Customer Modem Cyber Defense

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Presented on: Wednesday, 16:15-16:55 in Grand Cypress Ballroom B

Keywords. Modem Cyberdefense;Internet Service Provider;System Dynamics;System Security Engineering

Abstract. Internet service providers (ISPs) seek to increase revenue by reducing costs and increasing subscriptions. We take a systems security engineering (SSE) approach to compare different ways of enhancing customer modem cybersecurity, using a system dynamics (SD) model to show the impact of different solutions for improving customer modem bandwidth. The model is extensible and modifiable to test other stakeholder goals. We demonstrate this by modelling customer goodwill and solution cost. When used as a tool for planning system changes, the model can be compared to the live system before and during incremental system changes. This helps improve model validity, control risk, evaluate return on investment, and provide a platform for testing proposed system changes. Any business with similar cyber vulnerability concerns can benefit from using this system engineering approach.

A3 architecture views – A Project Management tool?

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Keywords. A3 Architecture Overviews;interdisciplinary knowledge sharing;development project;project management;autonomous system;subsea inspection;oil and gas;early systems life cycle;new technology;communication;conceptual architecture

Abstract. This paper explores the benefits of using A3 Architecture Overviews (A3AO) as a tool for project management and interdisciplinary knowledge sharing in a development project. The goal of the development project was to create an autonomous subsea inspection systems for the oil and gas industry. Sharing of implicit system knowledge early in the systems life cycle is a challenge, yet important for successful development of new technology. Through expert interviews and reverse architecting we made A3AO for two new system that were sequential steps into a fully autonomous solution. Through the research we applied these overviews in meetings with HSEQ, finance, senior management, and engineering. The immediate responses were positive, with comments like, "now I understand what we are trying to achieve", and "Can I please include the A3AO in my document for the management?" Project personnel, with limited system knowledge, quickly got an enhanced understanding of the project goals by viewing the A3AO. We also experienced that senior management used the illustrative tool as a supplement to support a business case for the board of directors. Clients were happy to see models and schematics as a supplement to textual documents when being presented with new technology. Inclusion of industry terminology and support from management would enhance adoption of A3AO within the oil and gas industry. Overall, our research strongly supports the use of A3 Architectural Overviews as a project management tool when developing new complex systems.

A3 architecture views – A Project Management tool?

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Presented on: Thursday, 11:30-12:10 in Grand Cypress Ballroom DEF

Keywords. A3 Architecture Overviews;interdisciplinary knowledge sharing;development project;project management;autonomous system;subsea inspection;oil and gas;early systems life cycle;new technology;communication;conceptual architecture

Abstract. This paper explores the benefits of using A3 Architecture Overviews (A3AO) as a tool for project management and interdisciplinary knowledge sharing in a development project. The goal of the development project was to create an autonomous subsea inspection systems for the oil and gas industry. Sharing of implicit system knowledge early in the systems life cycle is a challenge, yet important for successful development of new technology. Through expert interviews and reverse architecting we made A3AO for two new system that were sequential steps into a fully autonomous solution. Through the research we applied these overviews in meetings with HSEQ, finance, senior management, and engineering. The immediate responses were positive, with comments like, “now I understand what we are trying to achieve”, and “Can I please include the A3AO in my document for the management?” Project personnel, with limited system knowledge, quickly got an enhanced understanding of the project goals by viewing the A3AO. We also experienced that senior management used the illustrative tool as a supplement to support a business case for the board of directors. Clients were happy to see models and schematics as a supplement to textual documents when being presented with new technology. Inclusion of industry terminology and support from management would enhance adoption of A3AO within the oil and gas industry. Overall, our research strongly supports the use of A3 Architectural Overviews as a project management tool when developing new complex systems.

Paper#35

Addressing Uncertain Requirements

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Keywords. requirements;instability;project management;agile

Abstract. Project requirements change over time and are often uncertainty. Simulation studies have shown that the value of recognizing an uncertainty (versus ignoring it) can sometimes be comparable to the value of eliminating the uncertainty. This paper focus on enabling systems engineering managers to recognize requirement uncertainty using established methods. Our key result is an equivalence between a project with uncertain requirements and an augmented project with fixed requirements where the augmented project implicitly incorporates the uncertainty in the requirements into uncertainty in the activities intended to meet those requirements. This paper closes with discussions of applications of this augmentation method.

Paper#76

Agile Systems Engineering Life Cycle Model for Mixed Discipline Engineering

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Presented on: Monday, 10:00-10:40 in Grand Cypress Ballroom B

Keywords. Agile Systems Engineering;Agile Systems Engineering Life Cycle Model;Information Debt;Response requirements;ASELCM

Abstract. This article focuses on six recent understandings that have crystalized from INCOSE's Agile Systems Engineering Life Cycle Model (ASELCM) discovery project. The ASELCM project analyzed effective agile systems engineering processes in 3-day structured analysis workshops hosted by organizations that wanted deeper understandings of what works, why it works, and how to apply those understandings across a broader base. Four case studies arising from these workshops have been published. This article cannot cover everything of interest that was discovered, but will expose six key findings: a problem-space characterization heuristic, an asynchronous/concurrent life cycle model framework, a set of nine systems engineering operating principles, an encompassing pattern of three concurrent behavioral systems operating simultaneously in agile systems engineering, the concept of information debt, and general agile systems engineering response requirements.

Paper#7

Alternatives for Managing Atmospheric Warming

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Presented on: Thursday, 10:00-10:40 in Grand Cypress Ballroom DEF

Keywords. Global Warming;Trade studies;Architecture;Electricity generation;Solar power

Abstract. The current discussion regarding global warming (or “climate change”) centers on managing the contribution of carbon dioxide (CO₂) to incremental warming due to enhanced absorption of infrared radiation. If we are concerned about the warming, what is most important is the atmospheric heating regardless of cause. The incremental effect of CO₂ may enhance this, but it is not the dominant mechanism of atmospheric warming, which is solar irradiance and the net absorption compared with reflection. This paper analyzes the large energy flows from the sun, human-generated heat and CO₂ emissions, several alternative energy conversion and generation strategies, and the resulting contributions to atmospheric heating. It is shown that increasing terrestrial albedo can offset the effects of fossil fuel combustion on both direct heating and incremental heating from CO₂ emissions, and represents a viable alternative to replacing fossil-fuel combustion with solar power.

Paper#30

An A3AOs Method of Software Tools Integration in the Complex System Development

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Presented on: Thursday, 10:45-11:25 in Grand Cypress Ballroom GH

Keywords. Software tools;System development process;Complex systems;A3 Architectural Overviews

Abstract. Companies to-date commonly face cost pressures due to increasing market competitions. Software tools in this regard has become more and more popular during the complex systems development. However, the lack of a proper system development process integrating the usage software tools will hinder the efficiency of a company's project. This is especially visible in how different each engineer use software tools. Therefore, this research focuses on optimizing the system development process by integrating software tools in the context of complex system. We proposed an architecture of new system development processes using A3 Architectural Overviews (A3AOs) as a solution. Based on a real-life case study and quick-prototyping, the architecture evolves into in an optimized system development process that increases efficiency, quality and consistency in the case company projects.

An Approach for Formal Verification of Machine Learning based Complex Systems

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Presented on: Wednesday, 10:45-11:25 in Grand Cypress Ballroom DEF

Keywords. Complex Systems; Emergent Behavior; Machine Learning; Formal Verification

Abstract. A complex system is characterized by emergence of global properties which are very difficult to anticipate just from a complete knowledge of component behaviors. Emergence and numerosity are some of the characteristics of complex systems. With the recent trend towards increasing footprint of complex system's functionality being governed by machine learning based models, there is a need to ensure that emergent behaviors are well analyzed. Traditional verification and validation approaches are often inadequate to bring in the nuances of potential emergent behavior, which may be positive or negative. This paper describes a novel approach towards application of formal methods for analyzing and evaluating emergent behavior of complex systems that are governed by machine learning models. The proposed approach involves developing a machine learning classifier model that learns on potential negative and positive emergent behaviors, and leveraging the classifier in a formal verification model checking environment to assert negative emergent behavior.

An Evaluation Ontology Applied to Connected Vehicle Security Assurance

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Keywords. MBSE;model-based systems engineering;cybersecurity;ontology;evaluation;automotive;standard

Abstract. Connected vehicles have great potential to benefit society, yet create huge challenges. Vehicles, infrastructure and enterprise activities combine to form massively complex systems of systems (SoSs) that are vulnerable to cyber-attacks. Security is ill-defined, making it difficult to achieve a consistent, common understanding of security capabilities across the diverse industries that collaborate to develop connected vehicles. Rigorous evaluation is essential for developing strong security assurance cases. This paper contributes a model-based systems engineering (MBSE) ontology that enables integrated evaluation processes in enterprise SoSs. The Evaluation Ontology allows diverse types of evaluation to be captured in a single integrated model. A connected vehicle security story is presented to demonstrate the value of the approach. Benefits include enhanced business intelligence that can provide a quantifiable, reportable level of confidence in security-related processes and technologies. Further work will extend the ontology to develop a customisable suite of enabling patterns for security.

An SSM-TRIZ Methodology for Business Problem Structuring

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Keywords. Soft Systems Methodology;TRIZ;Contradictions;Professional Development

Abstract. Checkland developed Soft Systems Methodology (SSM) to tackle problem situations from a systems perspective; however, SSM needs to be extended with other methods to find superior solutions that overcome the need for a compromise or trade-off between conflicting or contradictory elements. This paper extends Checkland's SSM approach to resolve problems with conflicting or contradictory elements. This work integrates the powerful benefits of TRIZ-based analysis into SSM and provides a means for systemic resolution of business problems with conflicting sub-system elements. This paper acknowledges that soft problems can have conflicting relationship among their elements, compares the strengths and weaknesses of SSM and TRIZ in problem structuring, and presents a collaborative SSM-TRIZ approach for problem structuring. Finally, this paper applies the joint methodology to examine the business problem of developing a Professional Development platform for INCOSE.

Applying and analyzing A3 Architecture Overviews in a complex and dynamic engineering environment

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Presented on: Thursday, 10:45-11:25 in Grand Cypress Ballroom DEF

Keywords. Architecture Overview;E/E architecture;A3AO

Abstract. This research analyzes the implementation of the A3 Architecture Overview (A3AO) method at Mercedes-Benz R&D. An A3AO captures, organizes and presents architectural information of a complex system on an A3 sized paper. The goal is to communicate architectural knowledge in a human-oriented way, assuring all stakeholders obtain and maintain a common understanding and overview of the system.

The A3AO method was applied to 'high-voltage charging systems'. Two higher-level A3AOs and three A3AOs on more in-depth topics were created. The charging system is considered to be representative for the engineering environment of Mercedes-Benz R&D. General results showed that the A3AO method is useful in documenting and communicating architectural knowledge of a system. It furthermore produces good overviews of a complex system, which can be used in discussions and to train new employees.

The two main impact factors ensuring sufficient added value are the format and the integration in the development process

Paper#64

Applying Feature-Based Systems and Software Product Line Engineering in Unclassified and Classified Environments

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Keywords. Product Line Engineering; PLE Factory; Unclassified and classified environments

Abstract. Global aerospace and defense companies are reaping the benefits of feature-based systems and software product line engineering and management (FBPLE) (Gregg et al. 2014) (Gregg et al. 2015) (Krueger et al. 2014) (Lanman et al. 2011) in those situations where production must seamlessly span unclassified and classified environments. These benefits include leveraging company talent while awaiting access to classified material; leveraging employees who are members of other sovereign states; and optimizing system production and maintenance for export / import. In this whitepaper we present the architectural design and accompanying business processes for a PLE factory and its artifacts that comprise unclassified and classified digital assets. These digital assets are used in automated generation of unclassified and classified product instances. All production activities occur within a single logical enterprise spanning multiple information systems comprising multiple security zones.

Paper#112

Applying Mission-Based Adaptability to Discipline Designs

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Presented on: Wednesday, 14:15-14:55 in Grand Cypress Ballroom GH

Keywords. Systems thinking; Decision Analysis; System Architecture

Abstract. Mission-based adaptability is an important metric to develop sustainable systems. It is developed to guide system architecture designs. In this work, we found such a method can be used in a much broader scope including guiding detailed system designs. Specifically this paper has two contributions: applies mission-based adaptability theory to control systems, and provided a system design flow using mapping techniques, to allow them to be conveniently and more effectively co-designed with mechanical systems. The effectiveness is shown through two example cases, an aircraft engine and an HVAC (Heating, Ventilation, and Air Conditioning) system, demonstrating the power of systems engineering and systems thinking.

Appreciative Methods Applied to the Assessment of Complex Systems

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Presented on: Tuesday, 14:15-14:55 in Grand Cypress Ballroom B

Keywords. Appreciative Inquiry;Complex System;Complexity;Complicated;Distinguishing Characteristics;Integrating Perspective;Simple;System

Abstract. Complex systems have characteristics that challenge traditional systems engineering processes and methods. The purpose of this paper is to provide definitions and describe distinguishing characteristics of complexity using example systems to illustrate approaches to assessing the extent of complexity. The paper applies Appreciative Inquiry to identify and assess complex system characteristics. The characteristics are used to examine several different examples of systems to illuminate areas of complexity. These examples range from seemingly simple systems to complicated systems to complex systems. Different tiers of complexity are identified as a result of the assessment. The paper also identified and introduces topics on managing complexity and the integrating system perspective that represent new directions for the engineering of complex systems. The Appreciative Inquiry approach provides a method for systems engineering practitioners to more readily identify complexity when they encounter it, and to deal more effectively with this complexity once it has been identified.

Paper#51

Approach to structure, formalize and map MBSE meta-models and semantic rules.

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Presented on: Monday, 10:45-11:25 in Grand Cypress Ballroom DEF

Keywords. MBSE;Model;Meta-model;Ontology;Interoperability;Modeling tools

Abstract. For decades our company has largely used modeling and simulation techniques all along the development cycle. Models are nowadays key components of most advanced methods and tools, dealing with many different disciplines and addressing most of system engineering processes and domain specific needs. As a result, models come from a large variety of modeling tools that use different diagrams, domain specific languages and features. This paper aims to present an approach used in our company to ensure the full consistency of the information formalized and shared through these models. It relies on the definition of a generic pivot meta-model and on the identification of how model elements are depicted in each type of diagram used. Resulting correspondence rules are then used to ensure the overall semantic consistency of diagrams and to support the propagation of modifications.

Paper#43

Augmenting requirements with models to improve the articulation between system engineering levels and optimize V&V practices

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Presented on: Thursday, 11:30-12:10 in Grand Cypress Ballroom GH

Keywords. mbse;requirement;model;arcadia;capella;functional analysis;functional chain;V&V

Abstract. Model-based systems engineering has developed significantly over the last few years, resulting in an increased usage of models in systems specification and architecture description. The question of the positioning of requirement engineering versus MBSE is a recurrent one. This paper describes one vision of this articulation where textual and model requirements actually complete each other. The results are improved contracts across engineering levels and more formalized V&V practices.

Paper#106

Brownfield Systems Development: Moving from the Vee Model to the N Model for Legacy Systems

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Keywords. brownfield systems engineering; legacy systems; as-is and to-be systems; Vee model; N model

Abstract. Most systems engineering standards, references, and textbooks consider systems development from a “greenfield” (i.e., clean-sheet, new development) perspective. There are several development models used for greenfield developments, with the “Vee” model being a popular choice. Many development efforts are better considered from a “brownfield” perspective (i.e., improving upon or replacing legacy systems). This paper proposes an extension of the Vee model, called the N model, which adds a site survey and various reconstruction processes to help move from the as-is system to the to-be system for brownfield development efforts. Three examples are provided to demonstrate how the N model can be applied in different situations.

Paper#106

Brownfield Systems Development: Moving from the Vee Model to the N Model for Legacy Systems

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Presented on: Thursday, 11:30-12:10 in Grand Cypress Ballroom B

Keywords. brownfield systems engineering; legacy systems; as-is and to-be systems; Vee model; N model

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Can We Use Wisdom-of-the-Crowd to Assess Risk of Systems Engineering Failures?

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Presented on: Wednesday, 11:30-12:10 in Grand Cypress Ballroom GH

Keywords. Wisdom-of-the-Crowd; Crowd-based Risk Assessment; Prediction of Crowd Estimate Accuracy; Risk of Systems Engineering Failures

Abstract. Despite advances in project risk assessment methods, systems engineering failures like cost overruns, schedule slips, and failure to meet technical requirements continue to occur with high frequency. Wisdom-of-the-Crowd (WoC) signals from inside the project team can complement expert management experience for risk assessment and help reduce such failures. We consider three metrics of project risk: budget, schedule and technical performance and evaluate whether WoC can provide correct estimates of these three metrics. We present a crowd-based method to collect qualitative estimates of project metrics from engineering student teams and predict the probability that these estimates are correct. We investigate whether a team-centered WoC approach provides better estimates than an individual-centered case. The WoC approach provides consistently more accurate budget estimates than the individual-centered approach. For estimating project schedule and technical performance, the WoC approach performs better when the estimate comes from individuals with high confidence.

Challenges and opportunities in the integration of the Systems Engineering process and the AI/ML Lifecycle

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Keywords. systems engineering process; artificial intelligence; machine learning; lifecycle

Abstract. The Digital Age, the “Society 5.0” or the “4th Industrial Revolution” has created a challenging and evolving environment in which more up-to-date, secure, safer, cost-efficient and personalized products and services must be timely delivered. Furthermore, the growing interest in equipping systems with intelligence implies that the engineering process must be adapted to consider the specific characteristics of Artificial Intelligent (AI) and Machine Learning (ML) systems. From the AI/ML point of view, the possibility of following an engineering process must also imply an improvement to overcome their “hidden” technical debt. To pave the way to the development of the next generation of smart systems, a retrospective in the current engineering practice and, in the development of AI/ML systems, is presented. Afterwards, the main challenges to harmonize both disciplines are outlined to finally describe the main opportunities and expected impacts.

Elevating the meaning of data and operations within the development lifecycle through an interoperable toolchain

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Keywords. development lifecycle;toolchain;interoperability

Abstract. The use of different engineering methods and tools is a common practice to cover all stages in the systems development lifecycle, generating a very good number of system artifacts. Moreover, these artifacts are commonly encoded in different formats and can only be accessed, in most cases, through proprietary and non-standard protocols. In this context, the OSLC (Open Services for Lifecycle Collaboration) initiative pursues the creation of public specifications (data shapes) to exchange any artifact generated during the development lifecycle. In this paper, authors extend and apply the OSLC KM (Knowledge Management) specification as a solution with a two-folded objective: 1) representation of any kind of system artifact and 2) extension of OSLC mechanisms to support the notion of delegated operation. In this manner, it is possible to enhance the exchange of data items and to reuse existing operations within the toolchain as it is demonstrated through a case study

Paper#60

Eliciting Human Values by Applying Design Thinking Techniques in Systems Engineering

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Presented on: Tuesday, 15:30-16:10 in Grand Cypress Ballroom A

Keywords. Systems Engineering;Design Thinking;Human Values;Early phase development

Abstract. The objective of this study is to investigate the effect of Design Thinking techniques for capturing and communicating human values in the early phase of Systems Engineering. To develop products, systems, or services that satisfy the stakeholders, the systems engineer (SE) must understand the emotional needs of the stakeholder. The goal is to derive stakeholder requirements from the need analysis to create solutions that satisfy the quantitative and emotional need of the stakeholders. A development project team conducts three field visits where they interview and observe stakeholders in their work environment. The project team uses visual mapping tools to communicate and discuss findings and to create a mutual understanding of the stakeholder needs. We evaluate the method using interviews, surveys, and analyses of the derived requirements. The results indicate that the team gained better understanding of the human values and succeeded in deriving human values into stakeholder requirements.

Paper#77

Emerging Education Challenges for Resilient Cyber Physical Systems

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Presented on: Wednesday, 10:00-10:40 in Grand Cypress Ballroom A

Keywords. Engineering education;Cyber physical systems;Cybersecurity

Abstract. Engineering resilient cyber-physical systems (CPS) is viewed as a systems engineering challenge. The scale and complexity of today's critical computing systems used in engineering domains has increased immensely. There has not been a related increased focus on research, knowledge, and education specifically addressing dependable and secure computing in domains such as infrastructure, industrial control, defense, and emerging commercial autonomous systems and the Internet of Things. There is a lack of opportunities for engineering graduates to gain knowledge and skills for design of secure, safe, and dependable CPS, what we call resilient CPS. This paper discusses the primary foundations and characteristics of resilient CPS as a step toward a general taxonomy, the emerging needs and gaps in engineering education, and the bodies of knowledge that need to be developed in the education system. The goal is to bring broad attention in the systems engineering community to these needs.

Encoding Technique of Genetic Algorithms for Block Definition Diagram using OMG SysML™ Notations

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Keywords. Genetic Algorithms;OMG SysML™;Reasoning;Encoding;Real-value encoding;Tree encoding;Semantic;Formalized;Block definition diagram

Abstract. Genetic algorithms can be used to perform an automated trade study analysis for component selection with the OMG Systems Modeling Language or OMG SysML™. However, the genetic algorithm encoding based on a single string with real-value encoding failed to include the relationships in the OMG SysML™ model for the solution space. The genetic algorithm was then unable to perform an automated reasoning through the OMG SysML™ as a result. To solve this problem, this study proposes tree encoding as the encoding technique for the OMG SysML™ elements. Tree encoding offers a simple way to include blocks and their relationships into a genotype without altering its semantics. The scope of this study is limited to a preliminary investigation of the block definition diagram. The result from this study suggests that the conceptual idea can be applied to the genetic algorithm and the potential use of the approach in the trade study analysis, reasoning, and machine learning.

Encoding Technique of Genetic Algorithms for Block Definition Diagram using OMG SysML™ Notations

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Presented on: Monday, 16:15-16:55 in Grand Cypress Ballroom A

Keywords. Genetic Algorithms;OMG SysML™;Reasoning;Encoding;Real-value encoding;Tree encoding;Semantic;Formalized;Block definition diagram

Abstract. Genetic algorithms can be used to perform an automated trade study analysis for component selection with the OMG Systems Modeling Language or OMG SysML™. However, the genetic algorithm encoding based on a single string with real-value encoding failed to include the relationships in the OMG SysML™ model for the solution space. The genetic algorithm was then unable to perform an automated reasoning through the OMG SysML™ as a result. To solve this problem, this study proposes tree encoding as the encoding technique for the OMG SysML™ elements. Tree encoding offers a simple way to include blocks and their relationships into a genotype without altering its semantics. The scope of this study is limited to a preliminary investigation of the block definition diagram. The result from this study suggests that the conceptual idea can be applied to the genetic algorithm and the potential use of the approach in the trade study analysis, reasoning, and machine learning.

Evaluation of COTS Hardware Assemblies for use in Risk Averse, Cost Constrained Space-based Systems

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Presented on: Thursday, 08:00-08:40 in Grand Cypress Ballroom GH

Keywords. Commercial-Off-The-Shelf Evaluation;COTS Evaluation;Fixed Price Space Systems

Abstract. A need for reduction in cost has driven many aerospace companies to consider using Commercial-off-the-shelf (COTS) hardware products during a space-based system design and development phase. Newly developed fixed-price space systems have a difficult challenge to address; they need to optimize their processes and requirements for cost while still adhering to the appropriate level of risk and rigor for their project. For many government-funded fixed-price projects, there is still an expectation of compliance to government standards and associated proof, which can be a challenge when evaluating usage of COTS hardware that may contain limited documentation. This paper presents research done to date for COTS usage in both the software and hardware domains and provides a framework for COTS evaluation of hardware assemblies used in a risk averse, cost constrained space-based application to satisfy external stakeholders.

Evolution of the Helix Project: From Investigating the Effectiveness of Individual Systems Engineers to Systems Engineering Organizations

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Presented on: Wednesday, 11:30-12:10 in Grand Cypress Ballroom A

Keywords. systems engineering effectiveness;systems engineering capability;culture;organizations

Abstract. The U.S. DoD recognizes an improved systems engineering capability as one of the priorities in science and technology. In recent years, the DoD and the Defense Industrial Base (DIB) have faced challenges in systems engineering (GAO, 2008, 2011, 2012, 2013, 2018). The Helix project started in 2012 as a multi-year longitudinal research study mainly to understand what makes systems engineers effective. In 2018, the Helix team shifted from an exclusively workforce focus to encompass how organizations can become more effective at systems engineering, including how they better enable their systems engineering workforce. This paper provides an update on the ongoing progress of the research including the updated methodology to investigate the organizational characteristics that influence the effectiveness of the systems engineering workforce as the team transitions from understanding the effectiveness of individual systems engineers to systems engineering organizations.

Experience from a Program for Accelerating the Creation of T-shaped Technical Leaders

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Presented on: Wednesday, 13:30-14:10 in Grand Cypress Ballroom A

Keywords. Competence development;T-shaped engineer;Technical leadership

Abstract. In the aerospace industry systems are becoming more and more complex. Consequently there are fewer opportunities for engineers to experience the full system lifecycle and the associated nuances in development. This in turn makes it more challenging to grow staff suitable for technical leadership roles. People who has the experience and skills to efficiently lead the development of a complex system. This includes both technical skill and soft skills. In this paper we examine the desired competencies of a technical leader by extending the T-shape engineer model and use the said model to evaluate an organisation internal, 2.5 year, program to accelerate the creation of technical leaders. The evaluation is performed through interviews with program participants and organisational internal stakeholders. Overall the program has proven cost efficient and successful in the sense the program participants in many cases have progressed into technical leadership roles.

Exploring the Test and Evaluation Space using Model Based Conceptual Design (MBCD) Techniques

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Keywords. MBCD;Systems Architecture;Systems Analysis

Abstract. During the initial concept development phase, systems engineers focus on defining the problem space and system functions in order to explore candidate concepts that may address their problems. Model Based Conceptual Design (MBCD) techniques may be used to assist the customer and other stakeholders with greater understanding of the system concept, as well as identifying areas in the system that are affected by changes in requirements. As this approach has been documented for describing the system concept in the early stages in the lifecycle, it does not address the Test and Evaluation (T&E) space that would be needed to evaluate these concepts, or identify where the T&E space is affected with a change in requirements. Our hypothesis is that decision makers would gain insight on T&E considerations and system space considerations using MBCD techniques. An approach is offered to extend the current MBCD methodology to consider the T&E space.

Paper#6

Exploring the Test and Evaluation Space using Model Based Conceptual Design (MBCD) Techniques

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Presented on: Thursday, 11:30-12:10 in Grand Cypress Ballroom A

Keywords. MBCD;Systems Architecture;Systems Analysis

Abstract. During the initial concept development phase, systems engineers focus on defining the problem space and system functions in order to explore candidate concepts that may address their problems. Model Based Conceptual Design (MBCD) techniques may be used to assist the customer and other stakeholders with greater understanding of the system concept, as well as identifying areas in the system that are affected by changes in requirements. As this approach has been documented for describing the system concept in the early stages in the lifecycle, it does not address the Test and Evaluation (T&E) space that would be needed to evaluate these concepts, or identify where the T&E space is affected with a change in requirements. Our hypothesis is that decision makers would gain insight on T&E considerations and system space considerations using MBCD techniques. An approach is offered to extend the current MBCD methodology to consider the T&E space.

Paper#74

Famous Failures Revisited: A Focus on System Integration

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Presented on: Tuesday, 13:30-14:10 in Grand Cypress Ballroom B

Keywords. Systems Integration;Lessons Learned;Failure causes

Abstract. A prior INCOSE paper addressed several famous failures from the viewpoint of the impact of requirements, verification, and validation. This paper has been used for pre-reading material and initial class discussion in a course on system integration that also includes verification and validation. The discussion also notes that the original paper does not address the impact of integration on these failures. This paper adds that viewpoint and includes several other instances from which lessons on integration are gleaned.

Frenemies: OPM and SysML Together in an MBSE Model

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Presented on: Wednesday, 14:15-14:55 in Grand Cypress Ballroom I

Keywords. MBSE;SysML;OPM;OPCAT;Models

Abstract. A Frenemy is “a person with whom one is friendly despite a fundamental dislike or rivalry.”. The Systems Modeling Language (SysML) and the Object Process Methodology (OPM) are two such frenemies. OPM and SysML are different means of achieving Model-Based Systems Engineering (MBSE). SysML is based on UML and includes diagrams that can be used to specify system requirements, behavior, structure and parametric relationships. SysML provides a means of defining high-level abstract systems down to detailed physical systems. OPM can be used to formally specify the function, structure, and behavior of artificial and natural systems in a large variety of domains. OPM is used in some systems engineering graduate courses. Students graduating from these institutions are struggling to integrate the differing styles, philosophies, concepts and processes of SysML and OPM. This paper discusses a synergy of SysML and OPM in a SysML tool rather than promoting one language over another.

General Modeling Language for Supporting Model-based Systems Engineering Formalisms (Part 1)

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Presented on: Monday, 15:30-16:10 in Grand Cypress Ballroom DEF

Keywords. MBSE;Architecture design;Code generation;Architecture driven;Karma language

Abstract. Model-based systems engineering (MBSE) has been proposed for systems engineering (SE) where modeling approaches have been developed to support formalisms of system artifacts and development using SE approaches. By using traditional approaches, these formalisms are described by models under different languages; however, the use of different tools for such languages leads to gaps which result in difficulties for integration of different systems' engineering views of products, unified property analysis, constraint definitions, and satisfiability of logical formulas. In this study, a textual modeling language, "Karma," based on a GOPRRR approach, was developed to formalize the meta-models and models; its main aim was to describe different MBSE languages and their models and to formalize model-transformation and code-generation during the entire lifecycle. Based on the Karma language, an MBSE tool was developed to formalize the complete SE of products using models, and to support automated model-transformation for architecture-driven and code-generation.

General Modeling Language Supporting Architecture-driven and Code-generation of MBSE (Part 2)

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Presented on: Monday, 16:15-16:55 in Grand Cypress Ballroom DEF

Keywords. MBSE;code-generation;Architecture-driven

Abstract. With the increasing complexity of systems, MBSE has attracted increasing attention in industry. MBSE formalizes the whole lifecycles of products using models based on systems engineering aiming to improve the development efficiency of complex systems. Traditionally, MBSE approaches require many modeling languages in each phase of the entire lifecycle. The different syntax between such languages leads to difficulty in supporting an integrated description of transformations between models and data. Thus, it is challenged to utilize a unified language to describe model formalism and transformation, and code generation in one MBSE tool. In this paper, a multi-architecture modeling language called Karma (introduced in Paper Part 1) is proposed to support the model transformations for architecture-driven implementations in one modeling tool. Moreover, the model transformations across tools are also supported by code-generation. Finally, the flexibility of the Karma language supporting architecture-driven and code generation is verified by one auto-braking case.

Implementing Augmented Intelligence In Systems Engineering

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Presented on: Wednesday, 10:00-10:40 in Grand Cypress Ballroom DEF

Keywords. Artificial Intelligence;AI;Machine Learning;Augmented Intelligence;MBSE

Abstract. This paper will explore the opportunities for artificial intelligence (AI) in the system engineering domain, particularly in ways that unite the unique capabilities of the systems engineer with the AI. This collaboration of human and machine intelligence is known as Augmented Intelligence (Aul). There is little doubt that systems engineering productivity could be improved with effective utilization of well-established AI techniques, such as machine learning, natural language processing, and statistical models. However, human engineers excel at many tasks that remain difficult for AIs, such as visual interpretation, abstract pattern matching, and drawing road inferences based on experience. Combining the best of AI and human capabilities, along with effective human/machine interactions and data visualization, offers the potential for orders-of-magnitude improvements in the speed and quality of delivered.

Implementing systems engineering and project management processes in a Canadian company – Overview and Results Achieved

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Presented on: Monday, 10:45-11:25 in Grand Cypress Ballroom B

Keywords. Project management;Systems engineering;small enterprise;process;process improvement;processes;ISO 29110;standard;CMMI

Abstract. This article presents a project consisting of implementing project management and system engineering processes at CSinTrans Inc. (CSiT), a Canadian company founded in 2011. CSiT provides multi-modal integrated communications and security systems as well as information integration to the transit industry worldwide. This includes systems for trains, subways, buses, railway stations, subway stations and bus stops. ISO/IEC 29110 standard and guides for systems engineering have been used as the main reference for the development of these processes.

The approach and details on how the standard has been implemented are presented. The third-party audit process, conducted annually since 2016, that led CSiT to become the first systems engineering company successfully audited with ISO/IEC 29110, is presented as well as the benefits obtained.

ISO/IEC 29110 has helped raise the maturity of the organization by implementing proven practices and is the first step towards achieving CMMI® Maturity Levels 2 and 3.

Improving the information transfer between engineering and installation; case study at AS Nymo

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Presented on: Monday, 10:00-10:40 in Grand Cypress Ballroom I

Keywords. Engineering;Installation;Information transfer;Oil and Gas

Abstract. EPCI projects for the offshore industry become more complex, with a reduced timeframe, and increased demand for cost savings. The result is reduced profit margins; therefore, the need for increased productivity is higher than ever. Some of the aspects important for productivity include material flow, information flow, sound planning, and organizational structure. This paper focuses on the information transfer between the engineering team and the installation phase of the fabrication at The Company. Feedback from stakeholders, previous research and lessons learned indicate potential for improvement. We analyzed historical data and involved key stakeholders in an iterative process to analyze the handover format. By removing this insignificant information, we found that it is possible to reduce the number of handover revisions by 60%. Additionally, we found that improving the handover could give a 67% reduction in time spent for the receiving stakeholders to find the specific information they seek.

Inclusion of human values in the specification of systems: bridging design and systems engineering

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Presented on: Tuesday, 11:30-12:10 in Grand Cypress Ballroom GH

Keywords. Design Thinking; Human-centred design; Systems Engineering; Requirements; Human stakeholders; Use case scenarios; Human values

Abstract. This paper investigates a method for ensuring that systems engineers generate requirements related to human values. It looks at the work of a project team that designs and develops complex systems in a company recognized for the application of Systems Engineering to deliver innovative systems. The research data was drawn from a real project. We developed a tool that prescribes a structure to analyze human stakeholders and describe use case scenarios. The tool enabled the system engineers to generate twenty-five requirements to add to the specification of the system. Thirteen of these specify aspects of the system that are relevant to human values. Initially, the specification included only two requirements related to human values. We conclude that the importance of specifying human values have increased among the engineers of the team. Further investigation is ongoing in order to evaluate the potential of generalizing the new tool, its efficiency and effectiveness.

INCOSE Handbook V4 to CMMI Development V2.0 mapping

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Presented on: Wednesday, 14:15-14:55 in Grand Cypress Ballroom A

Keywords. CMMI V2.0;SE Handbook;Mapping;Analysis

Abstract. This paper addresses the need for a detailed mapping between INCOSE SE Handbook V4 (Handbook) and CMMI V2.0 Development (CMMI-DEV). CMMI-DEV was released in March 2018. The Handbook and CMMI-DEV are good references for Systems Engineering practitioners. Learning both of them enhances practitioner knowledge and provides complementary points of view for similar Systems Engineering concepts. This paper includes both high-level mapping, depicting the structure of Handbook and CMMI-DEV, and detailed mapping, depicting for each process activity in the Handbook all associated CMMI-DEV practices. Moreover, the detailed mapping provides percentage of coverage for each activity and its entire process. The paper addresses the target audience; the methodology followed to create both levels of the mappings; amount of commonality between Handbook process activities and the CMMI-DEV practices; percentage of coverage analysis at the process and process group level in the Handbook; and overall results.

Information-based Requirement Development & Management

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Presented on: Tuesday, 11:30-12:10 in Grand Cypress Ballroom DEF

Keywords. requirements;requirement statement;requirement expression;requirement development;requirement management;models;MBSE;model-based design;MBD;templates;ontology;integrated dataset;sharable data and information model

Abstract. This paper proposes an Information-based Requirement Development and Management (I-RDM) approach to developing and managing requirements from the perspective that the requirements should not be developed and managed separate from other system data and information model development and management activities. Instead, requirements should be developed and managed concurrently from the beginning of the project as an integral part of the data and information modeling activities. If done correctly, the Systems Engineering (SE) tools used can share data and information resulting in a shareable data and information model of the system of interest that includes all artifacts generated during all SE life cycle phases. Using this approach, the design modeling team would work concurrently with the I-RDM team such that the start of detailed design begins with a logical system model representing a concept whose feasibility has been already accessed.

Innovation in the Spirit of Design Thinking

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Presented on: Wednesday, 15:30-16:10 in Grand Cypress Ballroom GH

Keywords. Innovation;Iteration;Evaluation

Abstract. We define an innovation process that was designed for the provision of analytic services and soft-ware products. Our iterative process, which is based on design thinking, captures the need to both create value and accelerate value creation. The four steps in our iterative process include illuminate, ideate, create, and evaluate. We present a case study for which we used this process in the successful creation of a conversational non-player character within a virtual training environment for the Army.

Paper#14

Integrating Program/Project Management and Systems Engineering in Practice

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Presented on: Monday, 10:45-11:25 in Grand Cypress Ballroom I

Keywords. Mission Assurance;System Engineering/Project Management Integration;Integration in Practice

Abstract. Two practitioners who have experience integrating program/project management and systems engineering conducted two workshops on this subject (will insert the title and venues if paper is accepted). The workshops included presentations by the researchers about their respective integration implementations followed by small group discussion exercises on topics/issues to consider when making integration decisions. Discussion topics were drawn from Rebutisch (Ed., 2017) and included motivations to integrate, organizational environments that support or inhibit integration, influencers and influence, integration metrics, and success and failure contributors. Each exercise concluded with out-briefs of the small groups' observations, analyses, and recommendations to the collective. A synthesis of these observations, analyses, and recommendations provide the bases for this paper.

Paper#24

London Underground Deep Tube Upgrade Programme: System Function Definition Model Case Study

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Presented on: Thursday, 10:00-10:40 in Grand Cypress Ballroom GH

Keywords. System Integration;Functional Analysis;Rail Systems;Infrastructure Upgrades

Abstract. On complex rail projects involving a step change in technology or capability, it is important to understand what functionality is required from the system, especially if such changes are new or novel. This paper details a case study (Deep Tube Upgrade Programme) where a structured functional breakdown approach was developed to provide stakeholders (including operators and maintainers) with a means of checking their life-cycle concepts and stakeholder requirements for completeness, and to decompose those needs into system design requirements for allocation to one or more of the 19 delivery projects to ensure they will deliver the required emergent properties.

Managing Complexity with Agility and Openness

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Keywords. Complex;Agile;Open;MOSA;Complexity;Scrum

Abstract. This paper, based on a series of observational studies, workshops and panel sessions with systems engineering practitioners who apply agile and open concepts to complex systems, describes a pragmatic approach to identifying manifestations of complexity in engineered systems and applying agile and open concepts to managing that complexity. The author's intent is to apply the heuristics and recommendations in this paper to a number of projects in the form of structured pilots to advance empirical understanding of tactics for managing complexity in engineering. Engineering projects and systems are becoming increasingly dynamic, intricate and collaborative in response to forces such as globalization, interconnectivity, the pace of technical change and integration of human and natural systems. Approaches emerging in response to these changes include complex systems science, agile frameworks and techniques, and open architecture methods and standards. Systems Engineering practitioners are beginning to employ these approaches in combination to address the challenges of current and future needs. Domains such as Agile Space employ open architectures as enablers for agility. Teams employ agile methods to solve complex problems in security, networking and healthcare domains. As these pairwise applications become more common, the interaction between complexity, agility and openness become more frequent and intricate. This paper explores ways in which these interactions can enhance engineering practice.

Managing Complexity with Agility and Openness

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Presented on: Monday, 11:30-12:10 in Grand Cypress Ballroom B

Keywords. Complex;Agile;Open;MOSA;Complexity;Scrum

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OMG standard for integrating safety and reliability analysis into MBSE: Concepts and applications

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Presented on: Monday, 14:15-14:55 in Grand Cypress Ballroom DEF

Keywords. Safety and Reliability; Model-based systems engineering; MBSE

Abstract. Model-Based Systems Engineering (MBSE) is gaining popularity in organizations creating complex systems where it is crucial to collaborate in a multi-disciplinary environment. SysML, being one of the key MBSE components, has a good foundation for capturing requirements, architecture, constraints, views and viewpoints. However, SysML does not provide the necessary constructs to capture safety and reliability information in the system model. A group of industry experts at the OMG has been working since 2016 to define a new specification providing the necessary capabilities. This paper provides an update on the progress of this work. It discusses the proposed specification's use of generic concepts to allow information interchange amongst diverse analyses, its use of existing SysML constructs to provide automation of safety and reliability work in existing modelling tools, and describes several of the supported analysis methods.

Optimizing the Requirement Engineering Process: A Case Study of I/O List Management in Integrated Automation Systems

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Presented on: Tuesday, 10:00-10:40 in Grand Cypress Ballroom DEF

Keywords. Integrated Automation Systems; I/O list management; Requirements Engineering; Standardization

Abstract. Integrated Automation Systems (IAS) suppliers in the maritime sector face the cost pressure over the years, while the system complexity increases. As the IAS delivery process is mainly related to design and production activities of the software, like Input/Output list (I/O list) management during the Software (SW) design and engineering phases. This paper aims to optimize the requirements engineering (RE) process by the I/O list management in the IAS production. A real-life case study is conducted to investigate I/O list management in the RE process of the IAS production. It is found that late design changes to the I/O list are the main reasons for delays in an IAS production; the lack of standardization, documentation, inconsistency between customer and supplier milestones as well as the I/O list ownership by customers are the important root causes. Finally, the derived solution in resolving those root causes is introduced for reduced man-hours.

Problem Framing: Identifying the Right Models for the Job

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Presented on: Monday, 10:00-10:40 in Grand Cypress Ballroom DEF

Keywords. architecture; modeling; MBSE; problem framing

Abstract. In the world of modeling, we are now confronted with a problem. The richness of the tools and methods available to us now have led to an “agony of abundance” when it comes to available options for modeling a system. The recently released Unified Architecture Framework, for example, has specified 71 possible architecture views that can be created. How can systems engineering cope with all the choices? How does one effectively choose the right models? This paper presents a Problem Framing approach that facilitates selection of the right models for the job, the ones that can add the greatest value and have the greatest utility for the various potential users of these models, and those that can provide the greatest insight into system trade-offs and successful outcomes.

Professional Competencies - The Soft Skills to give Systems Engineers a Hard Edge

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Presented on: Tuesday, 10:00-10:40 in Grand Cypress Ballroom I

Keywords. Professional;Competency;Framework;Soft Skills

Abstract. The publication of the new INCOSE Systems Engineering Competency Framework is notable for many reasons, not least the inclusion of Professional Competencies which is the focus of this paper.

This paper reviews the general importance of the professional competencies (also known as “soft skills”), and the specific relevance of the individual competencies that have been included in the INCOSE framework. This provides a review and discussion of the importance of the Professional Competencies to enable those that do Systems Engineering to be successful. Systems Engineering is both done by people and integrates people: to do that the soft skills or Professional Competencies are essential.

Projects as Interventions in Infrastructure Systems-of-Systems

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Presented on: Tuesday, 16:15-16:55 in Grand Cypress Ballroom B

Keywords. Infrastructure;Projects;Systems-of-Systems;Interdependencies;Interventions

Abstract. Infrastructure involves highly interdependent transport, water, building, power and energy systems-of-systems. This paper considers projects as interventions into this existing infrastructure, building on workshops and discussions with professionals, and recent developments in systems engineering. Unlike the defence, aerospace and automotive sectors, in which many classic methods and tools for systems engineering were developed, infrastructure involves relatively open and interconnected systems. As these become increasingly cyber-physical, the delivery of projects as interventions is growing in complexity. It requires the integration of computing as well as more traditional engineering disciplines. We set out a research agenda on next-generation systems engineering methods and tools for infrastructure, proposing how the use of digital data and analytics can enable engineering decision-makers to rapidly understand interdependencies within infrastructure projects and across their boundaries.

Recommended Best Practices based on MBSE Pilot Projects

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Presented on: Wednesday, 15:30-16:10 in Grand Cypress Ballroom I

Keywords. MBSE;Model Based Systems Engineering;Best practices;Lessons learned

Abstract. Model-Based Systems Engineering (MBSE) is an emerging new paradigm for improving the efficiency and effectiveness of systems engineering through the pervasive use of integrated descriptive representations of the system to capture knowledge about the system for the benefit of all stakeholders. This paper describes some of the key lessons that have emerged from several internally-funded MBSE pilot projects over the past few years. It also provides recommended best practices based on these lessons learned.

Solution Validation and Customer Needs Understanding in the Early Phases of Product Platform Development; a Case Study in Digital Manufacturing Machines

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Presented on: Tuesday, 10:00-10:40 in Grand Cypress Ballroom A

Keywords. Early Validation;Agile;market segmentation

Abstract. We have observed in our company that the high-level specification of new products is difficult. The company works with legacy product platforms. Even with extensive knowledge about legacy products and applications, it can be difficult for engineers to understand if their proposed solutions for new products or features that will satisfy customers.

The goal of this study was to investigate why the company is having problems with specifying new products that eventually will constitute a new product platform. We show that relying on proxies and agile development is not sufficient to close the validation loop, how validation of solution concepts fails due to insufficient specifications of needs and that engineers must rely on indirect customer feedback, which they often receive late in the development process. We trace the problem to a sub-optimal definition of customer segments, causing a lack of validated needs and leading to challenges in calculating business cases.

Speaking in Tongues: The Systems Engineering Challenge

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Keywords. Concurrent engineering;Metamodel;communication;standards;simplification;representations;language

Abstract. The Hebrew Scriptures tell the well-known story of the construction of the tower of Babel. That project is easily begun using the single language common to all the people of the time. But in response to the plan to build a tower to the gates of heaven, God plants different languages among the builders frustrating their ability to communicate. This effectively halts the project and ends in the dispersal of the peoples to the "ends of the earth."

The ancient story carries a warning for our attempts to broaden the practice of systems engineering beyond the familiar bounds of defense and aerospace. Unlike the tower builders whose acquired problems halted their progress after a successful start, twenty-first century systems engineers are severely language-challenged from the outset. The demands of new domains involve the lan-guages of diverse stakeholders and subject-matter experts. The demands of concurrent engineering involve communicating with a variety of disciplines with their own models, methods and lan-guages.

This paper explores the challenges posed by the diversity of languages outside the usual market space and suggests possible solutions for them.

Speaking in Tongues: The Systems Engineering Challenge

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Presented on: Wednesday, 16:15-16:55 in Grand Cypress Ballroom C

Keywords. Concurrent engineering;Metamodel;communication;standards;simplification;representations;language

Abstract. The Hebrew Scriptures tell the well-known story of the construction of the tower of Babel. That project is easily begun using the single language common to all the people of the time. But in response to the plan to build a tower to the gates of heaven, God plants different languages among the builders frustrating their ability to communicate. This effectively halts the project and ends in the dispersal of the peoples to the "ends of the earth."

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This paper explores the challenges posed by the diversity of languages outside the usual market space and suggests possible solutions for them.

System Theoretic Process Analysis for Layers of System Safety

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Presented on: Thursday, 08:00-08:40 in Grand Cypress Ballroom I

Keywords. System Theoretic Process Analysis;Autonomous Vehicles;Complex Systems;Hazard Analysis

Abstract. The move toward autonomous vehicles (AV) and mobility services extends the scope of traditional vehicle system to include a much broader system definition. Questions often arise on how to identify the most relevant, practical level of system hierarchy for the analysis. System Theoretic Process Analysis (STPA) is a hazard analysis technique that can be used to handle emergent properties of large, organized systems. However, STPA lacks the degree of formalization required to implement it successfully in a fast-paced industrial environment. This paper introduces an agile framework for multi-level hierarchical progression of STPA on complex system architecture at multiple levels of abstraction. The outcome of the analysis is a set of requirements for safety, cybersecurity, performance and business needs. The paper also provides guidelines on using these derived requirements to steer the system design. We demonstrate the efficacy of the proposed methodology by applying it to an autonomous vehicle ride-sharing ecosystem.

Systems engineering and complex systems governance - Lessons for better integration

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Presented on: Tuesday, 14:15-14:55 in Grand Cypress Ballroom I

Keywords. systems engineering; complex systems governance; integrating methodologies; lessons learned; improved practice

Abstract. The relationship between systems engineering and complex systems governance (CSG) is not clear. CSG is early in its evolution. The paper examines the case for change in regulating the Australian defence maritime community; and the complication that caused a change to the approach half way through the six-year transformation period. Subsequently, 'traditional' systems engineering became less visible, and CSG took primacy while still employing systems engineering principles in the design, build and implementation of the transformation program. Three questions are considered: what was the nature of the change, why did it matter and what lessons do we draw for CSG and systems engineering? The authors highlight the traps of not connecting the two fields of ideas. They illustrate the value of the viable systems model in governing the design, build, and implementation of change as well as its ongoing operation and evolution.

Systems Engineering--Software Engineering Interface for Cyber-Physical Systems

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Presented on: Tuesday, 10:00-10:40 in Grand Cypress Ballroom GH

Keywords. Software engineering;Collaboration;Cyber-physical systems

Abstract. Almost all of today's man-made physical systems are actually cyber-physical systems, consisting of a significant amount of software performing computational work to receive, store and process data, and to issue instructions for actuators, based on the results. While the software may be well-engineered internally, the physical concerns may not be treated completely by the software architects and engineers.

Systems engineers and software engineers must work together for today's and tomorrow's cyber physical systems to be properly engineered, including physical components and the related soft-ware, so that system quality attributes such as safety, security, and maintainability are ensured.

The three main exhortations of this paper for systems and software engineers are:

- Learn what you can about the other discipline
- Establish coordinating relationships
- Agree on roles, to ensure the system is engineered correctly.

Systems Engineering: Transforming Digital Transformation

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Presented on: Tuesday, 15:30-16:10 in Grand Cypress Ballroom B

Keywords. Digital Transformation;Systems Engineering;Model Based;Change Management;Complexity

Abstract. While complex systems transform the landscape, the Systems Engineering discipline is also experiencing a transformation to a model-based discipline. In alignment with this, one of the International Council on Systems Engineering (INCOSE) strategic objectives is to accelerate this transformation. INCOSE is building a broad community that promotes and advances model-based methods to manage the complexity of systems today which seamlessly integrate computational algorithms and physical components across domains and traditional system boundaries. This paper addresses contextual drivers for transformation as well as obstacles, enablers, and INCOSE resources aligned with accelerating the transformation of Systems Engineering to a model-based discipline.

Paper#69

The Drone System II: Availability Performance Analysis and Modeling

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Presented on: Thursday, 08:45-09:25 in Grand Cypress Ballroom I

Keywords. Unmanned Systems;Autonomous Systems;Model-Based Systems Engineering;System Modeling and Simulation;System Performance and Trade-off Analysis;System Availability;System Reliability;RAM Analysis

Abstract. This paper is the second of two papers that together provide an example of how to use the systems engineering processes outlined in the INCOSE Systems Engineering Handbook and ISO/IEC/IEEE 15288:2015 to develop a SysML system architecture from a user's statement of need and then to develop a mathematical system model for system reliability, availability, and maintainability that may be used to perform system design and cost-effectiveness trade-off analyses. This paper focuses on the development of an analytic Markov model that may be used to determine the operational availability that results from alternative designs for the drone system described in the first paper and the use of this model to perform a design performance analysis and a design trade-off analysis. It also compares the results of this analytic stochastic model to a simple deterministic model.

Paper#63

The Enduring Path to System Success: Investment in Early-phase Quality Systems Engineering

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Presented on: Wednesday, 15:30-16:10 in Grand Cypress Ballroom C

Keywords. Systems engineering success factors;Early-phase systems engineering;Improving project success

Abstract. It is not always possible to apply Systems Engineering (SE) processes as comprehensively as practitioners would like. The question then becomes where and when best to allocate SE resources to maximize project success. A review paper that analyzed lessons learned twenty years ago highlighted inadequate early-phase systems engineering effort as a major cause of project issues. This paper opens with a discussion of this review material and progresses to review contemporary materials. The conclusion drawn is that the quality of early-phase systems engineering is as vital as ever to project success and that the recommended levels of expenditure on systems engineering are unchanged. The newer work, however, provides us with important new information: guidance on the sorts of activities that provide the greatest payoff in the early stages of the lifecycle and what proportion of the SE budget should be allocated to each major area of activity.

The Good, The Bad and The Ugly

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Presented on: Thursday, 10:00-10:40 in Grand Cypress Ballroom A

Keywords. Self-awareness;Judgement;Confidence;Accuracy;Estimation;Trust;Bold;Humble;Calibrated;Calibration

Abstract. Many aspects of Systems Engineering rely on Judgement; a benefit of having experienced Systems Engineers. But is there a way to mitigate the risk of relying on Judgement as a basis for decisions?

This paper shows that it is possible to assess a person's potential for good Judgement based on a simple test that takes less than ten minutes to complete. After testing over two hundred people from two companies, the test is shown to be a reliable predictor of a person's ability to make accurate Judgements.

If Systems Engineers are valued for their Judgement, it is important to know who is trustworthy and under what conditions. Industry research has shown the positive correlation between Judgement quality and decision quality. This paper provides a simple method for any organization to determine whose Judgment is trust-worthy and what to do if someone turns out to be poor at Judgement.

Paper#84

The State of Systems Engineering Technical Practice versus Discipline: A Survey of INCOSE Chapter Attendees in North America

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Presented on: Wednesday, 10:45-11:25 in Grand Cypress Ballroom GH

Keywords. SE Core Competency;SE Education;SE - Profession or Discipline?;SE Management;Project Performance Issues;Groupthink Paradigm;Specify-DEsign-Build-Test-Fix Paradigm

Abstract. In 2017, the author initiated an SE Fundamentals Research Project to assess the current state of SE. Peer Engineering disciplines often question and challenge the legitimacy of SE as a discipline. This paper summarizes results of a series of surveys conducted between October 2017 and November 2018. Survey results represent “core samples” from INCOSE chapter attendees – e.g., members and non-members - at geographically dispersed locations in North America. Project survey results correlate with _____’s (2018) personal assessment and serve a frame of reference for INCOSE’s Future of SE (FuSE) Team for instituting corrective actions to achieve its Vision 2025. The paper concludes with recommendations that build on _____’s (2018) recommendations concerning corrective actions that industry, government, academia, textbook authors and publishers, professional societies, and standards organizations should institute to realign and refocus of SE as an Engineering discipline, not SE Management.

Paper#65

Towards a model-based approach to Systems and Cybersecurity co-engineering

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Presented on: Thursday, 08:00-08:40 in Grand Cypress Ballroom DEF

Keywords. Cybersecurity;Model-Based Systems Engineering;System Architecture

Abstract. As cybersecurity threats multiply and global public opinion becomes aware of the potential consequences of cyber-attacks, customers become more demanding with regard to the proper addressing of cybersecurity concerns in the systems they acquire. As a consequence, systems providers should consider such concerns early in the development life-cycle of their solutions. This paper presents how a model-based approach can contribute to an effective co-engineering effort between cybersecurity and systems engineering during the definition of the system architecture.

Paper#18

Transitioning from technical 2D drawings to 3D models: a case study at defense systems

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Presented on: Thursday, 08:45-09:25 in Grand Cypress Ballroom GH

Keywords. Model Based Definition;CAD;engineering;3D

Abstract. Companies in the defense and aerospace industry are experiencing long time-to-market and high costs related to the development of new systems. Companies use traditional design elements such as technical 2D drawings and manual work along the development chain. Owing to today's software capabilities, a change to more automated processes is possible, where the use of 3D models as governing documents through the entire development process holds a natural part.

This paper studies a 3D model-based definition (MBD) approach to the design development work at Kongsberg Defence & Aerospace. Using a pilot project, we researched the current design processes and the effect a 3D MBD approach would have. We found that a 3D MBD approach would reduce the time-to-market and cost, since it eliminates the need for a technical 2D drawing and streamlines the development work. In addition, it reduces project risk by enabling early validation of the design.

Paper#72

Use of SysML for the creation of FMEAs for Reliability, Safety, and Cybersecurity for Critical Infrastructure

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Presented on: Monday, 13:30-14:10 in Grand Cypress Ballroom DEF

Keywords. Critical Infrastructure;Failure Modes and Effects Analysis;SysML;FMEA;Safety;Reliability;Cybersecurity

Abstract. A method for producing a Failure Modes and Effects Analysis (FMEA) from SysML is pre-sented together with a simple critical infrastructure system example. The significance of the method is the modeling of failure propagation which enables not only an automated approach but significant additional analysis results that can be used to support reliability, safety, and cyberse-curity. The analysis products from a tool implementing this method together with the insight and analytical benefits they provide are discussed.

Using Set-Based Design to Inform System Requirements and Evaluate Design Decisions

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Presented on: Tuesday, 10:45-11:25 in Grand Cypress Ballroom DEF

Keywords. Set-Based Design; Decision Analysis; Systems Analysis; Requirements Analysis

Abstract. Set-Based Design (SBD) is a concurrent engineering technique for system design and systems analysis. System analysts perform Tradespace Exploration to assess requirements and identify affordable designs. This paper demonstrates the use of SBD to inform system requirements and evaluate design options. We use a UAV case study with an integrated Model-Based Engineering framework with SBD to identify potential designs, assess design feasibility, inform requirements, and evaluate feasible designs. We use SIP Math from Probability Management© to explore 100,000 potential systems concepts in near real-time. Using our integrated framework, we found that only 2.7% of the potential designs were feasible. We validate that SBD finds the efficient frontier in the value versus cost tradespace. We use SBD to inform systems requirements by identifying the number of potential feasible designs in the tradespace for each requirement or combination of requirements. We also use SBD to evaluate design options.

Using Systems Theoretic Perspectives for Risk-Informed Cyber Hazard Analysis in Nuclear Power Facilities

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Presented on: Monday, 14:15-14:55 in Grand Cypress Ballroom I

Keywords. Systems-Theoretic;Risk-Informed;Cyber;Hazards Analysis;Nuclear Power

Abstract. Nuclear power plants (NPP) use several approaches and tools when assessing vulnerabilities and hazards, typically employing variations of traditional fault tree analysis (FTA). Yet, the Anonymous has sponsored research investigating the efficacy of such traditional risk assessment tools to evaluate hazards for digital instrumentation and control systems. One of the conclusions was that no single methodology is befitting to address the complexities of digital hazards. In response, Anonymous developed a digital hazards analysis process building on key tenets of Systems-Theoretic Process Analysis (STPA) and Fault Tree Analysis (FTA). This new methodology—Hazard and Consequence Analysis for Digital Systems (HAZCADS)—leverages the benefits of these two techniques to provide a more comprehensive, systems approach to hazard analysis for new and complex digital systems. It is anticipated that HAZCADS can provide a risk-informed tool for assessing digital systems.

Panel

Panel#8

50 years ago we went to the moon; where have we been since?

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Presented on: Monday, 10:00-12:10 in Grand Cypress Ballroom A

Keywords. Systems Thinking;Quality Management;Six Sigma;SAFe;Agile;Culture

Abstract. What is Quality Management, and how much have we gained and lost over the last 50 years. We must set the tools and techniques in the context of the organizational culture, and the individuals who make up the organization. We take a look at the orthodoxy of systems thinking as seen in Quality Management initiatives from the first quality revolution 50 years ago, through six Sigma, QFD and SAFe. The discussion will address how some of these have become mis-used over time, and how we can bring the values and benefits back on track to again deliver value. We also look at the parallels between systems thinking and orthodox quality management.

Biography

Hazel Woodcock (IBM) - hazel.woodcock@uk.ibm.com

Hazel is a member of the INCOSE SE QM working group and leads the UK SEQM group, and is faculty of the QMI. She has engaged with a QM culture since first learning the principles 25 years ago, and has more recently been looking at the parallels between QM and Systems Thinking as part of the Working group activities. She has been practising systems engineering for 20 years in various industries. She now works as a solution architect in IBM, supporting customers who are setting up tools, with both tool and process support.

Position Paper

Introduction to session, in which I highlight the parallels between systems thinking and orthodox quality management. We will look at various quality initiatives from the time of Crosby, Juran and Deming, through to current practices. We will have a short recorded video describing the good and bad of QFD as practiced and as described in ISO 16355-1, which was developed by a multinational team.

What is Quality Management, and how much have we gained and lost over the last 50 years. We must set the tools and techniques in the context of the organizational culture, and the individuals who make up the organization. This is a role of moderator and facilitator, with no stated position, but with the expectation of bringing forward positions that provoke thought and discussion, whether they come from the audience, or from interactions between the other members of the panel.

Christopher Hoffman (Cummins Inc) - christopher.d.hoffman@cummins.com

Chris was certified as a Master Black Belt at Cummins in 2005, as one of the first 'internal' Design for Six Sigma MBBs. In that role, he delivered a four-week Design for Six Sigma course worldwide to hundreds of students world-wide, training methods and tools to enable the movement from Concept to Design to Optimization to Capability verification. Over his

21 years at Cummins, Chris has applied this problem-solving methodology as well as DMAIC (Define, Measure, Analyze, Improve, and Control) method in multiple roles to shop floor processes and equipment, commercialized product, internal processes, and tools in Quality, Product Development, and Center of Excellence organizations. Currently, Chris is directing the Information Systems and software Tools strategy and architecture for the Cummins enterprise engineering function. He is a Certified Systems Engineering Professional, and is energized by learning.

Position Paper

What is Six Sigma? What is Systems Engineering? What is Quality? The difficulties of answering each of these questions with clear definitions give a hint at the challenges in transforming and maintaining the operational successes promised and attainable by each of these methodologies. If your QFD looks like it is for PhDs, then you've already failed.

Six Sigma to some is a rigorous set of tools and practices to be completed in a standard fashion: Defining the problem, Measuring the performance of the process, Analysing the factors, Improving the process, and Controlling the process to maintain an improved quality level. This DMAIC process is very useful in production environments, and lends itself well to continuous process improvement, targeting minimal defects to deliver a 'high quality' product to the customer. This of course, assumes that the product is what the customer wanted. Design for Six Sigma targets making better decisions on what the product should be for the customer, and uses quality management and system thinking approaches to ensure that the identified functions and behaviours of the product are well understood and perform robustly (perhaps to six sigma levels or more) for the customer over the life of the product.

Systems Engineering and Quality Management have similar challenges of perspective, in that to some they are a rigorous set of tools and practices set to be completed in a standard fashion, and that is the way to maximizing value. Success however, is not attained by over-prescriptive, dogmatic application of tools and methods in a programmatic execution of tasks that have been clearly documented in a work-breakdown structure, assigned to capable individuals, scheduled, and executed with a key focus on managing the critical path while preventing failures and closing issues along the way.

A healthy understanding of the history and intent of these processes and approaches is necessary to be successful. Without that knowledge, as tools and processes are appropriately tailored for each company and product development process, knowledge and wisdom will decay over time if not mitigated. This decay is like architectural decay, in which the initial intent and structure of the system degrades as design decisions are distributed with lesser and lesser awareness of the guiding 'north star' of the architectural intent.

Going forward, leaders, coaches, and individuals must know enough about these varied methods and tools to use the right ones at the right time to the right level of detail, to make a good enough decision for each situation. Being able to make this decision requires one to know the history of WHY that tool and method is to be used, know the unintended consequences of using the tool or method, know the factors that may impede the successful completion of that tool or method, and to know when to stop – when success has been attained for that decision.

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Position Paper

There is a huge misconception that Agile implies wild, wild west thinking and ad-hoc development practices. Nothing could be further from the truth. It's true that Agile principles de-emphasize formal requirements, documentation and plans, but this primarily refers to teams, not an enterprise. A true enterprise needs more than just Agile teams – it must scale those principles across disciplines and apply to both business and engineering resources and involve people, process and tools in that business transformation.

As organizations turn toward lean and agile methods to modernize their process, they are accepting the need to focus on three key things: Building quality and compliance in, understanding the "whole system" which defines an end-user experience, and transforming business models to enable faster time to value – as opposed to faster feature delivery cycle time. Value, economics and quality are key here and agile at scale defines best practices and methods to help enterprises drive transformations that provide business results.

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Dr. Barclay Brown is a Raytheon Engineering Fellow for Model Based Systems Engineering. Previously he was a Global Solution Executive and Chief Engineer for IBM in the Watson IoT division. An early pioneer in the home automation industry, Dr. Brown was president of the Home Automation Association, founder of Home Automation Laboratories and architect of several home automation systems before joining IBM. He is co-author of the book Model Driven Systems Engineering with Rational Tools. Dr. Brown holds a bachelor's degree in Electrical Engineering with master's degrees in Psychology and Business and a Ph.D. in Industrial and Systems Engineering. He is a certified Expert Systems Engineering Professional (ESEP), the former INCOSE Director for the Americas, Adjunct Teaching Professor at Worcester Polytechnic Institute and a Graduate Faculty Scholar at the University of Central Florida.

Position Paper

The System of Quality: Prevention

Are the customers and users of our systems harder to please these days than in the past? Do they have more needs, or

perhaps needs that are harder to meet? It might be more correct to say that their needs are more complex than they used to be. The systems we design and build are more complex, and their interactions with other systems make the entire situation more complex. So also, the systems we use to build those systems have become more complex. It should not be surprising that achieving quality is more complex as well. While quality is an inherently simple idea, that of conforming to requirements and thus keeping our promise to our customers, complex engineering systems and processes within complex organizations mean that engineering for quality is a complex task on its own!

To engineer the organization, systems engineers turn to the practice of systems thinking, the application of a systems approach to human activity systems. Systems thinking enables engineers and managers to see the system which is their organization as a system, understand its patterns, including those driven by human incentives, goals, and desires, and optimize the system for the prevention of errors.

Without systems thinking and a desire to use it, managing a complex engineering organization is much like overseeing a factory from an overhead vantage point, but with all of the lights turned off, except small lights at each workstation, enabling each worker to see only his or her own work. Naturally all workers operate only for the good of their own workstations, because that is all they can see! Managers too, see only small spots of light and are unable to trace the workflows, see the levels of work in process or find ways to improve the process. Everyone is aware that everyone else is busy and working, and that product is getting out the door, but no one knows exactly how it all happens.

Deming advises us to talk to the front-line workers and find out what they know about what needs to be improved or optimized. Providing the lights are kept on, they often do know what can be improved, but have neither the ability nor the charter to make the improvements. Changes that will result in new ways of preventing defects from reaching our customers may be known to those on the front lines, but must be corrected elsewhere, usually far upstream of those workers. Systems thinking helps us find, analyze and implement such changes, leading to a quality engineering organization.

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Larry Kennedy is the Founder and CEO of the Quality Management Institute and has provided consulting and training services to a wide range of businesses and nonprofit organizations. His clients have included criminal justice, educational, health care, and government leaders. His inter-disciplinary background in engineering and business, together with his practical experiences as a nonprofit trustee and foundation executive have uniquely prepared him to evaluate and train managers. Dr. Kennedy held systems engineering positions in Apollo Spacecraft Operations and Flight Crew Training where he first practiced Quality Management disciplines. This scientific background honed his practical expertise in systems analysis. His later experiences as a manager and business owner broadened his understanding of process management principles. He also gained national recognition for his sales and marketing expertise. He has a broad perspective on management reform processes and the development of public and private collaborations. He was also mentored by Phillip Crosby, the world-renowned Quality Management executive, who partnered with him in reaching out to the nonprofit world.

Position Paper

Since the days of the Apollo Moon Landing, the quality of systems engineering has both improved and deteriorated even though the problems of development and deployment are relatively the same as always – people and processes that are supported by the tools of the discipline, etc. – all with the demand of satisfying a set of requirements described by a customer or customers.

The Apollo project was one of the first of the “known and public” super-systems produced by the aerospace industry. Of course those of us with connections to the defence industry know that there were many and varied “wonders” produced over the years that the average citizen rarely hears about – if ever – until they’ve become obsolete.

There are at least two levels of significance to the business and systems engineering environments of today. First, super systems require an enormous amount of vision, the courage for investment and the foresight of implementing a culture of quality management; and when properly executed, they produce big profits, impact nations and create enduring legacies.

And second, the success of super systems break down to the practice of the fundamentals of competency, ethics and self-accountability. Unfortunately, we’re seeing a drift downwards for these attributes in both business and systems engineering.

While things like computer-aided engineering have greatly improved the speed and accuracy of engineering decisions. Systems engineering has deteriorated because of the lack of due diligence, rigor, and systems thinking; the failure to apply the scientific method to research and decision-making.

The disengagement of the workforce has also become a factor (70% in the U.S. and over 80% in Europe and across all disciplines, Gallup) and it has produced lowered competencies and ethics which undermine reliable systems engineering. Higher education has also failed to produce a workforce that is highly competent with as many as 50% of four-year college graduates in the U.S. (again, across all disciplines) unable to pass a basic literacy exam. We’ve also created some unrealistic goals for quickly producing an innovation and getting it to the marketplace.

The space race was a boost to the technological age and massive innovations will continue long into our future with no end in sight. The materials, products, advanced technologies and many social supports we enjoy are the result of converting the outcomes of space exploration and research.

Our work and home cultures are now very dependent upon things that are directly affected by the work of systems engineers; everything from GPS driven services to the many and varied connections to the IoT.

So now we need to reenergize our efforts by renewing the vigor, disciplines and conscience of the system engineer’s vision and agenda.

Panel#2

Actual and Potential Impacts of Cyberterrorism Attacks on Major National Strategic Systems and the Use of Systems Engineering to Mitigate These Impacts

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Presented on: Wednesday, 13:30-14:55 in Grand Cypress Ballroom B

Keywords. cyber-attack;cyber-terrorist attack;cybersecurity

Abstract. This expert panel discusses actual and potential cyber-attacks on selected systems of international importance (e.g., the Global Positioning System, the national election systems, financial systems and industrial control systems). Panelists discuss resilience to attacks and systems security principles; how those principles can be used to mitigate the actual and potential impacts; and balancing security and privacy related to preventing cyber-terrorist attacks.

Panelists use systems engineering principles/methods such as requirements analysis; add/subtract from current international strategies; emergency preparedness strategies; and provide benefit and risk analysis. Arguments also address feasibility, affordability, the consequences for the law and personal freedoms, and the ability to prepare, respond, recover and mitigate attacks.

Systems engineers benefit from this multidisciplinary discussion. They see systems engineering principles, techniques, and practices applied to a complex multi discipline societal issue, maintaining cybersecurity. The objective, disciplined approach to problem analysis controls the emotional response to difficult problems and offers insights that inform government decision makers.

Biography

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William Mackey, Ph.D., J.D., ESEP, President of Systems Engineering Solutions, has also been an adjunct professor at the University of Maryland University College. He attended the U.S. Naval Academy and has B.S. and M.S. degrees in physics from the University of Pittsburgh and the Rensselaer Polytechnic Institute. He received his Ph.D. in systems engineering from the University of Pennsylvania and his J.D. in law from the Washington College of Law, American University. Dr. Mackey is presently President of Systems Engineering Solutions consulting in major systems engineering issues. Dr. Mackey has more than 50 years of experience in scientific research, engineering, and management applied to homeland security, aerospace, energy development, transportation, systems integration, and law. He has held a number of progressively responsible management positions, including leadership of 120 professionals involved in systems engineering, telecommunications and networking, office information systems, and major systems development in the CSC Systems Division. During 2005 and 2006 he was Vice-President of Professional Services, Vitech Corp. Dr. Mackey is a member of both the District of Columbia and the State of Virginia legal bars. He has led and served on several INCOSE WG/IG's and was Chairman of the Systems Engineering Applications Technical Committee from 1995 to 2001. He served as the INCOSE Technical Board Chairman from June 2001 to June 2004. He chartered the Anti-Terrorism International WG within INCOSE in October 2001. He was facilitator of nine INCOSE panels on Anti-Terrorism at INCOSE Symposia. Dr. Mackey has also been the Chair of the INCOSE Fellows from 2006 -2010, having served as Vice-Chair from 2005-2006. Dr. Mackey led the development of a biometric-based Pedestrian Border

Crossing Prototype intended for use by the Department of Homeland Security. It has been fielded at the San Ysidro border crossing in the United States. Dr. Mackey is presently President of Systems Engineering Solutions consulting in major systems engineering issues. Dr. Mackey has more than 50 years experience in scientific research, engineering, and management applied to homeland security, aerospace, energy development, transportation, systems integration, and law. He has held a number of progressively responsible management positions, including leadership of 120 professionals involved in systems engineering, telecommunications and networking, office information systems, and major systems development in the CSC Systems Division. During 2005 and 2006 he was Vice-President of Professional Services, Vitech Corp. Dr. Mackey is a member of both the District of Columbia and the State of Virginia legal bars. He has led and served on several INCOSE WG/IG's and was Chairman of the Systems Engineering Applications Technical Committee from 1995 to 2001. He served as the INCOSE Technical Board Chairman from June 2001 to June 2004. He chartered the Anti-Terrorism International WG within INCOSE in October 2001. He was facilitator of the INCOSE panels on Anti-Terrorism at INCOSE 2002 in Las Vegas, NV, INCOSE 2003 in Washington, D.C, INCOSE 2004 in Toulouse, France, INCOSE 2006 in Orlando, FL, INCOSE 2007 in San Diego, CA, INCOSE 2008 in Utrecht, NE, INCOSE 2009 in Singapore, SG, and INCOSE 2012 in Rome, Italy, and INCOSE 2015 in Seattle, WA . Dr. Mackey has also been the Chair of the INCOSE Fellows from 2006 -2010, having served as Vice-Chair from 2005-2006. Dr. Mackey led the development of a biometric-based Pedestrian Border Crossing Prototype intended for use by the Department of Homeland Security. It has been fielded at the San Ysidro border crossing in the United States.

Position Paper

Privacy and Security: What is the Proper Balance? William Mackey

Privacy, defined by Black's Law Dictionary, is "The right to be let alone; the right of a person to be free from unwarranted publicity." The "right of privacy", a generic term encompasses various rights recognized to be inherent in the concept of ordered liberty, and such a right prevents governmental interference in intimate personal relationships, and freedoms of an individual to make fundamental choices involving himself, his family, and his relationship with others.

Most western industrialized countries hold the right of privacy to be sacred. The US Constitution never uses the terms "privacy" or "right to privacy", so how does it come to be considered a right at all? Many of the Bill of Rights hold it as an inherent right (Amendments I to X). For instance, Amendment I – the right of peaceful assembly; Amendment IV – the right to be secure against unreasonable searches and seizures; and Amendment V – nor shall any person be compelled in any criminal case to be a witness against himself.

The issue normally arises when during war or other defensive actions, when the national interests of security often trump the right to privacy and other civil liberties. However, the issue has also arisen in abortion and birth control law, blood sample and other bodily extractions, electronic surveillance, loudspeaker volume, unwanted mail, marital relationships, name or picture appropriation, possession of obscene matter, sexual relations and individual lifestyles. Most recently, the issue has been front page news in the revelations of Edward Snowden regarding possible abuses of the National Security Agency (NSA) and the use of drones to survey landscapes. The U.S. Supreme Court is considering the future of these issues and trying to determine the bounds of electronic surveillance and the use of defensive and commercial drones.

Some ethics and information technology experts believe that privacy versus security is not a zero-sum game, and that privacy and security must improve together. By adding technological improvements (e.g. encryption) one can improve both privacy and security.

In the year 2000 there were 350 million internet users and as of 2018, there were 4 billion. Clearly the internet has gained in its importance for telecommunications in spite of potential misuse. What approaches are suggested to preserve civil liberties and provide for security in the future? For example, consider the automobile. The automobile has been an integrated system of metal, plastic, leather. Now, the automobile has a collection of electronic and sensor subsystems that monitor the wellness, location and use of the vehicle. Who should have access to this kind of information?

This presentation discusses suggested principles to balance privacy and security.

The Principles of Systems Security and Concepts of Resilience and Their Application to Cyberterrorist Attacks. William Mackey

Terrorism today is practiced by a networked distributed community, driven internally by an ideological grievance which takes advantage of vast sources of innovative technology and information externally. This 4th generation warfare has highly decentralized guerrilla tactics. When directed at critical national infrastructure, the cost of attack is extremely low compared to the large cost to the targeted systems and users. When cyber-attack is the threat the leverage is even greater. John Robb's 2007 book, *Brave New War - The Next Stage of Terrorism*, makes the irrefutable case for the terrorist's compelling advantage to target infrastructure.

Decentralized guerrilla tactics are inherently resilient, and technology fuels collaborative access to global tactical and strategic innovation. Terrorism becomes an agile self-organizing distributed intelligent community evolving under Nature's natural selection algorithm, but at speeds accelerated by global communication and technology. And cyber threats offer anonymity and relative safety to the experimentally innovative terrorist who can try again until successful. System security resilience can't simply restore functionality, no matter how quickly; it must aim to be distrustful at a granular level and functionally unaffected by attack. System security innovation can't simply invent new responses to known attacks, no matter how quickly; it must aim to be aware and dynamically reconfigurable. These underpinnings aren't present and don't appear to be driving security strategy at the systems engineering level today.

Both resilience and composable innovation are fundamental characteristics of a cyber-security strategy that leverages

the fundamental Agile Architecture Pattern and Reusable, Reconfigurable, Scalable design principles (Dove and LaBarge, IS14 paper) for its Systems Engineering concept of operations. The allocation of the architecture and design principles as applied to cyber security will be discussed in the position presentation during the panel session. There is no reason to believe that cyber terrorism can ever be defeated. We must instead develop a new generation of cyber security strategy that provides parity with the evolution of terrorism, and provides mitigation of the effects. To this end, new strategy must focus on predictive community intelligence, granular distrust, self-organized reconfiguration, peer-peer behavior monitoring, and self-organized response. These concepts are not present in current strategy to any sufficient extent.

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Stephen J. Sutton, PE, ESEP. Steve retired from TASC, Inc. in 2011 and directed the systems engineering education programs at the University of Maryland's Institute for Systems Research from 2011-2014. Currently, he provides pro bono services that apply systems engineering to a variety of non-engineering problems. He holds B.E.E. and M. Eng. (E.E.) degrees from Rensselaer Polytechnic Institute and the Engineer Degree (E.E.) from George Washington University. He is a Registered Professional Engineer in Maryland and an INCOSE Expert Systems Engineering Professional. Steve has more than 50 years of experience in systems engineering and analysis, enterprise and system-of-systems architecture, and management for telecommunications, information, and intelligence systems all of which required cybersecurity protections. He has held program management, lead systems engineering, and line management positions. Further, Steve currently serves as INCOSE's Liaison to the Accreditation Board for Engineering and Technology, Inc. (ABET) and a co-chair of the Anti-Terrorism International Working Group.

Position Paper

The Actual Impact of the Cyberterrorist Attacks on Election Systems. Stephen J. Sutton

Democracies depend on fair and free elections so that citizens can choose their elected officials. If this essential process becomes corrupted, then democracy dies. Democracies have systems that supports national, regional, and local elections. The systems has various parts: Laws and regulation; election management and operations; candidates, campaigns, all forms of media.

Systems may run centrally or distributed. Some use paper ballots with manual counting. Others use automation for efficiency, accuracy, privacy, and security. Designing an election system requires a systems engineering approach. Today, and the US provides an example, election systems that rely on automation and information stored in cyberspace have become targets for hostile entities (nation-states, terrorists, unaffiliated hackers, anti-government groups). They manipulate, destroy, release, or create information in cyberspace to influence voters. They foster distrust of election systems, steer results to preferred candidates, and induce chaos into stable societies.

The US has its federal laws that govern electing the President, Vice President, and members of Congress. State and local laws govern all elections within each jurisdiction including state-specific requirements for national offices. For instance, a Presidential candidate must file to be on the ballot in each state.

While some candidates claim election fraud, cyber-attacks on electronic systems that help manage elections and media sites pose a more serious threat to a democracy. The reasons: 1) free and open expression of opinion via traditional and new media; 2) each state has its own approach to managing and protecting elections without minimum common standards. In the US, each state and locality has its own lifecycle for its election infrastructure that depends on funding from the state or local government. Thus, the US election system has 50+ systems within which local jurisdictions manage their parts.

To ensure that the US election system has significant resistance to disruptions, the Center for American Progress suggests the following nine actions:

1. Require voter-verified paper ballots or records for every vote cast.
2. Replace old voting machines.
3. Conduct robust postelection audits to confirm election outcomes.
4. Update and secure outdated voter registration systems and e-poll books.
5. Require minimum cybersecurity standards for voter registration systems and other pieces of voting infrastructure.
6. Perform mandatory pre-election testing on all voting machines, as well as continuous vulnerability analysis.
7. Expand threat information sharing, including comprehensive threat assessments accompanied by mandatory reporting requirements.
8. Elevate coordination between states and federal agencies on election security, including real-time notification of security breaches and threats.
9. Provide federal funding for updating election infrastructure.

Each action addresses at least one perceived exploitable vulnerability of the system. Individual states have begun to improve their systems, but more needs doing. Candidates' campaigns and social media also must improve information protection and integrity. The cyber threat is real; several attempts to hack state systems have occurred. The actual impact: democracies and associated information sources must spend more resources and stay continually vigilant to ensure election systems have citizens' trust.

The panel presentation attempts to correlate the threats and vulnerabilities with the actions to thwart the threats. It also attempts to give a status of the resiliency of election systems to cyber terrorist attacks.

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Anthony P. Gigioli, M.E.M, PMP, CSEP is a Senior Systems Engineer working as a contractor in the U.S. Intelligence Community in the Washington, DC/Baltimore, MD region. He has a Bachelor's of Science degree in Mathematics from the University of South Carolina and a Master of Engineering Management degree from George Washington University. He also studied Physics (Nuclear Weapons Effects) at the Naval Postgraduate School in Monterey, CA from September 1984 until December 1986, and completed the course work for a Doctor of Science degree in Engineering Management and Systems Engineering (EMSE) at George Washington University from the Fall of 1999 until the Spring of 2004. Mr. Gigioli spent more than 15 years in the U.S. Navy as a Surface Warfare Officer, retiring in 1995 under the Temporary Early Retirement Program (TERA) offered during the drawdown of the number of ships post-Cold War. He then transitioned to the contractor community, supporting the Space and Naval Warfare Systems Command (SPAWAR) in Crystal City, VA while he worked on his Master's degree. Upon receiving his Master's, he found a job in the Intelligence Community, where he has remained ever since. He has nearly 20 years of Systems Engineering experience since retiring from the Navy.

Position Paper

Lessons Learned from Previous Cyberterrorist Attacks. Anthony Gigioli

Cyberterrorism, cybercrime, information warfare, no matter what we call it, people, organizations, and countries use the internet to attack the IT infrastructure of governments, enterprises, and individuals around the world.

Recently, JP Morgan Chase, Target, Home Depot, Anthem Blue Cross and Blue Shield, Sony Pictures, Staples, and Michaels Stores, have all experienced cyber-attacks that affected millions of people. Entire countries are vulnerable as exemplified by the attacks on Estonia's cyber infrastructure in 2007, or the Stuxnet Worm that destroyed 984 uranium enriching centrifuges in Iran in 2010. The consequences of these attacks range from stealing of names and addresses or more sensitive information like social security numbers to cyber actions approaching physical attacks.

I am a victim of this sort of crime. Several years ago, someone had gathered sufficient information about me to actually file an Income Tax Return with the IRS in my name. Luckily, I discovered this within a month of the attack when I filed my real return. I was told that there was another return already filed. I get little comfort in having five years of free credit monitoring.

What have we learned from such attacks: 1) Educate users, engineers, administrators, and decision makers; 2) Patch system vulnerabilities immediately; 3) Maintain continual awareness of activity on the infrastructure and react to attacks quickly; 4) Monitor personal credit; 5) Create a comprehensive regulatory environment that forces protection in the use of critical data; and 6) Recognize that the threat grows daily in strength and velocity and the battle continues unabated.

While these might seem like mundane and obvious countermeasures, constant vigilance is the price of security. Reactions to previous events have provoked programs to produce stronger defenses and new policies and methods, but the best defenses need not be the most expensive solutions. The most significant lesson is that individuals and organizations fail to act in accordance with established policies and put themselves at risk for cyber-attacks no matter how strident the guidance. We don't embrace the discipline needed to minimize the risk of exploitation of weaknesses and known vulnerabilities. The IEEE Center for Secure Design is an initiative to recognizing design flaws and build security in.

Systems engineers must define and deploy comprehensive, executable, and sustainable design, analysis, and operational processes and practices that actually reduce the risk of attack while still allowing systems (that includes the human component) to perform their functions as designed and expected.

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Ken Kepchar is a Sr. Consultant for a private consulting firm, EagleView Associates, LLC, which specializes in System Engineering training and consulting across the entire system life cycle, specializing in Risk & Program Management and Information System Security. Ken has over 40 years of experience in all life cycle aspects of system engineering and program management on a number of military and commercial aviation programs at McDonnell Douglas (MDC) and in Air Traffic Management at the Federal Aviation Administration (FAA). The MDC experience spans flight test engineering, subcontract management, system engineering, and includes configuration & data management and risk management for the F-4 Phantom II, F-15 Eagle, AV-8B Harrier and F/A-18 Hornet programs. Ken served as chair of the St. Louis McDonnell System Engineering tool committee and as a program management evaluator for programs across the Boeing Company. His tenure with the FAA spanned several positions as Chief System for NextGen Integration, Information Security, Enterprise Risk Management, and at the Agency's Technical Center in Atlantic City. He managed the in house SE training program, and was lead instructor for several of its courses. He is a member of the International Council of Systems Engineering (INCOSE), having held a number of positions at the chapter and International levels, including serving on the INCOSE Board of Directors. He holds ESEP Certificate #0001 and was the initial Program manager for the INCOSE System Engineering professional certification program. Ken is presently co-chair of the System Security Working Group, INCOSE representative to ISO SC-27 (IT Security Techniques) for Cyber Security standards, and associate director for the INCOSE Standards Initiative.

Position Paper

The Potential Impact of Cyberterrorist Attacks on the Critical Infrastructure Systems. Kenneth Kepchar

All countries' economies are directly dependent on critical infrastructure systems such as air traffic control. Healthcare, space applications, power grids, shipping & maritime applications, financial management, oil exploration, emergency services, and telecommunication systems. In the United States critical infrastructure (per Presidential Directive 21) is defined as: "Assets, systems, and networks, whether physical or virtual, so vital to the United States that their incapacitation or destruction would have a debilitating effect on security, national economic security, national public health or safety, or any combination thereof." Other countries have similar definitions.

While not defined as a "critical infrastructure domain" per se, the Global Positioning System (GPS) is a critical enabler for much of this country's critical infrastructure. GPS is used in every critical infrastructure domain, and its use continues to expand. Timing is the most critical aspect of Positioning, Navigation & Timing (PNT) services offered by GPS for critical infrastructure operations, and GPS is over-relied upon for that information. GPS service is so reliable that we have no way to fully understand extent of GPS outage impacts and how those impacts would cascade into the various critical infrastructure domains.

In 2011 the US government conducted a Strategic National Risk Assessment (SNRA) to evaluate known threats and hazards that have the potential to significantly impact homeland security and grouped these into three categories: natural, technological/accidental, and adversarial/human-caused. Mitigation strategies were developed for each category. Consequently, efforts to fortify and protect our national critical infrastructure must include steps to ensure GPS services remain available. What is necessary from a SE perspective to ensure this happens?

Because of the reliance on GPS, ensuring critical infrastructure protection and resiliency requires the SE to look beyond the system of interest and address vulnerabilities of interfacing systems. There are basic principles to accomplish this, namely through Integrating Security into SE decisions:

1. Establish a sound security policy as the foundation for design of secure systems.
 - Driven by the value and state of the information involved
 - Affects system (and organizational) performance objectives (viewed as an "internal system function" – one that is essential to delivering system value, but not necessarily seen as an "operational system function")
2. Architect in security to allow flexibility to adopt new technology, including a secure and logical technology upgrade path.
 - THE one constant in the security equation – Threat landscape is always changing and faster than you can react
 - System behavior should include addressing damage as well as continued operations.
3. Start early and revisit your decisions often – In particular, include system security in development of the functional architecture

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Gang Qu, Professor, received his Ph.D. degree in computer science from the University of California, Los Angeles, in 2000. He is currently a professor in the Department of Electrical and Computer Engineering and Institute for Systems Research, University of Maryland at College Park. He is also a member of the Maryland Cybersecurity Center and the Maryland Energy Research Center. Dr. Qu is the director of Maryland Embedded Systems and Hardware Security (MeshSec) Lab and the Wireless Sensors Laboratory. His primary research interests are in the area of embedded

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Position Paper

Smart Grid: A New Cybersecurity Battlefield In Power Grid. Gang Qu

The vulnerabilities of the U.S. power grid are well-documented along with various reported attacks. However, when we take a closer look at these attacks, majority of them that have received public attention and (might) have caused catastrophic impact to the society are not cyberattacks. It is the Mother Nature and physical attacks that cause blackouts and service stoppages.

Does this mean that our power network is well engineered against cyberterrorism attacks? Of course, the answer is NO. But why have we not seen any severe cyberattacks to the power grid, and what can we do to prevent such attacks from happening?

Cyberattacks are expensive. The electrical power network is one of the oldest systems and also one of most robust ones, along with the transportation system and telephone network. Since the launch of the first commercial power grid by Thomas Edison in 1882, the power network has been constantly growing and well-maintained due to its importance to other infrastructures and its vulnerability to severe weather. A significant amount of the existing equipment in the power grid, old but still in use, has no or limited access from cyber, unlike the Internet and online financial systems. Launching cyberattacks to the power grid that can cause blackouts is possible, but requires very specific knowledge and skills as well as sophisticated planning and coordination, making it not one of the top options for terrorists. Security actions are taken. Meanwhile, both the U.S. government and electrical power industry have taken proactive approaches to the security of power grid. For example, within a year of the 2013 Metcalf attack that caused \$15 million to repair the damage of 17 transformers, Pacific Gas & Electric announced a 3-year \$100 million plan to upgrade the security at its substations across the country. The U.S. Department of Energy has also invested hundreds of millions on cybersecurity. NIST has produced detailed documents on the study of vulnerabilities in the power grid. All these efforts make the power grid robust and secure.

Smart grid: the new battlefield. The two-way communication between service providers and customers in smart grid becomes a double-edged sword and makes it a new cybersecurity battlefield. With the trend of the power grid getting smarter and smarter with devices such as advanced meters and the connection to the Internet, the power grid can better serve its customers. However, the cyberterrorists will also be better equipped to launch various cyberattacks. This poses a challenging question that requires a system engineering approach, integrating cryptography, network, software, hardware, and access control among others, to solve. Currently, the smart power grid is already the number one target for malwares. But it remains secure against cyberattacks mainly because attackers have limited access to the hardware and control units.

Lessons have been learned from the banking systems, where physical robbery becomes rare, but credit card fraud, identity theft, and other online financial crimes have surged. Security must be considered as a top priority when we make the power grid a smart grid. If the vulnerabilities in smart grid do not get addressed, it is just a matter of time when we lose the cybersecurity battle in power grid to the attackers.

Application of Systems Engineering in Submarine Programs

Quoc Do (Frazer Nash Cpsultancy (Australia)) - q.do@fncaustralia.com.au
Andrew Smith (Future Submarine Program, Depart of Defence) - andrew.smith59@defence.gov.au
Terje Fossnes (Norwegian Navy) - tefossne@online.no
Olivier Dessoude (Naval Group (France)) - olivier.dessoude@naval-group.com
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Presented on: Wednesday, 10:00-12:10 in Grand Cypress Ballroom B

Keywords. MBSE;Submarines;Systems engineering

Abstract. We live in an increasingly interconnected world driven by advancements in ICT and sensors technology. This creates more complex, congested and contested operational environments for future naval platform-centric systems. Systems Engineering provides the systematic and structured approach to manage the definition, design, development and sustainment of these large and complex naval acquisition programs, including submarines, warships, and their associated support systems.

This panel brings together international practitioners from submarine programs around the world to share and discuss best practice, benefits, challenges and lessons learnt from the application of Systems Engineering and Model Based Systems Engineering (MBSE) to submarines programs. The application of MBSE to support the development of submarine capability system definition, architecture definition, functional requirements as part of the Conceptual Design stage has been an increasingly accepted practice within the maritime domain. This is due to the benefits of end-to-end requirements traceability, ensure completeness and consistency in the Conceptual Design stage, and subsequent engineering design, development, and sustainment.

Panellists from Australia, Norway, US and France have applied SE/MBSE to varying depth and breadth across the submarine lifecycle using different methods, tools and techniques. Given the varied background of the international panellists, they will identify and discuss common elements as well as the differences in approaches, and context that will help establishing a set of consolidated recommendations, lessons learned and key challenges to inform current and future application of Systems Engineering and MBSE in large-complex submarine and warship programs.

Biography

Quoc Do (Frazer Nash Cpsultancy (Australia)) - q.do@fncaustralia.com.au
Dr Quoc Do is the Submarine Systems Engineering Advisory Lead at Frazer-Nash Consultancy (Australia). He is recognised as the DSS Level 5 – Pre-eminent Consultant in three categories by the Australian Department of Defence: Systems Engineering, Capability Definition, and Systems Architecture and Integration. He is also an internationally recognised systems engineer with knowledge and experience in Model-Based Systems Engineering and Defence Architecture Frameworks (AusDAF, DODAF and MODAF), obtained through numerous collaborations with DST - Group, Royal Australian Navy, CASG, VCDF, RPDE, and Australian Army. He is currently seconded as the Future Submarine Program Systems Engineer Governance Manager. He has knowledge and experience in organisation design, Complex System Governance, Model-Based Systems Engineering (MBSE) methodologies, using SysML and system definition language, and architecture frameworks such as AusDAF, US DoDAF & UK MODAF, to model the operational domain and understand the problem space. This provides added rigour to capability systems definition and also addresses cross-projects interdependency. His leadership roles span across many professional organisations including: Past President of the Systems Engineering Society of Australia, Co-Founder of the Model-Based Conceptual Design (MBCD) Working Group, and former Associate Director Technical Review of INCOSE.

Position Paper

Submarine programs have complex sociotechnical challenges across organisational and national boundaries. The moderator will provide a view on best practice, benefits, lessons learnt and challenges for the application of Systems Engineering, and MBSE to effectively support the definition, design, development and sustainment of submarines,

focusing the following key areas:

1. Systems Engineering Paradigm - It is important to fully understand the complexity in the "problem-space" before developing solutions to avoid realisation of a "perfect" solution to the "wrong" problem! The transition to Model-Based Systems Engineering (MBSE) provides added rigour to systems engineering practice in defining, designing, implementing, integrating, sustaining and managing interdependencies throughout the lifecycle of the submarines and associated support systems.

2. Single Source of Truth - In submarine programs, often project team spans across organizational and national boundaries. These bring significant constraints to MBSE practice, project information tends to be segregated into multiple models across organisational and national boundaries for IP protection and information classification. How do we best address this constraint?

3. Systems Engineering Competency - The skills of today Systems Engineers are expanded beyond the traditional role of developing and managing requirements to being a technical leader. This encompasses the provision of systems thinking, technical leadership, integration and interoperability across a broad range of socio-technical disciplines and stakeholders in diverse and distributed work environments. How do we raise, train and sustain sufficient Systems Engineering workforce to meet the demand?

4. Systems Engineering Management - Well balanced and effective management of systems engineering activities are required to cope with the dynamic, non-deterministic, stochastic and evolutionary project environment across national and organisational boundaries. Stafford Beer's Viable System Model (VSM) may provide the key to sustainable organisational management?

As we prepare to face increasing challenges in the definition, design, development and sustainment of future submarines, we need to keep the ultimate systems engineering end-goal in mind, which is to meet that end-users and stakeholders' needs, within the constraints of the Law and Regulations, in the most effective, safe, secure and affordable way possible.

Andrew Smith (Future Submarine Program, Depart of Defence) - andrew.smith59@defence.gov.au

Mr Andrew Smith has 35 years of experience in submarine systems development, construction, and maintenance. Prior to retirement in 2016 from the U.S. Department of Defence, he served as the Submarine portfolio lead for the Space and Naval Warfare Systems Centre where he oversaw Command, Control, Communications, Computers and Intelligence (C4I) submarine and shore based systems and all classes of submarine production of Non Propulsion Electronic Systems in new construction and modernization. He then provided systems engineering support to the Naval Sea Systems Command and Space and Naval Warfare Systems Command while working for Progeny Systems Corporation and Systems Technology Forum. He has gathered experience in systems engineering, test and evaluation, and hardware and software design through work in Permit, Sturgeon, Los Angeles, Seawolf, Virginia, Ohio, and Columbia Class submarines. He is currently seconded as the Future Submarine Program Systems Engineering Director and is employed by AECOM.

Position Paper

Mr. Andrew Smith will share the Future Submarine Program Offices' experience in the establishment of an MBSE approach to Australia's Future Submarine acquisition.

The establishment of an MBSE approach in the Future Submarine Program has been an enabler in the performance of the Future Submarine Program Office as a supplier and acquirer. Examples include :

- delivering support to the Royal Australian Navy in the development of Function and Performance; Specifications for the Mission and Support Systems;
- enabling supporting analysis needed to define and bound requirements and trade off studies;
- evaluating design alternatives;

• assuring that system development occurs in a logical manner, documenting design decisions and corrective actions;

The Future Submarine Program Office has realized many benefits of MBSE:

- Reduces complexity;
- Hierarchical view covers the details to the big picture;
- Reveals disconnects ;
- Facilitates communication - visual representation of relationships and interactions;
- Reduces turnaround time for evaluating concepts and changes for decision making;
- Common data source - everyone operating from the same set;
- Views can be tailored to needs; and
- Traceability from needs to specifications.

Mr. Smith will highlight these benefits and outcomes and how the flexibility of MBSE can be used throughout the lifecycle.

Terje Fossnes (Norwegian Navy) - tefossne@online.no

Mr Terje Fossnes works for the Norwegian Defence Materiel Agency, Naval Systems, Submarine Projects as a chief engineer and Head of Systems Engineering. Terje has over 30 years of experience working on Submarine Acquisition projects. Since early in this millennium he has been head of the SE and ILS efforts during the update and upgrade of the current Ula-class submarines, and he is currently leading the SE effort for the acquisition agencies in the new joint Norwegian and German submarine acquisition program. Terje was among the first in the Norwegian Armed Forces to apply Systems Engineering principles to achieve balance between operational, environmental, and technical /

functional performance. His duties and responsibilities related to the former Frigate Project comprised a.o.: responsible for the RDD-100 Systems Engineering process, and team lead of the requirements development for the Frigate project. He has also been head of the process modelling center of competence for the Norwegian Armed Forces. During a 3-year sabbatical from the Navy, Terje was a Systems Engineering consultant in a USA based company, and Head of Systems Engineering training in Europe with respect to RDD-100. Terje is an Expert Systems Engineering Professional (ESEP), and a Certified Project Leader in the Norwegian Armed Forces.

Position Paper

In 2014, Mr Terje Fossnes reported on the use of MBSE on the Norwegian Frigate acquisition program. There was consensus in the Norwegian Armed Forces that without the use of RDD-100 and the dedicated and consistent work of the project personnel, the success of the project would have been less obvious, with respect to both schedule and cost. In this panel, Terje will add to this report with experience from the update and upgrade of the current Ula-class submarines brought forward to acquire the next generation submarines based on Military-Off-The-Shelf (MOTS) acquisition strategy. MOTS offers a different set of challenges to the military acquisition process than the bespoke design.

Tailored MOTS entails that the customer may determine capabilities not present in the pure MOTS solution that serves as the basis for the system to be acquired. The latter approach has been adopted by the Norwegian Navy for the future submarine program. The most significant implications for Systems Engineering are in the specification of requirements and in the validation as well as verification of the system.

Terje will present how MBSE will play a key role in the common work environment, and in assisting with traceability and life cycle issues for the entire submarine enterprise.

Olivier Dessoude (Naval Group (France)) - olivier.dessoude@naval-group.com

Dr Olivier Dessoude is a Systems Engineering Senior Expert at Naval Group, the European leader in naval defence. Since 2017, he holds at the same time the role of SE manager of the Cherbourg submarine shipyard, and that of SE lead for the Australian Future Submarine Program. He began his career in the French MoD, earning the rank of Ingénieur-en-Chef (Commander), Armement Corps. He started as a research engineer in multi-sensory data fusion. In 1992, he joined DCN (former name of Naval Group), holding technical and management positions in combat systems engineering and getting involved in major domestic and international programs. In 2001, he joined AREVA, a world leader in nuclear power plant building and fuel cycle operations. For ten years, he promoted and developed the Systems Engineering in the French nuclear industry, as a path to performance improvement and risk reduction for the design & build of nuclear power plants. Dr Dessoude graduated from École Polytechnique (1986) then ENSTA (1988), and holds a Doctorate in Physics from the University of Paris.

Position Paper

Dr Olivier Dessoude will present a perspective on the similarities and specificities of several major programs, carried out in the same timeframe, in terms of Systems Engineering practices and frameworks.

Systems Engineering provides the convenient and efficient lingua franca for a community as complex as a submarine program management organisation, gathering individuals with various professional backgrounds, tools, policies, laws, languages and cultures. In such an environment, Systems Engineering is especially beneficial to the analysis of customer needs in early program stages. Systems Engineering drives the convergence towards a balanced set of requirements, then towards the most valuable response in design mixing existing, adapted or developmental solutions. MBSE provides the structure on which all engineering artefacts can be anchored and shared, while preserving clarity, consistency and traceability, and enabling a disciplined process understood by all actors.

A submarine program is developed as a long-term strategy. Beyond its inherent complexity as a product, the submarine is also a knowledge management challenge. Programs usually involve training, technology and knowledge transfer over decades. Systems Engineering and MBSE are key to making knowledge explicit and available, and maintaining it through the systems lifecycle.

Furthermore, Systems Engineering and MBSE ought to be considered as a means of transformation. Each program is, at the same time, a challenge to deliver the best capacity to the customer navy, and an opportunity to gradually improve the Systems Engineering processes, models and tools, as well as individual competencies and overall maturity.

Joseph Bradley (Patrona Corp.) - jbradley@patronacorp.com

Dr. Joseph M. Bradley, received the Ph.D. degree in Engineering Management from Old Dominion University, received the Degree of Mechanical Engineer and a Master of Science in Mechanical Engineering from Naval Postgraduate School, and a BE from The Cooper Union. Prior to joining Old Dominion University, he was Deputy Director for Force Maintenance at Commander, Submarine Force, Atlantic Fleet. Prior to that, he served in various consulting roles, including Program Manager's Representative for the conversion of the USS OHIO and USS MICHIGAN to SSGNs. He is a retired Engineering Duty Officer and submariner, having served over 26 years in the United States Navy. He is a member of the American Society of Naval Engineers, INCOSE and IISE. His research interests include complex system governance, action research, project management, system dynamics, and decision making using modeling and simulation.

Position Paper

Dr. Joseph Bradley will share his extensive experience in the operation, maintenance and acquisition of submarines from a Systems Engineering perspective. This spans the entire Pacific Fleet submarine force maintenance effort, and shipyard roles in Project and Program Management, Engineering and Trade workforce leadership, culminating in the

management of the largest Naval Shipyard.

He will provide insights and lessons learnt from the on-site Program Manager's Representative viewpoint for the conversion of the first two OHIO Class submarines from SSB to SSGNs. Widely hailed as a successful program, the conversions were a complex amalgam of systems engineering activities from two prime contractors and multiple supporting organizations, systems integration was a key challenge

He will present his academic research on competencies required for complex system governance, including Systems Thinking, Project Management, Complex System Governance, Organizational Competencies, and various topics related to dealing with complexity. His current research thrusts are Complex System Governance and the science of systems engineering in large complex systems such as submarines and naval platform program.

Panel#3

Beyond Space and Weapons: System Engineering in the Commercial Enterprise

David Long
Alejandro Salado
Patrick Godfrey
Kerry Lunney
Zane Scott (Vitech Corporation) - zscott@vitechcorp.com

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Presented on: Monday, 15:30-16:55 in Grand Cypress Ballroom B

Keywords. Future of systems engineering; INCOSE's Vision; large and complex engineered systems; complexity and interdependence of system elements; systems engineering application to unfamiliar fields

Abstract. Beyond Space and Weapons: System Engineering in the Commercial Enterprise

INCOSE's Systems Engineering Vision 2025: A World in Motion sets out a call to the systems engineering community to expand its horizons and grow beyond the military/aerospace environment in which it was born.

"When we look for ways to meet fundamental human needs, we see that the solutions often lead to large and complex engineered systems — systems that can only be successful if they are socially acceptable and provide value to society." INCOSE SE Vision 2025

"Across a wide variety of domains, stakeholders are demanding increased functionality, higher reliability, shorter product life cycles, and lower prices. Stakeholders are also demanding environmentally and socially acceptable solutions that assure safety and personal security while delivering more value to the users. In maximizing value to stakeholders, systems engineers have to cope with greater levels of complexity and interdependence of system elements as well as cost, schedules and quality demands." INCOSE SE Vision 2025

Meeting the challenges posed by this vision entails opening the discipline of systems engineering to application in unfamiliar fields. Often this work requires interface and cooperation with problem-solvers whose approaches, tools and processes are novel from a systems engineering perspective. This panel will address the challenges and opportunities residing in answering the call of INCOSE's Vision.

Biography

David Long

For twenty-five years, David Long has focused on helping organizations increase their systems engineering proficiency while simultaneously working to advance the state of the art across the community. David is the founder and president of Vitech Corporation where he developed CORE™. He continues to lead the Vitech team as they deliver innovative, industry-leading solutions to help organizations develop and deploy next-generation systems. David is a frequent presenter at industry events worldwide delivering keynotes and tutorials spanning introductory systems engineering, the value of systems engineering and systems engineers, the advanced application of MBSE, and the future of systems engineering. His experiences and efforts led him to co-author the book A Primer for Model-Based Systems Engineering to help spread the fundamental concepts of this key approach to modern challenges. A committed member of the

systems community and Expert Systems Engineering Professional, David was the 2014/2015 president of INCOSE.

Position Paper

Those with a holistic systems perspective can see the system in almost everything. Applying a fit-for-purpose systems engineering approach to problems complicated and complex appears self-evident. However, as a practice and a profession, we find that we are often challenged in seeing the full reach of systems engineering. Key factors include:

- Missing the principles – Early systems engineers underpinned their practice with principles and developed processes, methods, and tools as enablers on top of these unifying and universal principles. Often, subsequent generations have been trained in the processes, methods, and tools rather than educated in the principles. As such, we are often artificially limited to problems where the shape matches our existing domain of practice.
- Process-centricity – If we are educated in process without principles, our application becomes process-centric. As a result, we struggle to tailor process to problem, missing the fit-for-purpose aspects key to a value-driven systems engineering approach.
- Differing terminology – While the fundamentals of systems engineering may be universal across application domains, the terminology differs widely based upon evolution and concern. As such, communicating across application domains often mirrors a Tower of Babel with no Rosetta Stone to map different words to common concepts.
- Name and brand disconnect – As noted in SE Vision 2025, systems engineering is practiced under many names. Worse yet, most who practice what we would term systems engineering would never affiliate with the label “systems engineer”. They may associate with a parallel term or simply consider systems something they do as part of their job. We are a practice artificially divided by name and characterized by a vague brand.
- Product-centric mindset – SE Vision 2025 calls for the application of systems engineering to all types of socio-technical systems. However, many who affiliate with the practice and the title are formally educated as engineers and are fundamentally more comfortable with hardware and software than with humans and policy. The net result is we limit our visit to products and ignore (or fear) systems engineering the enterprise or embracing the grand systems challenges at the societal level.

So while our practice may be universal across all classes of systems, we frequently self-limit. If we overcome these impediments and embrace (i) all those who practice systems engineering regardless of the name, (ii) all types of systems challenges, and (iii) all levels of practitioners, even those who treat systems as an aspect of what we do, we can begin to share and leverage insights from a diverse range of practice and practitioners. Studying those broader insights – where they align and where they differ – brings needed understanding, richness, and diversity to our practice. It better equips us with a principled foundation; a toolbox of processes, methods, and tools to tailor to the problem; and a body of knowledge which spans and connects the greater scope of systems and systems engineering. All are necessary as we seek to advance systems engineering from an often misunderstood art and practice to a highly respected discipline critical to understanding and addressing the challenges of today.

Alejandro Salado

Dr. Alejandro Salado is an assistant professor of systems engineering with the Grado Department of Industrial & Systems Engineering at Virginia Tech and the Co-Director of its Systems Engineering Program. His research focuses on applying decision analysis to improve the practice of engineering. He is pioneering research in the area of verification and validation. His approach is transdisciplinary and intersects mathematical foundations, decision analysis and methods, and behavioral and cognitive models. In addition, Dr. Salado is engaged in developing disruptive educational approaches to smooth the transition of students to engineering work, as well as to build up capabilities to operationalize engineering ethic responsibility. Before joining academia, Alejandro spent over ten years as a systems engineer in the space industry, developing and leading space systems of up to \$1b. He has published over 40 scientific publications, has received several paper awards, and his work has received federal funding. He is a recipient of the Fabrycky-Blanchard Award for Systems Engineering Research, the international Omega Alpha Association's Exemplary Dissertation Award, and the Fulbright International Science and Technology Award. Dr. Salado holds a BSc/MSc in electrical engineering from Polytechnic University of Valencia, an MSc in project management and a MSc in electronics engineering from Polytechnic University of Catalonia, the SpaceTech MEng in space systems engineering from Delft University of Technology, and a PhD in systems engineering from the Stevens Institute of Technology. He is a member of INCOSE and ASEE, and a senior member of IEEE, AIAA, and IISE.

Position Paper

SE's expansion beyond its traditional sectors will need to overcome three main challenges. The first challenge is de-learning. Most of current SE wisdom results from decades of experiences gained in the defense and aerospace sectors. Unquestionably, such wisdom base is very valuable. However, it is also heavily tailored (biased) to a few specific instances of what SE could be. Therefore, the SE community needs to pursue an effort of de-learning some of that wisdom that may be no longer applicable at all, or simply not applicable in other sectors. This effort does not only covers jargon and processes, but goes deep to practices that we consider fundamental. Second, de-learned wisdom will need to be refilled with new knowledge. If a field of general systems engineering that can efficiently and effectively reach a wide variety of sectors is desired, scientifically proven theories, laws, and methods are necessary. We, as a community, need to leave behind best practices to develop a true understanding of what systems engineering is, what and why certain tools and heuristics actually work, or more importantly, when and under which conditions they do. Engineering projects are not small endeavors that can be easily controlled in an experiment. Hence, tight collaboration between industry and academia is necessary. This leads to the third main challenge. A new education paradigm for systems engineers is necessary. Given the pace at which technology and engineering challenges evolve, the role of the

systems engineering as a senior technical manager is not sufficient. Systems engineering is required at different seniority levels with different responsibilities. Systems engineering specialties need to emerge. Hence, universities need to adopt systems engineering at the undergraduate, graduate, and doctoral levels. The experience gap needs to be shortened and programs have to focus on three main pillars: rigorous theories, pragmatic methods, and behavioral skills, all of which undergo accelerated experiential activities.

Challenges will be tough. But benefits will overpower them. Reaching to non-traditional sectors will have symbiotic effects. Some sectors, such as humanitarian projects, face problems that SE can solve, but they are unaware of what SE can do for them. In some other sectors, SE is actually practiced, but they do not know it or call it differently. Even outside of engineering, SE is practiced sometimes by ear, unknowingly. Chefs use systems engineering to create and operate high-quality menus. Artists use systems engineering to create movies and music. Non-traditional sectors may benefit from applying systems engineering tools and methods formally, not by ear. Similarly, the SE community may acquire new insights from them to tailor or refine its theories, methods, and tools. Reaching out to other domains will always be a win-win.

In this panel, I will discuss with some examples these challenges and benefits. Examples in which practice limits expansion, examples in which knowledge beyond the practice can enable expansion, examples in which expansion can benefit new adopters, and examples in which expansion can benefit traditional SE.

Patrick Godfrey

Patrick Godfrey has been a civil engineering practitioner for 50 years of which he was a Director of Halcrow, an international firm of Consulting Engineers, for 30 years and 10 years the Professor of Engineering Systems at the University of Bristol. He is now an Emeritus Professor and his aim is to help people deliver the Sustainable Development Goals within 30 years. He believes systems thinking and full set of learning skills are two sides of the same coin required for success. Patrick is a Fellow of: The Royal Academy of Engineers, INCOSE, the Institution of Civil Engineers, the Energy Institute and Honorary Fellow of the Institute of Actuaries. He is coauthor of *Doing it Differently Systems for Rethinking Infrastructure*: ICE Publishing (2017).

Position Paper

The Sustainable Development Goals provide a metric for the delivery of INCOSE Vision 2025 which in turn informs the metrics for systems impact. To meet the goals, it is generally recognized that a systemic approach is needed that recognizes that these are a mix of social, economic and environmental skills. The challenge is to deliver the outcome by 2030.

Nobody knows all the answers but we can approach this as a learning journey where we accelerate the learning process by working within a culture that values diversity, people works collaboratively, with mutual respect, humility and very importantly transparency - a learning together environment. This needs to be supported by evidence based modeling with a shared integrated support structure that generates shared understanding and feedback. It follows that evolutionary design is required as we accelerate towards the goals.

It is really inspiring to work in this way because it enables levels of purposeful creativity which of course is necessary to reach the goals. As all the stakeholders become engaged in the purpose so a virtuous cycle of change is created where many of the drivers of waste are reduced and more attention is paid to positive creative change.

It is remarkable but this widening agenda is generating opportunities for systems thinking engineers in most areas of human endeavor which includes INCOSE's traditional market.

Kerry Lunney

Ms Kerry Lunney has extensive experience developing and delivering large system solutions, including design, software development, infrastructure implementation, hardware deployments, integration, sell-off, training and on-going support. She has worked in various industries including ICT, Gaming, Financial, Transport, Aerospace and Defence, in Australia, Asia and USA. The systems delivered include combat systems, mission systems, communication systems, road and rail ITSs, flight simulators, security systems, vehicle electronic systems, gaming systems and ICT foundation systems. Kerry is Country Engineering Director and Chief Engineer in Thales Australia. In this role she provides technical leadership and governance on bids and projects, delivers technical training programs, and participates on a number of Technical Boards and Communities of Thales. Kerry is a member of IEEE, a Fellow Member of Engineers Australia with the status of Engineering Executive and Chartered Professional Engineer, and holds the INCOSE ESEP qualification. Kerry is also the INCOSE President-Elect, and has been a past-INCOSE Asia-Oceania Sector Director, and a past-National President of SESA, the Australian Chapter of INCOSE.

Position Paper

When I started my journey in the world of systems and systems engineering a number of years ago we focused on what we believed needed to be addressed to deliver a solution that met the mission needs of the client, provided the required interoperability, (yes before the term Systems of Systems was coined), and the solution was safe, secure and supportable. New analytical methods and problem-solving techniques were introduced followed by the evolution of processes, practices, tools and applications. At times, the systems theory lagged the engineering.

But where did systems engineering diverge from its roots as it took hold in the Defence and Aerospace world? Why, in many instances, did processes and practices rule the thinking of some of our brethren, and in turn gave systems engineering a narrow definition of a hard skills, process driven discipline. In turn, this reinforced the divergence of a systems engineering approach in other domains.

As my career moved in and out of Defence industry the term and perceived practice of systems engineering was my

“golden chalice” as well as my “cross to bear”. As systems engineers it is our ability to think holistically, to drive detail where necessary, and to discuss possibilities and alternatives with stakeholders in the language that was understood by each of them. It is these characteristics, the foundation of systems engineering that makes us invaluable to the successful delivery of a solution in any domain. We are and need to be adaptable – we morph to suit the different domains and stakeholders. Tailoring is mandatory – in processes, practices and language to match the mission need and the domain. We need to shift from a monoculture focus to biodiversity – in problem definition, design, implementation, verification, acceptance, support, all phases of the lifecycle.

I will present my experience in systems engineering working in multiple domains, and in different countries. I will then draw on this experience, correlate it to current evolutions, trends and new technologies to extrapolate what may be useful in the advancement of systems engineering in the future across diverse domains. Once more we can be “pioneering” modern systems engineering.

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

Zane Scott is the Vice President for Professional Services at Vitech Corporation. He is active in INCOSE and currently serves as the Co-Chair of the Corporate Advisory Board and a member of the Board of Directors. Zane is a member of the Technical Leadership Institute. He is active in the Training, Healthcare and Professional Competency Working groups. Zane comes to the systems engineering world with an unusual background, having received a BA in economics from Va Tech and a JD from the University of Tennessee George C. Taylor School of Law. He did graduate work in both Business Administration and Educational Administration (Counseling). He is a trained mediator, labor/management ADR facilitator and a hostage/crisis negotiator. Zane is particularly interested in the role of systems engineering in solving socio-technical problems outside the military/aerospace sector. He has written and blogged extensively on that subject. In 2016 he and Dave Walden of Sysnovation won a Best Paper Award for their paper on legal liability for systems engineers.

Position Paper

Systems engineering stands at a crossroads. It can continue its path as the progeny of the military-aerospace complex or it can move beyond those bounds into the many areas and problem sets where it can bring value. This choice rests on a number of advances. Systems engineering must find its principles at a conceptual level free from application specific frameworks. It must move away from a process centric orientation and live in the concept centric spaces. It must capture those concepts in language that can be easily translated into the parlance of the applications to which it seeks to move. It must see itself as the servant of the efforts to design and improve system solutions in the target application spaces and adapt to them.

If systems engineering can do these things it can begin to live into the INCOSE Vision 2025 and become all that it can be as the problem solver for the twenty-first century.

How Essential are Cognitive Flexibility and Cognitive Diversity to Developing Effective World-Wide Sustainable System Solutions?

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Presented on: Tuesday, 10:00-12:10 in Grand Cypress Ballroom B

Keywords. cognitive flexibility;cognitive diversity;strategic diversity

Abstract. Cognitive Flexibility is an individual skill related to adapting one's thinking to face new or unexpected situations. Cognitive flexibility requires creativity, logical reasoning, problem sensitivity, and the ability to tailor how you communicate your ideas, concepts, and message based on the audience, and is in the top 10 skills that will be most desired by employers by 2020 per the World Economic Forum. Cognitive Diversity is a team capability - that goes beyond gender, ethnicity, and age - to differences in styles in knowledge processing (existing or new) and leveraging ideas and perspectives (own or others) when dealing with new situations. Each panelist brings a different perspective from industry experience and academic research, leveraging a variety of approaches and tools, to investigate the role of cognitive flexibility and cognitive diversity in high performance teams, complex system designs, experience diversity, strategic diversity, and the impact of these approaches and tools on developing effective sustainable system solutions to complex global problems.

Biography

Bill Parkins (SESA, Rockwell Collins (RET'D)) - Wparkins@sesa.org.au
Bill completed his role of Principal Engineering Manager and Chief Engineer at Rockwell Collins Australia on 30 June 2018. Bill had a 25 year career in the Royal Australian Navy followed by a second career in industry built on the foundations systems engineering and management background from the Navy. Bill worked in several companies in Systems Engineering, Technical or Project management roles. Companies included Andrew Australia, Telstra Applied Technologies, Rockwell (later Boeing) and back to Rockwell Collins. Bill was a foundation member of the Systems Engineering Society of Australia (SESA) and is currently the President. He has been an INCOSE member since 1993 and is certified as an Expert Systems Engineering Professional (ESEP). Bill's ongoing professional interests include coaching and mentoring systems engineers and project managers and promoting initiatives for early career systems engineering development.

Position Paper

There is a diverse mixture of skills, styles and experience among the people involved in project teams. As a project grows in size, so does the need for specialist skills in products, tools and processes and also management of the teams. The Systems Engineering Professionals (SEP) in a project need to be able to communicate with people in the teams they interact with. The ability to recognise and understand how people interact is necessary if the best possible result is to be achieved. Cognitive flexibility in this context is the ability to elicit information from others about their needs from a system, to understand their drivers and how the interaction with them and the SE products presented back to them can be tailored to be most appealing for their strategic mindset. Agility is needed as the concepts, needs and early solutions develop to be able to be the mind that can move around looking the diverse collection of lenses and seeing where they fit and overlap. Each stakeholder has perhaps a couple of lenses, the SE must be able to look through them all. While we will have people who are 'big picture' visionaries and those who are skilled in elements of intricate detail and interfaces, we need some people with the skill to dive in and out between the two and to know when to do each (back to lenses its like being able to wear varifocals without getting a headache!). Interesting this skill can also make for very effective Project Directors. The leadership challenge is to provide the mechanisms to allow people to

interact with the individual performer and let those people get on with their roles while making interactions with others more comfortable. It might be possible to overcome a shortage of systems engineers in a workforce by understanding the different skills and styles needed to execute the necessary engineering activities 'Outside the SEP Square'. Instead of asking one brain to have cognitive diversity beyond its capacity, is it possible to build a 'whole brain' from a collection of specialists?. The essential skills required are the softer ones of enabling effective operation of this human system comprising a number of minds which integrate and interact. Our team is exploring ways to develop this concept and I will discuss progress.

Lisa Hoverman (lisa@hsmcgroup.biz) - HSMC

Lisa Hoverman is a small business owner dedicated to helping large and small STEM businesses pursue federal funding. Her company, HSMC – Healthcare, Scientific, and Medical Communications aids clients in winning federal contracts – Dr. Hoverman has led contract successes in excess of \$4B. Lisa obtained her PhD in Biochemistry in 2006 from the University of Pittsburgh and transitioned from faculty at Penn State in 2008 to a small business owner. Lisa built her business on her success from personal experience in competing successfully for grants in biochemistry as an academic. Dr. Hoverman transitioned from an academic to a small business owner supporting others in federal grant and contract capture and writing because she loved to tell the entire story (for funding!) - with the desired output, from the detailed beginning. Without knowing it, Lisa had been a systems thinker all along. Lisa helps small and large US and UK businesses pursue government funding for complex STEM systems projects. In her spare time, Lisa serves on the Board of Directors of three innovative women's groups in her local region.

Position Paper

Omega Alpha – considering the end from the beginning, in the mind of this panelist requires incredibly diverse and flexible thinking in an increasingly complex world of systems. As an avid yoga practitioner, scientist, startup angel investor, and small business owner in the federal funding space my mantra has long been 'blessed are the flexible, for they shall never be bent out of shape.' My unique perspective, specifically from that of aiding women and start-up entrepreneurs in general, suggests that cognitive flexibility in the face of many factors – the STEM factors usually being the easy ones – is key to funding, where funding often means survival for a company in our domain of complex systems. My position and view point comes down to an element that I consistently see as key among my winningest clients – the team, and the more diverse and communicative the team, the more likely their long-term success. I will present the data my company has gained over a decade in aiding over 600 clients in federal acquisition at both the highest (new National Lab) and lowest (start-up R&D funding) levels that shows that cognitive flexibility, that comes from a diverse team (diversity can be background, training, skillset, etc) to be the most successful companies in terms of federal and other funding.

Hazel Woodcock (IBM) - Hazel.woodcock@uk.ibm.com

Hazel Woodcock trained as an Electrical Engineer, and worked in the Defence and Automotive industries before discovering systems engineering. As with many systems engineers, with hindsight this was always present, and the journey had an inevitable destination. Her introduction to the systems engineering world was through requirements management and she joined Telelogic in 2005 as a consultant. Now IBM, Hazel works with customers worldwide to best fit their systems engineering practices with the capabilities of the IBM tools they are using. There are no fixed industry or geographical locations to this work, enabling a transfer of good practices across these traditional boundaries.

Position Paper

A few years ago I took the Clifton Strengths Finder test, and my top talent is Adaptability. The description tells me that it enables me to '...respond willingly to the demands of the moment even if they pull you away from your plans.' This often puts unrelated ideas next to each other in my head, and gives me the opportunity to see connections in a way that somebody stressed by change cannot. The remainder of my top five strengths are Relator, Deliberative, Context, and Intellection. Relator being associated with building one to one relationships, Deliberative is about consideration before making decisions, Context is looking to the past to inform decisions, and Intellection is about liking to think. This combination maps well to the definition of cognitive flexibility, containing creativity, logical reasoning, problem sensitivity, and the ability to tailor how you communicate your ideas, concepts, and message based on the audience. In a consultancy role, the ability to adapt communication style is hugely helpful. An understanding of our talents with the Clifton Strengths Finder can be very revealing, it consists of 34 'Talents' and the standard test gives a personalised result of your top 5. What I had previously seen as a predilection for lack of focus, and being easily distracted, showed up as a positive strength of Adaptability, which needs to be focused in that positive direction. My role drops me into client teams for workshop facilitation, and mentoring roles. Organisational culture reduces diversity of thinking to some extent, and an external consultant can broaden the options for thinking styles. As the consultant, I am exposed to an ever changing landscape of ideas and thinking styles. The best thing to do with all that variety is to share it widely, starting with the next client engagement. Much has been said in recent years about 'traditional' diversity, particularly around encouraging more women in to Engineering and other STEM areas. We do this partly because we have a lack of young people entering the profession, and so cannot afford to ignore 50% of the population, but also because we have come to recognise that a diverse team is more creative. We are moving beyond the mindset of recruiting in our own image. It is easy to tick the diversity box when I can outwardly see that I have different 'types' of people, it is harder when the diversity is hidden in how we think. I want the cautious to work with the carefree, the fine detail to work with the big picture, the shy and quiet to work with the loud and outgoing. I often ask people 'what' they are – electrical engineer, physicist, modeller, requirements expert, with minimal prompting this question will reveal some of the

diversity in the team, as well as providing a context for the conversation. The juxtaposition of ideas in my head leads to creativity and understanding. On a larger scale, that meeting of ideas and approaches in a team leads to greater innovation.

Alice Squires (Washington State University) - alice.squires@wsu.edu

Dr. Alice F. Squires has over thirty years of experience and is an Associate Professor at Washington State University. Previously, she served as Systems Engineering Manager at Aurora Flight Sciences, Senior Researcher and Online SSE Director at Stevens Institute of Technology, Senior Systems Engineer consultant to LM, IBM, and EDO Ceramics, Senior Engineering Manager at GD and LM, and Advisory Engineer/Scientist at IBM. Dr. Squires is a contributing author and editor to the Systems Engineering Body of Knowledge (sebokwiki.org) and the Graduate Reference Curriculum for Systems Engineering (bkcase.org/grcse). She holds ESEP-ACQ, Project Management Professional, Professional Engineering Manager certifications and is a lifetime member of the Beta Gamma Sigma, Tau Beta Pi, and Eta Kappa Nu Honor Societies, a Senior Member of the IEEE, a Director on the ASEE Systems Engineering and Corporate Member Council boards. She wrote: "Dandelion Wishes: A World Where We Collaborate As Equals" to be published by IEEE Women in Engineering as part of the career series in 2019. Degrees earned include a BSEE, MBA, and SE PhD.

Position Paper

Solutions to complex issues do not lie in the mind of one individual but rather are built from the ingenious integration of ideas and perspectives across many individuals contributing historically through the learning process and presently through dynamic interactive and creative brainstorming and problem solving. Both cognitive flexibility at the individual level and cognitive diversity at the group level have been shown to correlate with higher group performance. How can one measure cognitive diversity when one's 'thinking' is not a visible attribute? The AEM cube model - named after three core dimensions of Attachment, Exploration, and Managing - represents an evaluative approach to team performance prediction that integrates the fields of biology, cybernetics, and systems theory and can be used to measure cognitive diversity. While one might assume that gender diversity, age diversity, ethnic diversity or other forms of diversity on a team will also result in cognitive diversity, this is not a given. What is a given, is that practices of hiring in our own image includes gravitating towards people that think and express themselves like we do. This inhibits the building of a team high in cognitive diversity. Thus, to build the highest performing team that increases our chance of developing optimal globally sustainable system solutions, we need to invite in members of the team who think differently than we do - who we seem to disagree with more than we agree with - who take 'for the sake of argument' role. I will present research and examples that show the impact of cognitive flexibility and diversity on overall team performance and the team's timeliness and ability to develop successful solutions to complex problems.

Emmet Eckman Iii (Northrop Grumman) - Emmet.Eckman@ngc.com

Emmet C. Eckman III ("Rusty") is currently the Northrop Grumman Corporation's Program Manager for the US Air Force Cyber Unified Platform (UP) System Coordinator contract. He leads a multi contract and interdisciplinary team of engineers and subject matter experts developing, operating, maintaining and evolving the UP Cyber factory. Rusty has over 30 years of expertise in the Intelligence Community, in and out of the government, as a civilian, contractor and US Army reservist. He has experience designing, building and maintaining systems across the entire system lifecycle for customers in the Aerospace and Defense domain. Rusty obtained his BS degree in Computer Science and Political Science from the Millersville University of Pennsylvania and a MS degree in Computer Science from the Johns Hopkins University. He is a Northrop Grumman Emeritus Technical Fellow and a PMI certified PMP, an INCOSE ESEP and the current INCOSE Certification Advisory Group chair. He is also a SAFe® Product Consultant (SPC) a certified SCRUM Master and eXtreme Programming practitioner.

Eric Specking (University of Arkansas) - especki@uark.edu

Eric truly brings a unique prospective and skill set to any team with his technical background, strategic and team based mentality, personal situational based management style and recruiting experience. In 2009, Eric earned a Bachelor's of Science in Computer Engineering with a minor in math and computer science from the University of Arkansas. In 2013, Eric finished his Master's of Science in Industrial Engineering while working full time at the University of Arkansas. He is currently working on a PhD in Industrial Engineering with a focus on decision analysis and data analytics. Eric serves as the Director of Undergraduate Recruitment, Outreach, and Summer Programs at the University of Arkansas where he increased new freshman enrollment by 100%, tripled the number of summer programs, and developed a social media presence for the College. He is the current Past Chair for the American Society for Engineering Education's Committee on Diversity, Equity, and Inclusion. As chair, he led efforts to help make the engineering environment more diverse, equitable, and inclusive. Additionally, he aligned the Committee with ASEE's Diversity Strategic Plan and developed organization structure for a more sustainable Committee.

Position Paper

The SEBoK defines a system as a "combination of interacting elements organized to achieve one or more stated purposes." This is a very broad definition of a system and could include a UAV, a group of people in an office, or a summer camp. No matter the system, the goal is typically the same: maximize system's performance. Additionally, we often want to minimizing cost and stay on schedule. In this context, performance is a measure of effectiveness. Developing effectiveness typically takes a team with a leader. The effectiveness of the team depends upon its leadership, the team's cohesiveness, and the capability of each team member. One way to help develop a cohesive

team is to use personality test. Organizations use personality tests in candidate screening processes and on current employees to help encourage team cohesiveness. You will find thousands of personality tests or characteristics classifications by doing a quick online search. Some of the most popular include the Myers-Briggs Type Indicator, Big Five, The Caliper Profile, Employee Personality Profile, DISC, Sixteen Personality Factor Questionnaire, StrengthsFinder, and the Hermann Brain Dominance Instrument (HBDI). These tests are not used to measure performance but determine “fit” or improve “fit”. When used on current organization members, I believe personality tests help team members understand themselves and how to work with others. In systems engineering, personality tests aid in the development of design alternatives. We want teams to have divergent thoughts that converge to a group of solutions. Divergent thinking is difficult if everyone acts and thinks the same ways. For example, the ideal behind the HBDI is to identify individual’s thinking preferences to develop “whole” brain teams. A team that collectively can use the “whole” brain is able to better approach problems. This is essentially because of cognitive diversity. In my presentation, I will provide an overview of personality test and discussion how they can be used to increase a team’s cognitive diversity.

Panel#4

Implementing Systems Engineering in Early Stage Research & Development Projects

Gina Guillame-Joseph (MITRE Corp.) - ginajg@mitre.org
Heidi Hahn (Los Alamos National Laboratory) - hahn@lanl.gov
Ann Hodges (Sandia National Laboratories) - alhodge@sandia.gov
Mitchell Kerman (Idaho National Laboratory) - mitchell.kerman@inl.gov
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Presented on: Wednesday, 10:00-12:10 in Grand Cypress Ballroom C

Keywords. Early stage R&D;SE implementation;Graded approach (tailoring and scale-up) of SE

Abstract. A group of knowledgeable panelists from research-oriented organizations such as federally funded research and development centers (FFRDCs), e.g., study and analysis centers, research and development centers including national laboratories, will discuss their experiences, lessons learned, and opinions in implementing systems engineering (SE) principles, practices, and methodologies in early stage research & development (R&D) projects. FFRDCs may execute over a thousand different projects on an annual basis and undertake projects that range from basic research, proof-of-concept demonstration, advanced technology development, technology demonstrations, technology assessments, and support of client operations. Projects may vary in size from \$25k to over \$100M. Clients may be well versed in systems engineering and provide resources for its implementation or may not understand or want to implement any aspects of systems engineering. Application of formal systems engineering processes (e.g., DOD 5000) is often not warranted nor affordable, particularly where it is uncertain whether a technology can meet key performance goals.

The panelists will address questions and topics including:

- What are the challenges in applying SE to early stage R&D?
- When should SE be applied to early stage R&D?
- What SE concepts have the biggest "bang for the buck" in these types of projects?
- Are there triggers that could identify when SE should be applied, e.g., dollar threshold, minimum technology readiness level, stakeholder complexity, etc?
- Is there a compelling value proposition for “selling” the idea of applying SE to early stage R&D projects?
- How does one go about tailoring SE for these early stage projects that, quite frankly, may not exist for more than a year?
- What SE practices, when applied early in an R&D project, support future growth if there is a desire to “productionize” the R&D’s focus area?

Participants will gain insights into what to do (and what not to do) when implementing SE in R&D organizations, and

especially in the early stages of R&D projects.

Biography

Gina Guillame-Joseph (MITRE Corp.) - ginajg@mitre.org

Dr. Gina Guillaume-Joseph currently serves as INCOSE's Director of Outreach, Assistant Director of the Northeast Sector, and is a Past President of INCOSE WMA. She is an Information Systems Engineer at The MITRE Corporation and served as project lead, software developer, test engineer, and quality assurance engineer within the private, government consulting, and non-profit industries. Her work has won her numerous awards, to include the 2016 Black Engineer Modern Day Technology Leader Award. She was a regional finalist in the prestigious and competitive White House Fellowship Program in 2015. She obtained her Ph.D. in Systems Engineering from the George Washington University, B.A. in Computer Science from Boston College, and M.S. in Information Technology Systems from the University of Maryland. She is an adjunct professor at the George Washington University, published author, and conference presenter.

Position Paper

The MITRE Corporation's mission-driven team is dedicated to solving problems for a safer world. We are a not-for-profit company that operates multiple federally funded research and development centers (FFRDCs). If you've ever flown in a jet or used GPS, you've benefited from technology that arose from an FFRDC. But despite the name, FFRDCs are about much more than R&D. These unique organizations serve as long-term strategic partners to the government, providing objective guidance in an environment free of conflicts of interest. They work with their government partners—also called sponsors—to assist with:

- Systems engineering and integration
- Research and development
- Study and analysis

The government first created FFRDCs in the 1940s. Back then, they focused largely on national-security challenges and provided technical capabilities unavailable within government or the private sector. Today, FFRDCs work in the fields of aviation, defense, energy, health and human services, space, federal agency modernization, homeland security, and more. They exist to:

- Address long-term problems of considerable complexity
- Approach technical questions with a high degree of objectivity, and
- Provide creative and cost-effective solutions to national problems

FFRDCs have a proven record of accomplishment. They have developed new technologies and contributed to the success of others—from advanced radar and air traffic control systems to global climate models, landmine detectors, and radiation therapy treatments for cancer.

MITRE has played a significant part in many such advances, often in collaboration with other FFRDCs or national laboratories. We work across the government, through our FFRDCs and public-private partnerships, to tackle problems that challenge our nation's safety, stability and well-being. Our unique vantage point allows us to provide innovative, practical solutions in the defense and intelligence, aviation, civil systems, homeland security, judiciary, healthcare, and cybersecurity spheres.

Heidi Hahn (Los Alamos National Laboratory) - hahn@lanl.gov

Dr. Heidi Ann Hahn is Senior Executive Advisor to the Associate Laboratory Director for Weapons Engineering at Los Alamos National Laboratory (LANL). She is responsible for development of processes and tools to promote engineering capability; professional development of R&D engineers and technicians; and engineering capability assessment. She is the author of LANL's Systems Engineering Methodology (now called Mission Assurance for R&D) and the developer of and instructor for the R&D Engineering Primer; she was also a Visiting Research Professor at the Naval Postgraduate School serving as mentor for the Mission Assurance Support Tool (MAST) development project. She holds a Ph. D. in Industrial Engineering and Operations Research (Human Factors Option) from Virginia Tech and is an Expert Systems Engineering Professional (ESEP) as well as a certified Project Management Professional (PMP).

Position Paper

Los Alamos implemented an enterprise-wide systems engineering (SE) methodology in 2012 and has evolved that into a Mission Assurance program that includes the integrated application of SE, project management (PM), and quality and rigor. The most challenging thing about the initial implementation was gaining stakeholder support, especially among scientists who thought that there should be a de minimus level of rigor at which there would be no required actions. Criteria were established for determining which set of requirements apply under what circumstances. Additionally, proving the value of SE was difficult, since SE activity was widely viewed as an add-on that would add cost and schedule. A compelling example in which a very successful R&D project turned into a failure when the customer wanted several production units of the prototype – and there were no requirements documented, no drawings, no manuals, no... and the first article was deployed and we weren't getting it back – provided some leverage as a value proposition for including basic SE work products in all R&D projects.

To help facilitate adoption of the SEM by engineers and scientists not familiar with SE, we used a waterfall method rather than the traditional V model, and “translated” SE jargon into more familiar terms. We also provided a tool, the Mission Assurance Support Tool or MAST, that guides users through a series of questions (with tool tips) to help them perform risk level determination and address key SE and PM topics.

We recommend applying SE principles as early in the concept phase as possible, preferably from project initiation onward. Business and mission analysis, stakeholder analysis, and life cycle analysis are among the most valuable SE activities, ensuring that the project team thoroughly understands the problem space before progressing to solution development.

Risk level determination is used to guide the degree of rigor in SE application as well as the required reviews, approvals and documentation. Risk events/conditions reflect technical risks, including the technical readiness of the technology under development, scope definition, and work activity hazards; resource risk, including the availability of personnel and equipment, and the need for cross-organizational integration; cost and funding risks, such as total project cost, number of funding sources, earned value management performance, and funding source expectations; schedule risks, including schedule constraints and earned value management performance; and transition risks, especially those related to public interest in the project. Every project to which the SEM applies must have a written statement of need or problem definition, a list of applicable standards, and a risk level determination. Technical baselines for these projects must be under configuration control.

If I had to do it again, I would first ensure management’s willingness to enforce implementation in their own organization – implement in a vertical slice of the organization and demonstrate success before moving to an enterprise-wide implementation. I would also not recommend moving to either a more sophisticated local implementation or an enterprise-wide implementation until the organization is at at least CMMI Level 2 “Managed” with respect to its SE practices. 'LA-UR-18-30892'

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

Ann Hodges is the lead for the systems engineering part of the corporate-level Mission Assurance Framework at Sandia National Laboratories, and is currently a deputy program manager and systems engineer for a complex exploratory-phase project. She is a primary author of the Mission Assurance Framework, which is a risk-informed graded approach to the application of project management, systems engineering and quality management. She has worked over 40 years at Sandia National Laboratories and is a Distinguished Member of Technical Staff. Ann holds an M.S. in Computer Science and a B.B.A., both from UNM. Her certifications include Certified Systems Engineering Professional, CMII, and SAFe SPC4. She is Past President and Secretary of the INCOSE Enchantment Chapter. Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy’s National Nuclear Security Administration under contract DE-NA0003525.

Position Paper

Sandia National Laboratories has implemented a risk-informed graded approach to the application of systems engineering (SE), project/program management (PM), and quality management (QM). It was initially developed for a large Program Management Unit (PMU), and is currently being propagated to the rest of the organization. This PMU Vice President required his organization to use the mission assurance framework, and the adoption of the framework’s practices and artifact development continues to be tracked at the executive level monthly. A challenge in the development of this framework was determining the core set of practices that every project is required to follow – from the small best-effort research efforts to large pathfinder operational systems. The set of practices need to be at the right level of rigor to provide research-oriented projects an efficient and solid foundation for growth – either for future research efforts or further development of the research results – without stifling creativity and exploration.

The framework is applied early in the project creation phase using a rigor-level determination template, followed by the tailoring of a mission assurance plan template for the determined level of rigor. Rigor attributes consist of timing (how early, how often), scope (breadth and depth), and formality (form of artifacts, who has access). The mission assurance plan templates are based on industry standards, lessons learned, and address the rigor attributes. The industry standards include EIA-748 and PMBOK for PM, ISO 15288 for SE, and AS9100 for QM. The low-rigor mission assurance plan template contains the minimal set of practices and information for artifacts that facilitate capturing enough information for future growth, thus providing a roadmap for researchers. These are the practices and artifacts that provide the most value: a charter (why and what), milestone list, WBS, budget, change tracking, requirements management approach, risk management approach, configuration management approach, and quality control. The rigor determination is reviewed when the project scope changes or minimally yearly for required changes in rigor.

An approach that we are currently exploring is deploying a systems engineer on a research project to coach/mentor the principle investigator and technical leads on the right-sized mission assurance practices. Equipping the technical leads with enough SE/mission assurance knowledge to perform defensible research that positions the project for potential future growth shows promise for a scalable solution. (SAND2018-13035 C)

Mitchell Kerman (Idaho National Laboratory) - mitchell.kerman@inl.gov

Dr. Mitchell Kerman is Director of Idaho National Laboratory's Systems Science & Engineering Division. He has a diverse background with extensive experience in computer modeling and simulation, operations analysis, systems engineering, engineering management, and business development. Prior to joining INL, he was the Director of Program Development and Transition for the Systems Engineering Research Center (SERC), a Department of Defense University Affiliated Research Center (UARC) led by Stevens Institute of Technology in Hoboken, New Jersey. Dr. Kerman has taught graduate classes in both operations analysis and systems engineering. He is the author of two textbooks on the topics of computation and introductory computer programming and has published numerous articles in technical journals and trade publications. Dr. Kerman is also a retired Navy officer with 27 years of combined active duty and reserve experience in submarine warfare, naval coastal warfare, coordination and guidance of merchant shipping, and NATO operations. Dr. Kerman has a BS in computer systems engineering from Arizona State University, a MS in operations analysis from Naval Postgraduate School, and a PhD in systems engineering from Stevens Institute of Technology.

Position Paper

As the home of the nation's (and the world's) first nuclear reactor to provide power, Idaho National Laboratory (INL) is historically an applied research laboratory that also conducts critical, very early stage R&D in many areas applied to nuclear engineering, physics, materials, radiochemistry, and several other disciplines. Additionally, INL is one of the nation's lead resources in cyber security research especially as applied to industrial control systems.

The Systems Science & Engineering division is a cross-cutting division that supports every directorate and their major programs across the lab. Even in early stage R&D, our division is often sought out to provide support in planning, mission analysis, and requirements management. We find that there are some key challenges in applying systems engineering to early stage R&D, such as:

- Working with the research staff to "bake in" systems engineering activities throughout the R&D project and make it part of the research proposal rather than an afterthought.
- Gaining support from the Program Manager and Principal Investigator that systems engineering is a necessary activity that will contribute to successful development.
- Educating the stakeholders on applicable systems engineering methodologies and activities that will add the most value to their project.
- Scoping or creating a hybrid systems engineering "Vee" diagram applicable to the specific R&D project.
- Obtaining consistent funding for these systems engineering activities.

To date, we have been very successful in our approach, but we are looking for ways to improve and add even more value.

Nick Lombardo (Pacific Northwest National Laboratory) - Nick.Lombardo@pnnl.gov

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

Position Paper

The Pacific Northwest National Laboratory is the nation's premier laboratory for scientific discovery in chemistry, earth sciences, and data analytics and for solutions to the nation's toughest challenges in energy resiliency and national security. Founded in 1965, PNNL is operated by Battelle for the U.S. Department of Energy's Office of Science. At PNNL, our mission is to transform the world through courageous discovery and innovation. PNNL stewards 19 core capabilities in the execution of ~2000 projects annually. Given the focus on both basic and applied research, as well as the wide range of project types and technology readiness levels, a one-size-all formal system engineering (SE) approach is not viable.

Projects are the fundamental building blocks of PNNL and the successful execution of projects is so critical for its future. As a result, PNNL has instituted a Project Management Office construct where Project Management Office Directors (PMODs) are appointed to evaluate and accept risks associated with new and existing projects and set, maintain, and ensure standards for project management across PNNL. An "electronic risk and prep" system has also been developed to assist the PMODs evaluate general, corporate, customer, and technical risks associated with proposals and projects.

As a result of an internal investment to enhance PNNL's SE capability, a SE framework was developed. The framework defines a set of SE trigger questions that determine the "SE track" that a proposal/project may fall in (e.g., no SE, light SE). It also defines a set of systems development risks that span the project lifecycle and that can be assessed by the

PMOD in conjunction with other project risks. For each risk, different risk levels are defined and a set of mitigation actions—based on sound SE practices—are defined. The optimal time to perform the SE risk assessment is at the proposal stage where SE scope may be integrated into the project plan.

The creation of a SE framework represented a significant step in institutionalizing SE at PNNL. Its use, however, is highly dependent on the internal organization. For example, organizations focusing nearly exclusively on basic science do not use the framework. Others that are more focused on technology development use the framework on an ad hoc basis or largely rely on the SE rigor written into the project/program execution plan. To address the ad hoc use of the framework, an effort has been undertaken to train project managers (PMs) on system engineering fundamentals and the primary system development risks. It is believed that by giving PMs a fundamental awareness of SE and SE risks, they will begin to organically implement key elements of the framework to improve their ability to meet budget and schedule, and improve the maturation and transition of their technology. In the end, not all projects need systems engineering, but all projects can benefit from systems thinking. For the projects that have some level of SE content, the risk-based approach to SE tailoring (aligned with technology readiness levels) is a “light” touch that is generally accepted by PMs.

Frederic Autran (Airbus Defence and Space) - frederic.autran@airbus.com

Frédéric Autran is Systems Engineering Senior Expert in Airbus Defense & Space. He has an engineer degree from Ecole Centrale de Paris (1984). After 5 years in the development of Computer Aided Software Engineering environment (used for the A320), he acted for 8 years as a consultant for the French Ministry of Defense and contributed to the building of the semantic interoperability framework for the various French Army C3I systems. He joined Aérospatiale in 1997 to set up the management of interoperability among systems composing the new command and control system for the French Air Force, and introduced emerging Systems Engineering principles in this programme. Since 2000, he is involved in the deployment of Systems Engineering in Airbus Defence and Space, from process definition to project coaching. At corporate level, in the frame of the PLM Harmonization Center, he chaired from 2011 to 2014 the “PLM4SE” group harmonization projects that defines the interface between Systems Engineering activities and the Master Product Definition. He is a member of the Airbus group Systems Engineering Steering Group (SESG). Outside of Airbus group, he created in 2005 and chaired until beginning of 2009 the System of Systems and Complex Systems working group of AFIS (French chapter of INCOSE). He chaired the Tool Vendor Challenge of the INCOSE International Symposium in 2012. He was certified INCOSE Certified Systems Engineering Professional (CSEP) in 2009, and Expert Systems Engineering Professional (ESEP) in 2013. He is a member of the INCOSE Certification Advisory Group (CAG) since July 2014 and served as Chair in 2017.

Position Paper

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

Early stage of system development is a challenge for systems engineers. I will define early stages as all what happens before development is actually planned and resources are allocated. It can be a bid phase, or a feasibility study, or even a proof of concept. We all know that the lack of proper systems engineering at that time is likely to provoke disaster during development. On the other hand, there is limited budget, because all what we do is at risk (risk of no-go decision). There is a tendency for discarding all SE activities that do not provide tangible marketing material. But we shall also remember that the goal of any commercial company is not only to get contracts, but to have profitable contracts. This is what SE should support, by carefully analysing the problem and solution scope, identifying potential issues, and focusing the early engineering effort of the risky part of the development. This does not only addresses technical risks, but as well uncertainty on real operational needs, impact of the industrial organisation (e.g. multinational workshare – aka geographical or industrial return - decided by governments and not by engineers!). SE shall give inputs for an informed go/no-go decision.

Another important contribution of early systems engineering is the identification of technologies to be developed. Here is the link with laboratories (private or public). Early stage system development shall sketch a system/solution concept. The concept will rely on technologies, whose TRL may be too low for being used in the final product as such. Planning TRL increase shall be done in alignment with system development schedule. Thanks to appropriate SE techniques applied for technology development, it should be possible to evaluate the risks that the candidate technology is not mature enough when system realisation begins. It should be a matter of classical risk management to decide to include or not this technology in the product to be developed. And maybe launch anyway the technology development so that it is available for the next system. To summarise my "commercial company" point of view, any technology development needs to be justified by a need regarding development of an end product, and systems engineering of this end product shall be used to set the targets of the technology R&D.

Set-Based Design

Gregory Parnell (University of Arkansas) - gparnell@uark.edu
Dennis Buede (Innovative Decisions Inc.) - dbuede@innovativedecisions.com
William Miller (Steven Institute of Technology) - wmiller@innovativedecisions.com
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Presented on: Tuesday, 10:00-12:10 in Grand Cypress Ballroom C

Keywords. Set-Based Design;Systems Design;Systems Analysis

Abstract. Set-Based Design (SBD) is a concurrent engineering technique for system design and systems analysis. Toyota developed SBD to develop better designs on a shorter schedule. The Department of Defense (DoD) is exploring SBD to address the problems of lengthy acquisition cycles, performance shortfalls, and cost overruns. The Navy, Army, and Air Force are interested in applying SBD to improve tradespace exploration, select affordable concepts for development, and shorten the acquisition process. The panel will present their experience with SBD, the advantages and disadvantages of SBD, and the technical and organizational challenges for implementing SBD.

Biography

Gregory Parnell (University of Arkansas) - gparnell@uark.edu

Dr. Gregory S. Parnell is a Research Professor in the Department of Industrial Engineering at the University of Arkansas 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 is an INCOSE Fellow. He has a Ph.D. from Stanford University. He is a retired Air Force Colonel.

Position Paper

Set-Based Design (SBD) is a concurrent engineering technique for system design and systems analysis. System analysts perform Tradespace Exploration to assess requirements and identify affordable designs. A necessary condition to perform SBD is to have an integrated framework with MBE that calculates all the performance measures, the overall design value, and the life cycle cost for every possible combination of design decisions. Implementing this framework requires physics models, performance models, and a life cycle cost model. Integrated means that the design decisions simultaneously calculate the performance, value, and cost. SBD can inform system requirements and evaluate design options. We have used a UAV case study with an integrated Model-Based Engineering framework with SBD to identify potential designs, assess design feasibility, inform requirements, and evaluate feasible designs. We use SIP Math from Probability Management© to explore 100,000 potential systems concepts in near real-time. We found that only 2.7% of the potential designs were feasible. We validated that SBD finds the efficient frontier in the value versus cost tradespace. We used SBD to inform systems requirements by identifying the number of potential feasible designs in the tradespace for each requirement or combination of requirements. We also used SBD to evaluate design options.

Dennis Buede (Innovative Decisions Inc.) - dbuede@innovativedecisions.com

Dr. Buede has over forty years of experience in both the theoretical development and engineering application of decision support technologies. He received his Ph.D. and M.S. from the Engineering-Economic Systems Department of Stanford University and his B.S. in Aerospace Engineering from the University of Cincinnati. He has been a Professor of Systems Engineering and Engineering Management at Stevens Institute of Technology and Professor at George Mason University. He has done extensive research in the fields of decision analysis, data fusion, probabilistic modeling, and systems engineering. He has pioneered in the development of new decision methodologies in the areas of system

design and evaluation, and resource allocation. He has authored *The Engineering Design of Systems: Methods and Models*, coauthored a book titled *Decision Synthesis*, and authored or coauthored numerous professional and technical papers in the above fields. He belongs to the Institute for Operations Research and Management Science, and the International Council on Systems Engineering. He is a Fellow of INCOSE.

Position Paper

The Department of Defense (DoD) is exploring Set-Based Design (SBD) to address the problems of lengthy acquisition cycles, performance shortfalls, and cost overruns. These problems can be attributed to current DoD processes, which force Program Managers to select a point solution too early in the development cycle despite the presence of significant uncertainty, and therefore risk. The root problem is that the design space is not understood with enough certainty when the acquisition process pushes for a point design. As the design problem becomes better understood, rework is needed to compensate for poor initial design solutions and meet new requirements.

The focus of my discussion will address what the key uncertainties that need to be resolved as part of SBD and what systems engineering activities should be most productive at resolving these uncertainties. These systems engineering activities typically do not receive as much attention as they should. We will also explore some analytical methods that can be used to guide the decision making associated with SBD as these uncertainties are resolved.

William Miller (Steven Institute of Technology) - wmillers@innovatedecisions.com

William D. Miller, INCOSE Founder awardee (2017), is editor-in-chief of *INSIGHT practitioners' magazine*. He leads the systems community Future of Systems Engineering (FuSE) initiative and co-leads the NDIA/INCOSE Mission Engineering initiative. Bill worked previously at Bell Labs (20 years) and AT&T (5 years). He is executive principal analyst with Innovative Decisions, Inc. and a researcher and adjunct with Stevens Institute in the School of Systems & Enterprises, where he researched mission engineering competencies. Bill is co-author with Dennis Buede of the 3rd edition of *The Engineering Design of Systems: Models and Methods* and also contributed to *Trade-off Analytics: Creating and Exploring the System Tradespace*, edited by Greg Parnell. Bill is a 3-term former secretary of INCOSE and former Technical Director (2013-2014). He has BS and MS degrees in electrical engineering with emphasis in control systems and digital design.

Position Paper

Set-based design (SBD) to perform mission engineering has the potential to increase the trade space for feasible mission threads and mission webs compared to current manually generated point solutions that are fragile to counter measures.

Mission Engineering is defined by the US Department of Defense as –

? Disciplined translation of mission needs into a Enterprise Mission Architecture providing the foundation to subsequently develop solution architectures and field systems

? Synchronization of solution architectures and system dependencies to achieve the enterprise mission architecture and meet the mission need

? Champion Capability-Enabling Technical Practices across the department to enable more relevant, timely, and agile solution architectures and systems

? Authoritative identification of Technical Risk, Opportunities, and Data-driven Insight to address decisions at all levels: chief engineer, PM, decision authority.

The focus of mission engineering is enterprise-level systems-of-systems (SoS) architectures, interdependencies, enabling practices, and authoritative technical insight to achieve end-to-end mission effects.

The scale of potential combinations and permutations of assets with individual capabilities to achieve the desired end-to-end mission effects is enormous, with humans in and/or on the loops of such SoS, and non-determinism in the context of thinking/adaptive comparative opponents or competitors. The UAV case study is extended to UAV swarms to demonstrate the value of SBD for mission engineering.

Robert Borderly (University of Michigan) - rbordley@umich.edu

Dr. Robert F. Bordley, Professor and Program Director of Systems Engineering, University of Michigan of Ann Arbor. Vice-chair of lean systems engineering working group and President of Michigan chapter of INCOSE. Bob worked previously at Booz-Allen-Hamilton for six years after retiring from General Motors. Bob has ninety publications and has been closely involved in the successful tailoring of systems engineering to the automotive domain.

Position Paper

Set-based design should be informed by research in two areas:

(a) Random utility theory which specifies the utility of a set of alternatives with constant variance

(b) Target-oriented utility theory which focuses on the probability of an alternative satisfying a possibly uncertain target

Ed Pohl (University of Arkansas) - epohl@uark.edu

Edward A. Pohl is a Professor and Head of the Industrial Engineering Department and holder of the 21st Century Professorship at the University of Arkansas. Ed has previously served as the Director of the Center for Innovation in Healthcare Logistics (CIHL) and as the Co-Director of the emerging Institute for Advanced Data Analytics at the University of Arkansas. Ed spent twenty-one years in the United States Air Force where he served in a variety of engineering, operations analysis and academic positions during his career. Ed received his Ph.D. in Systems and Industrial Engineering from the University of Arizona. He holds a M.S. in Systems Engineering from the Air Force

Institute of Technology, and M.S. in Reliability Engineering from the University of Arizona, an M.S. in Engineering Management from the University of Dayton, and a B.S. in Electrical Engineering from Boston University. Ed has published more than 50 peer reviewed Journal Articles, 50 conference papers and given more than 100 presentations at national and international conferences. Ed is a Fellow of IISE, Fellow of SRE, Fellow of ASEM, a Senior Member of IEEE, Senior Member of ASQ, member of INCOSE, INFORMS, ASEE, and MORS.

Panel#6

Social Systems-Where Are We and Where Do We Dare to Go?

Ian Presland (Charterhouse Systems) - ian@charterhouse-systems.com
Erika Palmer (Ruralis- Institute for Rural and Regional Research) - erika.palmer@ruralis.no
Donna Rhodes (Massachusetts Institute of Technology) - rhodes@mit.edu
Cecilia Haskins (Norwegian University of Science and Technology) - cecilia.haskins@ntnu.no
Christopher Glazner (MITRE Corporation) - cglazner@mitre.org
Camilo Olaya (Universidad de los Andes) - colaya@uniandes.edu.co

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Presented on: Monday, 13:30-16:10 in Grand Cypress Ballroom A

Keywords. social systems;INCOSE SE Vision 2025;social systems engineering

Abstract. Expanding the capacity of systems engineering to include evaluating and designing social systems is a desired goal as stated in the INCOSE SE Vision 2025. Systems engineering applications in socio-technical contexts, from management and organizational to learning and education studies is already documented. There is room for adaptability in systems engineering methodology to accommodate a further reach into the social domain. The growing interest in this expansion is leading to the establishment of a sub-field of systems engineers: social systems engineering. Though few in number, social systems engineers adapt and apply systems engineering tools in a range of social policy areas in industry, government and academia. Examples of these applications include not only social policies such as healthcare, pension, and homelessness, but also the investigation of social phenomena such as gender equality. In order to further develop social systems engineering and bring together those who are currently working in this domain, we need to establish "where are we now?", "where do we want to go?" and "how do we get there?" This panel will define the context and discuss the current state of social systems engineering and elicit feedback from attendees for how to bring social systems engineering into the mainstream of systems engineering. INCOSE has an important role in the development of social systems engineering, and the panel will address where social systems engineering fits into the framework of systems engineering practice and how it can be supported by INCOSE.

Biography

Ian Presland (Charterhouse Systems) - ian@charterhouse-systems.com
After graduating from Bristol University with a BEng in Electronic and Electrical Engineering in 1980, Ian worked as an electronics engineer before moving into firmware, software and finally systems engineering where he has spent the last 25 years. His full lifecycle experience covers multiple sectors: aerospace, defence, automotive, transportation and learning and development including several senior leadership roles. In 2015, Ian left corporate life to establish an independent consultancy which now supports a variety of clients in the UK and internationally in the areas of competence development, process optimisation and architecting. He lectures in Systems Engineering at Warwick University (UK) and for the University of California (Irvine). Ian is a Chartered Engineer, Member of the British Computer Society, Fellow of the IET, INCOSE ESEP and is the current INCOSE UK Professional Development Director. His other INCOSE activities include two terms on the INCOSE Certification Advisory Group and most recently as editor and co-author of the recently updated INCOSE Systems Engineering Competency Framework. In 2017, Ian was awarded an INCOSE Outstanding Achievement Award for his work in Certification and Professional Development.

Position Paper

MODERATOR STATEMENT

I'm going to start the conversation with just a few thoughts, which I hope the panellists will take-up as challenges or as

inputs to their positions...

Just how much of a systems engineer's role is actually "social"? Many of our solutions have a deep relationship with human beings: We respond to a need. We use a solution. Human behaviour impacts systems and systems impact human behaviour. So, is there a relationship between systems engineers and social scientists? And if there is, are we exploiting it successfully?

INCOSE's Vision 2025 develops several themes. They include embracing and learning from the diversity of systems engineering approaches and applying systems engineering to help shape policy related to social and natural systems and moving decision-making in this area to leverage a systems approach in order understand the diverse set of stakeholder needs and the implications of various policy options.

So, regarding Vision 2025, if we assume that social systems engineering (SSE) is at least a part of the future of INCOSE, what are we doing, and how are we doing?

For a second topic, I will mention INCOSE's latest publication, released in July 2018: the New Systems Engineering Competency framework; the result of a six-year global academic and industrial collaborative development containing contributions from experts in many countries, national and multinational organisations and domains.

The framework was designed as a structure through which organisations and individuals define systems engineering capabilities, roles and learning and development interventions in an internationally-standardised way. The INCOSE international working group wanted to define the framework so that it could be deployed in any domain. To do this, the framework is expected to require tailoring to reflect domain-specific language and concepts.

Since we know that some are already deploying systems engineering in the SSE domain, another obvious question is "CAN the new framework be tailored to reflect systems engineering capabilities, roles and learning and development interventions in social systems engineering (SSE) or is there something missing?" As a non-traditional domain for systems engineering, this would be a significant test to the adequacy of the framework and its aspirations towards becoming a global reference point. Of course, if tailoring is not feasible, we have different questions to ask, such as "Why after 6 years collaboration, does the new framework fail to encompass the needs of this developing area?" or "What can be done to improve the product to support SSE?"

Overall, I see my role as moderator as examining the evidence presented by the other panellists, so we can get a coherent picture of the status of SSE in the community and conclude how (or indeed if) INCOSE is responding adequately to the challenges it presents.

Assuming this is an area we feel would benefit from further work or improved focus, we might then ask, "What work needs to be done to clarify or elaborate INCOSE's position or work products in this area?"

Oh, yes - and one final question: "What is the best name for this area of systems engineering?" Some may feel that the term "social systems engineering" has rather undesirable connotations...

Erika Palmer (Ruralis- Institute for Rural and Regional Research) - erika.palmer@ruralis.no

Erika Palmer is a social systems engineer with a PhD in Systems Engineering and Social Policy from the University of Bergen, Norway. She holds an MSc in Industrial Ecology, an MSc in Bioarchaeology and a BA in Psychology. Her PhD project used systems engineering methodology for the evaluation of Norwegian social policy systems, applying system dynamics modeling to investigate the social sustainability of pension and sickness absence systems. In several papers, Erika has used systems engineering to evaluate structural gender inequality in social systems. She is currently a research scientist at Ruralis - Institute for Rural and Regional Research, a national applied social science research institute in Norway. At Ruralis, Erika uses systems engineering in a variety of social science research projects, on topics such as: agricultural policy, farmer well-being, rural social policy, land rights and social inequality. Her work also focuses on the development of systems engineering methods for application in social science research projects, including the development of methods for quantifying notoriously difficult to quantify social and cultural variables. Erika has previously served as a lead for EWLSE-Empowering Women Leaders in Systems Engineering and has been active in the System Dynamics Society, chairing the System Dynamics Colloquium 2016-2018.

Position Paper

We're doing it anyway! The "where are we now" in the social sciences and the argument for developing social systems engineering as a sub-field of systems engineering.

Almost no social scientists have heard of systems engineering or INCOSE. Yet, the argument that systems engineering can/should/will venture into the social domain assumes that the application of systems theory by social scientists does not already exist. Social scientists are not immune to systems. Systems thinking in social science disciplines is not common, and social systems engineers are rare, but one can find systems thinking in the social sciences on both the theoretical and methodological level. On the theoretical level, as an offshoot of general systems theory, sociologists developed sociological systems theory. On the methodological level, there are both qualitative and quantitative methods for evaluating social systems. Formal (i.e. quantitative) systems modeling is not unheard of in social science disciplines. For those outside the social sciences, social science disciplines have a reputation for being soft on quantitative methods. This is not without basis in reality, as the social sciences have strong qualitative methods. When it comes to quantitative social science methods, social scientists almost exclusively focus on statistics. Quantitative systems modeling in the social sciences does exist, though it is not common. When it is used, it most often takes the form of structural equation modeling, agent based modeling, discrete event simulation and system dynamics modeling. Low hanging fruit for systems engineering in the social sciences is the evaluation of social policy. Examples of applications in academic research include health care, poverty and pension. High hanging fruit, though application examples exist, is the investigation of social phenomena, such a gender inequality.

Social scientists who have ventured into the application of systems engineering methodology have usually done so by

chance. I would argue that there are social scientists who are informally social systems engineers without realizing it. The term social systems engineering is foreign to social scientists in general, but by using the term, it gives a home to those in the social sciences who use a systems approach – those who are formally using systems engineering methodology and those that want to learn. It also gives a home to systems engineers who crossover into the social sciences, and social systems engineering can become a resource for systems engineers and social scientists alike who want to add value to their projects by dipping their toes in each other's ponds. By developing social system engineering as a sub-field and giving these practitioners a home, it will foster the development and adaptation of systems engineering methods for social systems at greater speed. I agree that there is an issue with the term social systems engineering. Social scientists automatically recall social engineering. The use of the term is growing however, and the increasing use and an improved dialogue between the social sciences and systems engineering will change the perception of social systems engineering within the social sciences.

Donna Rhodes (Massachusetts Institute of Technology) - rhodes@mit.edu

Donna H. Rhodes is a principal research scientist at the Massachusetts Institute of Technology, and director of the Systems Engineering Advancement Research Initiative (SEARI), a research group focused on advancing theories, methods, and practice of systems engineering applied to complex sociotechnical systems. She teaches, conducts research and consults on innovative approaches and methods for architecting complex systems and enterprises, designing for uncertain futures, and human dimensions in model-centric enterprises. Her research is informed by her formal education in anthropology, systems science and engineering, and by her prior career in industry where she held senior leadership positions at IBM, Lockheed Martin, and Lucent. Dr. Rhodes is a Past President and Fellow of the International Council on Systems Engineering (INCOSE), and recipient of the INCOSE Founders Award. She received her Ph.D. in Systems Science from the T.J. Watson School of Engineering at Binghamton University.

Position Paper

Pursuing a Dual Approach

Social systems engineering is emerging as a renewed area of interest in the systems community. While to some social systems may seem outside the bounds of the landscape where systems engineering is most needed, there are many arguments against this perspective. Many of the earliest pioneers in the systems engineering field thought deeply about the social dimension, exploring underlying theory and principles as well as the application of methods from systems engineering to societal problems.

In his 1962 book, Arthur D. Hall states, "the environment is the source of knowledge for every phase of systems engineering". He asserted that the environment could be divided into three: (1) physical or technical, (2) business or economic, and (3) the social. Hall believed a study of these environmental factors should consume a large fraction of the systems engineer's time. He further divided the social environment into large-scale social factors and small-scale influences of individuals on system design.

Hall noted that several subfields of interest to the systems engineer in regard to the total environment come from sociology. The first is "social physics" (a term dating back to the 1800s), as it relies heavily on physical analogues to describe social phenomena. The second is concerned with the study of cities in their many forms. In today's landscape, we see significant research on these very same areas. Today, social physics research involves analysis and discovery of social phenomena and behavior through big data analytics and machine learning. The use of systems approaches in the study of cities is a key area of current research, particularly with urbanization shifts and the technology that enables smart-cities. Fifty years ago, the social environment received minimal attention within the field of systems engineering, whereas today it rises to the level of importance of the technical and business factors.

Another pioneer in the field, Harold Chestnut, came to realize the importance of collaboration between systems engineers and social scientists. Chestnut was influential in the development of systems engineering and control theory, and authored one of the earliest books on systems engineering methods. As a new graduate student transitioning from the social sciences field to systems science and engineering, I had the opportunity to study with him when he was a visiting scholar at my university following his retirement. I was deeply influenced by our conversations of how he had increasingly turned his attention to applying systems engineering and control methods to societal problems, specifically world peace. Chestnut described the positive contributions of our field, but noted that we as engineers have also helped to create "...a world in which international relations are such that the very civilizations we have helped to build over centuries can be destroyed in a matter of hours". He had a deep conviction that "control systems people, working with persons skilled in other professions, can increase the likelihood for a considerable improvement in international relations in the years ahead".

Accordingly, he started a working group Supplemental Ways for Improving International Stability (SWIS), and subsequently a foundation. The importance and urgent need for social systems engineering has never been greater, as societal challenges overshadow the technical ones. The question arises as to whether we as systems engineers need a specialization of social systems engineering, or need to focus our efforts on supporting social scientists by applying engineering principles and methods in collaborative societal endeavors. I advocate for taking a dual approach.

Cecilia Haskins (Norwegian University of Science and Technology) - cecilia.haskins@ntnu.no

Cecilia Haskins entered academia after more than thirty years as a practicing systems engineer. Her career spans large and small firms, commercial and government projects, as employee and entrepreneur. During the mid-1990's she was actively part of the tool creation community working on early generations of model-based systems engineering products. Her educational background includes a BSc in Chemistry from Chestnut Hill College, and an MBA from

Wharton, University of Pennsylvania. This combination has contributed to her ability to understand issues with an insider's view of both the business environments and the technical solution domains. She has been recognized as a Certified Systems Engineering Professional since 2004. After earning her PhD in systems engineering from NTNU she developed and teaches an overview course with a novel lab. Her research interests include engineering education, and innovative applications of systems engineering to socio-technical problems such as those encountered in software intensive systems, sustainable development, and global production systems.

Position Paper

Deja-vu all over again!

Five years ago, INCOSE dedicated and issue to the interpretations of agile systems engineering. Today we take up the topic of deciding whether we are talking about <social systems> engineering, versus social <systems engineering>. First, we need to unload some historical baggage that has kept this topic in the shadows because of abuse by authoritarian regimes and other experiments in social engineering that have given the term a negative connotation. For example, in the realm of cybersecurity, "Social engineering is the art of manipulating people so they give up confidential information" (www.webroot.com/).

Evidence exists that the time is right for INCOSE to step up their involvement or miss the opportunity to shape this evolving discipline.

- New Wiley publication –Social Systems Engineering: The Design of Complexity, by César García-Díaz (Editor) , Camilo Olaya (2017)

- Engineering Social Systems research agenda supported by institutions such as MIT, Harvard, and Northwestern (<https://content.sph.harvard.edu/ess/>) addressing topics that include Big Data for Social Good and Global Health
- WOSSE – World Organization of Societal Systems Engineering (wosse.org) – a non-profit formed to build a network of experts interested in solving Business and Societal Sustainability problems, using a framework they call Societal SE (BTW – they use an INCOSE definition of SE, their President, Dr. Dieter Feldmann is an INCOSE member)

On the personal front, I dedicated my own PhD study to addressing ways that systems engineering methods could be applied to decision making in the domain of industrial ecology. I have advised other PhD's who have taken up similar topics, such as simulations of Norwegian customer's response to adopting pellet burning stoves as an alternative to coal or other fossil fuels. In my master's level overview course on systems engineering my students designed a Compact Urban City solution in their 2018 lab (<https://mediasite.ntnu.no/Mediasite/Catalog/catalogs/tpk4185>). Early definitions of the term looked at analyzing humans and societies in the same way scientists and engineers analyze machines in an effort to derive maximum societal efficiencies. The University of Pennsylvania Wharton Graduate hosted Russel Ackoff's department of Social Systems Science in the period where he was refining his views of the evolution of this discipline from deterministic (e.g., mechanistic) and animate (e.g., organismic), to social, and ecological systems and models. His writings explore the consequences of viewing society through these different lenses. It is my opinion that it is time to pick up the thread in INCOSE and derive benefits from ongoing research conducted in various working groups, such as the Systems Science WG, and others.

Christopher Glazner (MITRE Corporation) - cglazner@mitre.org

Dr. Christopher Glazner is a senior principal systems engineer and Department Head of Model-based Analytics at the MITRE Corporation, where he leads development of decision-oriented models of socio-technical systems for the U.S. Government, including the Department of Homeland Security, Department of Veterans Affairs, Internal Revenue Service, Department of Defense, Census Bureau, the Intelligence Community, and the U.S. Courts. His research focuses on rapid development of models that improve learning and understanding at the intersection of technology and decision making. Dr. Glazner holds a Ph.D. in Engineering Systems and an M.S. in Technology Policy from MIT, and bachelor degrees in Electrical Engineering and Plan II Liberal Arts from the University of Texas at Austin.

Position Paper

Social systems engineering is critical – but don't travel the path alone!

Few would argue that social systems do not exhibit all of the hallmark complexity of our most complex technical systems. They are highly interconnected with tremendous opportunities for feedback and with dynamic behaviors that are clearly driven by the structures, processes, and rules around them. To the system engineer, this is a domain crying out for our approaches and tools to design and improve them! When we step back and look in practice, however, governments and other authorities typically do not seek the advice of technically trained engineers or do so only late in implementation at a low level; these complex social systems and programs are largely designed by policy makers and social scientists.

In truth, social scientists can benefit from the rigor of systems engineers, and systems engineers can benefit from the far more nuanced practical and theory-driven understanding of social structures that violate the traditional engineering mindset of "solve the equation for x." As we have heard on this panel, there are social scientists in practice who are applying principles of systems thinking, and even some applying systems engineering methodologies. Largely, however, this has occurred out of chance and necessity, and is not the core capability of these systems-oriented social scientists. For systems engineers seeking to apply their methods to social systems, we often see a different dynamic: most classically trained engineers seek to put social systems into the same design paradigms as other technical systems where designs are optimized subject to constraints, with an optimal design presented with three decimal places of precision. While the trend in the practice of systems engineering has been to embrace uncertainty and diverse stakeholders with conflicting needs, the application of systems engineering to social systems by systems

engineers in practice can often rub policy makers and the public in the wrong way, even if the approaches are sound. This is where our profession can learn and benefit from the social scientists.

In my own professional experience, the practice of social systems engineering is best done by a multidisciplinary team composed of policy makers and social scientists who have developed an appreciation for the rigor and methods of the engineers, as well as systems engineers who are particularly adept at applying their tradecraft in areas with extremely diverse stakeholders and deep uncertainty. Social scientists are critical in establishing the goals, objectives, context, theory, and communication; the engineers are critical to designing processes and incentives that are robust, resilient, and designed for the realities. While “unicorns” capable of the full spectrum of social science and systems engineers exist, they are rare and cannot meet demand; in practice, teams of social scientists and systems engineers with a mutual appreciation of each other’s skills are more likely to be able solve complex technical challenges and present them to the public in ways that will achieve buy in.

Camilo Olaya (Universidad de los Andes) - colaya@uniandes.edu.co

Camilo Olaya is a researcher and consultant in model-based engineering of social systems. He is an Associate Professor and Head of the Department of Industrial Engineering at Universidad de los Andes in Bogota. Camilo is the co-editor of the recently published book “Social Systems Engineering” (Wiley) and author of papers, teaching notes and academic material related to the discussion and development of the epistemology, methodology and tools for advancing social systems engineering and with a special interest in applications in public policy, justice administration, crime and security. He has been a consultant and advisor for private and public sector organizations such as Continental AG (Germany), Centre for International Crime Prevention (United Nations Office for Drug Control and Crime Prevention, Vienna), The World Bank, Bill & Melinda Gates Foundation, Inter-American Development Bank, The National Police of Colombia (Directorate of Criminal Investigation and Interpol), Office of the Attorney General (Republic of Colombia), Ministry of Justice and Law (Republic of Colombia). He is a Systems Engineer and holds a PhD in Economics from the University in St. Gallen, Switzerland.

Position Paper

The possibilities and challenges are wider

The expression “Social Systems Engineering” (SSE) seems to denote the application of Systems Engineering to “social” problems. However, it suggests a broader connotation, not meaning exclusively the application of engineering methods to social issues. The engineering of “social” (human) systems (as opposed to mechanical systems, electrical systems, etc.) requires to address systems formed by purposeful actors that display agency, with diverse, clashing interests and goals. Human beings continuously co-design and re-create the social systems that they form.” In Hobbes’s words, human beings are both the ‘matter’ and the ‘artificers’ of organizations. Human beings both design and create organizations as artifacts and themselves from the primary ingredient of organizations. Organizations are, thus, artifacts that contain their own artisans” (Ostrom, 1980, p. 310). Firms, public and private organizations, a city, NASA, are examples of social systems. Engineering these systems entails the design of social artefacts such as management structures, projects, incentive schemes, routines, procedures, ways of working (formal and informal, planned and spontaneous), agreements, contracts, policies, roles, discourses, among others. These artefacts are not only intangible and invisible but also evolve, depend on and are constructed through human action and collective intentionality, meaning that not only individuals but also their emotions, culture, language and meanings are involved. This is why those designs might be intentional up to some point, but they cannot be completely determined or planned beforehand; these designs are also emergent, dynamic, incomplete, always ‘in the making’, unpredictable, self-organizing, adapting and evolving out of diverse dynamics. Hence, SSE is a special challenge for engineers for whom the artefacts to be designed are usually tangible, predictable, complete, definitive and controllable. A further consideration is the fact that engineering emphasizes “action” and does not necessarily rely on theoretic (scientific) knowledge. Indeed, SSE relies more on trial and error, failure, iteration, experimentation and adaptability. Stimulating self-organization (as opposed to direct intervention) as a way to foster growth of desirable properties (e.g., adaptability and resilience) is also intrinsic to SSE. Engineering a social system also implies ‘steering’ the system towards a desirable state (even if such a state is not completely understood and is subject to different interpretations). Rather than deliberately imposing order, SSE aims at influencing the self-organizing path of human societies. Consequently, and given the complexity entailed by the social world, for which producing scientific explanations is particularly challenging, SSE highlights the need of developing solutions that should be especially context-dependent, iterative, experimental, built upon both diverse options for solutions for a same problem and on unjustified knowledge. This is a starkly different approach from a purely scientific viewpoint. Hence, SSE represents a particular challenge for building interdisciplinary teams and working with social scientists for whom acting without universal, theoretic knowledge or without fully justified understanding is usually unacceptable. SSE accentuates this divide. The tradition of systems thinking in social systems (e.g. the works of Ackoff, Checkland, Ulrich, Churchman, Forrester etc.) has developed ways to deal with the complexity implied by SSE and it shows ways to face the mentioned challenges.

Tutorial

Tutorial#21

A Practical Guide to Determine the Readiness of Systems - Innovative Methods, Metrics and Tools for the Systems Engineer

Donald York (Engility Corp.) - dsrsb@verizon.net

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Presented on: Saturday, 13:30-17:00 in Palm AB

Keywords. system;development;readiness;maturity;integration;risk;life-cycle

Abstract. As systems become more and more complex, it is critical to develop a more comprehensive understanding of the system's development maturity, or system readiness, to aid more informed system-level technical and managerial decisions throughout the life cycle. To develop potential system-level metrics, a greater emphasis must be placed on the integration and dependencies of the individual system elements. It is also critical to measure the system's readiness at multiple points along the development life cycle to avoid pitfalls that can occur when readiness is only assessed once or twice. This tutorial presents a systems readiness assessment methodology, metrics and accompanying tools that equip the systems engineer to determine the readiness of the entire system, its elements and all its interfaces throughout the development life cycle.

The material learned in this tutorial will provide decision-makers with an awareness of the system's holistic state of maturity and help them quantify the level of integration the system has attained over the course of the system development life cycle. Implementing the methodology, metrics and tools in this tutorial will help to reduce the risk of integration failures and enable more effective system development management that can ultimately lead to shortened delivery timelines.

Biography

Donald York (Engility Corp.) - dsrsb@verizon.net

Dr. Don York is a Technical Fellow and Senior Systems Engineer for Engility Corp. Dr. York has over 40 years of systems engineering and technical leadership experience in the design, development, engineering and productization of advanced technology systems. He holds a Ph.D. in Systems Engineering and both a Bachelor and Master Degree in Mechanical Engineering. Dr. York is an INCOSE Certified Systems Engineering Professional and a Licensed Professional Engineer. He has served as an Adjunct Professor teaching graduate level systems engineering courses at both George Mason University and the University of Maryland. Dr. York is a member of the U of MD's Institute for Systems Research SE Education Advisory Group. He is currently the Co-Chair of INCOSE's Corporate Advisory Board and Past President and Program Director of the INCOSE Chesapeake Chapter.

An Introduction to Systems Thinking, Modelling & Simulation focused on the Acquisition and Sustainment of M&S Systems

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Presented on: Saturday, 13:30-17:00 in Grand Cypress Ballroom I

Keywords. Systems Thinking;Modelling & Simulation;Systems Engineering for M&S Systems;VV&A of M&S Systems;Fidelity and Resolution

Abstract. Modelling & Simulation (M&S) is increasingly being recognized as a universal enabler, while Systems Engineering (SE) has long been recognized as the systematic application of Systemic Thinking (ST) to deliver complex systems. Interestingly, M&S is an intrinsic part of the SE process itself (refer MBSE), and while the principles presented in this tutorial are directly applicable in an MBSE context, the focus will be on M&S itself and not on principles of MBSE. The session will start with an introduction to basics of Systems Thinking and will then focus on fundamentals of M&S, touching on the motivation for M&S, definitions, categorizing M&S, explaining Fidelity and Resolution, considering the tailoring of the SE life-cycle processes for the acquisition and sustainment of M&S Systems, including their Verification, Validation and Accreditation. There will be opportunity for discussion at the conclusion, with engagement encouraged throughout the session.

Biography

Jawahar Bhalla (CAE Australia) - jawaharb@cae.com.au

Jawahar Bhalla (JB) has over 28 years' experience across complex projects, with particular strengths in Systems Thinking (ST), Systems Engineering (SE), Modelling and Simulation (M&S), Interoperability and Technical Governance. At CAE he is responsible for definition of integrated training solutions, driving the technology road-map and communication and advocacy across the ME-APAC region. He passionately promotes ST, SE and M&S, is an elected member of the Simulation Australasia (SA) Board, a founding member and past Chair of SA Professional Development committee. He was the Convenor of the SimTecT conferences 2006 to 2008 and is the current Technical Director for the Systems Engineering Society of Australia (SESA). He has delivered numerous papers, workshops, tutorials and presentations to industry and defence on Systems Thinking, Systems Engineering and M&S.

Back to Basics: Fundamentals for Systems Engineering Success

David Long (Vitech Corporation) - dlong@vitechcorp.com
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Presented on: Sunday, 08:00-12:00 in Palm AB

Keywords. foundational concepts of systems engineering; classic domains; requirements; behavior; architecture; V&V; fundamental concepts

Abstract. “I know the processes”, “we’re managing requirements”, “I have a tool”, “it’s all checklists and documents”. Systems engineering is a rich practice leveraging an evolving set of processes, methods, and tools to address problems complicated and complex. With this richness, it is easy to become lost in nuance, details, and disconnected processes. In reality, the path to systems engineering success lies in perspective, the big picture, and integration. This half-day tutorial provides a primer to the foundational concepts of systems engineering within a framework for overall project success. We will focus on the classic systems engineering domains of requirements, behavior, architecture, and V&V. Rather than treating these in isolation, the fundamentals are positioned within a flexible systems engineering process suitable for system development tasks across the complexity spectrum. While there is a place for process and documentation standards, our focus will be on eliciting the proper requirements, understanding the problem and solution domain, enhancing communication amongst the design team and the stakeholders, and satisfying the system need. Through discussions of the fundamental concepts integrated with sample exercises, we will maintain our focus upon the true deliverables – the system itself and overall project success.

Biography

David Long (Vitech Corporation) - dlong@vitechcorp.com

For twenty-five years, David Long has focused on helping organizations increase their systems engineering proficiency while simultaneously working to advance the state of the art across the community. David is the founder and president of Vitech Corporation where he developed CORE™. He continues to lead the Vitech team as they deliver innovative, industry-leading solutions to help organizations develop and deploy next-generation systems. David is a frequent presenter at industry events worldwide delivering keynotes and tutorials spanning introductory systems engineering, the value of systems engineering and systems engineers, the advanced application of MBSE, and the future of systems engineering. His experiences and efforts led him to co-author the book *A Primer for Model-Based Systems Engineering* to help spread the fundamental concepts of this key approach to modern challenges. A committed member of the systems community and Expert Systems Engineering Professional, David was the 2014/2015 president of INCOSE.

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

Zane Scott is the Vice President for Professional Services at Vitech Corporation. He is active in INCOSE and currently serves as the Chair of the Corporate Advisory Board and a member of the Board of Directors. Zane is a member of the Technical Leadership Institute. He is active in the Training, Healthcare and Professional Competency Working groups. Zane comes to the systems engineering world with an unusual background, having received a BA in economics from Va Tech and a JD from the University of Tennessee George C. Taylor School of Law. He did graduate work in both Business Administration and Educational Administration (Counseling). He is a trained mediator, labor/management ADR facilitator and a hostage/crisis negotiator. Zane is particularly interested in the role of systems engineering in solving socio-technical problems outside the military/aerospace sector. He has written and blogged extensively on that subject. In 2016 he and Dave Walden of Sysnovation won a Best Paper Award for their paper on legal liability for systems engineers.

Correcting Misperceptions of Systems Engineering Practices

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Presented on: Saturday, 08:00-12:00 in Grand Cypress Ballroom GH

Keywords. SE technical processes;SE best practices;Misperceptions of SE

Abstract. This tutorial will address common misperceptions of systems engineering, explain from where these misperceptions arise, demonstrate through exercises the problems that can arise, and provide solutions to correct these misperceptions of systems engineering concepts, methods, and practices. Examples of common questions and misperceptions include: Should requirements come first before functions? Should decomposition be done independently of the solution architecture? Should high-level requirements be different from other requirements?

Attendees are encouraged to bring their own questions about SE processes for further discussion.

Biography

Ronald Carson (Seattle Pacific University) - ronald.s.carson@gmail.com

Dr. Ron Carson is an Adjunct Professor of Engineering at Seattle Pacific University, an Affiliate Assistant Professor in Industrial and Systems Engineering at the University of Washington, a Fellow of the International Council on Systems Engineering and a certified Expert Systems Engineering Professional (ESEP®). At the University of Washington he teaches a graduate course on "Systems Architecting and Model-Based Systems Engineering". He retired in 2015 as a Technical Fellow in Systems Engineering after 27 years at The Boeing Company. He is the author of numerous articles regarding requirements analysis and systems engineering measurement, and is the developer of numerous industry systems engineering training courses. He has been issued six US patents in satellite communications, and two patents regarding "Structured Requirements Generation and Assessment". His current interests are in quantitatively incorporating sustainability considerations in systems engineering methodologies and education. Dr. Carson has a PhD from the University of Washington in Nuclear Engineering (Experimental Plasma Physics), and a BS from the California Institute of Technology in Applied Physics.

Developing Verification Requirements to Assure Project Success

Mark Powell (Attwater Consulting) - mark.powell@attwaterconsulting.com

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Presented on: Saturday, 08:00-12:00 in Grand Cypress Ballroom I

Keywords. Verification;Requirements;Planning

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.

Biography

Mark Powell (Attwater Consulting) - mark.powell@attwaterconsulting.com

Mark Powell has practiced Systems Engineering for over 40 years in a wide variety of technical environments including DoD, NASA, DOE, and commercial. His roles in these environments have included project manager, engineering manager, chief systems engineer, and research scientist. Mr. Powell began teaching in academia in 1980, and has been teaching Systems Engineering at the graduate level since 1989 at the University of Idaho, the University of Houston, Stevens Institute of Technology, and the University of Texas at Austin. Mr. Powell maintains an active engineering and management consulting practice in North America, Europe, and Asia. He is an active member of Sigma Xi, ISBA, AIAA, and helped to found the Texas Gulf Coast Chapter of INCOSE in 1991. Mr. Powell has served INCOSE as Chair of the Risk Management Working Group, and as Assistant Director for Systems Engineering Processes.

Getting Ready for Industry 4.0 and IoT with Model-Based Systems Engineering

Dov Dori (Technion, Israel & MIT, USA) - dori@ie.technion.ac.il

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Presented on: Saturday, 08:00-17:00 in Grand Cypress Ballroom C

Keywords. Internet-of-Things;IoT;Industry 4.0;MBSE;Modeling and Simulation;ISO OPM

Abstract. The emergence of the Internet of Things (IoT) and Industry 4.0 signifies a disruptive departure from traditional systems engineering practices to a collaborative model-based SE environment that enables the concurrent, agile design, modeling, and simulation of systems' and products' hardware and software. The tutorial introduces the state-of-the-art in IoT and Industry 4.0. We discuss what the current rapid transition means to systems engineering professionals and how adopting an agile MBSE approach can prepare them for this era. We then introduce principles and basics of Object-Process Methodology - OPM ISO 19450 as a viable infrastructure for Industry 4.0 and IoT through hands-on experience with OPCloud – a Web-based collaborative conceptual modeling environment that facilitates online and off-line collaboration in developing complex systems, utilizing OPM ISO 19450. We will seamlessly model both conceptual qualitative aspects and quantitative aspects of a couple of systems of interest.

Biography

Dov Dori (Technion, Israel & MIT, USA) - dori@ie.technion.ac.il

Professor Dov Dori is Fellow of IEEE, INCOSE, and IAPR, and member of Omega Alpha Association - International Honor Society for Systems Engineering. He is intermittently Visiting Professor at MIT, where he holds an adjunct position. Since 1993, when Dr. Dori invented Object-Process Methodology (OPM), he has been central to the field of Model-Based Systems Engineering. OPM is the first conceptual modeling language and methodology recognized as industry standard, ISO 19450. Prof. Dori has authored over 300 highly cited publications. He has supervised over 50 graduate students in Israel and USA, of whom 13 are faculty members in three countries. Prof. Dori has chaired nine international conferences. He was Associate Editor of IEEE T-PAMI and is Associate Editor of Systems Engineering. He was Co-Chair of the IEEE Society on SMC, TC on Model-based Systems Engineering. His 2002 book on OPM has been cited over 530 times, and he authored another book on Model-Based Systems Engineering with OPM and SysML (2016). He has received various research and innovation awards, and public and industrial sponsors, including the EU, have funded his research.

Inserting Systems Engineering into a Resistant Organization

David Walden (Sysnovation, LLC) - Dave@sysnovation.com

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Presented on: Sunday, 13:30-17:00 in Palm AB

Keywords. organizational change management; process improvement; soft skills

Abstract. You diligently attended all your excellent INCOSE chapter meetings over the past year. You made it to this year's INCOSE symposium and started participating in an INCOSE working group. You are even contemplating getting your ASEP or CSEP certification. You are ready to insert some of the great Systems Engineering things you have learned into your organization. However, you soon discover that getting your organization to adopt Systems Engineering may be more difficult than you anticipated. Your senior staff does not recognize the systems issues your company is facing, middle managers sense a loss of control and/or power, and your peers are so buried in work they are not too keen on changing anything until things settle down.

The objective of this one-day tutorial is to provide guidance to practitioners and change agents on effectively and efficiently inserting Systems Engineering into an organization resistance to change. Systems Engineering is increasingly used to plan, manage, and realize complex systems within the context of demanding business constraints. However, many organizations, especially those new to the discipline, resist its deployment.

Participants are introduced to key concepts and principles to help them insert Systems Engineering into their organizations, answering questions such as:

- What is Systems Engineering and why is it important?
- Why is Systems Engineering relevant to you and your organization?
- What are the key factors that foster resistance to Systems Engineering?
- What are some key things that can make a difference at your organization?
- What are some of the soft skills that can be used?
- What are the key aspects of an effective deployment plan?
- How do we know if our Systems Engineering deployment is working?

Practical information and tools will be provided. The tutorial includes several in-class exercises to solidify the concepts being presented. The tutorial follows the terminology and conventions of the INCOSE Systems Engineering Handbook, ISO/IEC/IEEE 15288, and the Guide to the Systems Engineering Body of Knowledge (SEBoK). Each student will receive a complete set of lecture notes and an annotated bibliography.

Biography

David Walden (Sysnovation, LLC) - Dave@sysnovation.com

David D. Walden, ESEP, is co-owner and principal consultant for Sysnovation, LLC, an SE consulting and training firm he formed in 2006. Previously, Mr. Walden was with General Dynamics Advanced Information Systems for 13 years and McDonnell Aircraft Company for 10 years. Mr. Walden was the PM of the INCOSE Certification Program from 2007-2013. He is an INCOSE liaison to ISO/IEC JTC1/SC7 Working Groups 10 and 20 and the lead editor of the INCOSE SE Handbook Fourth Edition. He has an M.S. in Management of Technology (MOT) from the University of Minnesota, an M.S. in Electrical Engineering and in Computer Science from Washington University in St. Louis, and a B.S. in Electrical Engineering from Valparaiso University in Indiana. Mr. Walden was one of the first to earn the INCOSE Certified Systems Engineering Professional (CSEP) credential in 2004 and was awarded the INCOSE Expert Systems Engineering Professional (ESEP) credential in 2011.

Introduction to Systems Security Engineering

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

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Presented on: Saturday, 08:00-17:00 in Magniola BC

Keywords. Systems Security Engineering; Assurance; Trustworthy Systems

Abstract. Systems security engineering (SSE), as an integral part of systems engineering, applies scientific, mathematical, engineering, and measurement principles, concepts, and methods to coordinate, orchestrate, and direct the activities of security and other contributing engineering specialties (e.g. reliability, safety and human factors) to deliver dependably secure systems. This tutorial provides an overview of SSE, its concepts, and the increasingly critical role that SSE has as part of Systems Engineering (SE). The tutorial is aligned with IEEE 15288 and the INCOSE SSE Working Group-reviewed NIST SP 800-160 Volume 1 (Systems Security Engineering).

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

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

Biography

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

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

Secure Systems.

Daryl Hild (The MITRE Corporation) - d.hild@ieee.org

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

Tutorial#23

Master your Product Lines and yield greater benefits through an integrated Model-Based Product Line Systems Engineering approach

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Stephane Bonnet (Thales) - stephane.bonnet@thalesgroup.com

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Presented on: Sunday, 08:00-17:00 in Palm DE

Keywords. Product Line Engineering; Model-Based Systems Engineering; Variabilities and Commonalities; Value Management

Abstract. Come and learn how to take control of your product and make it target the most valuable business markets, by applying efficient model-based architectural design principles in a Product Line Engineering (PLE) context.

When combined effectively, Model-Based Systems Engineering (MBSE) and PLE can lead to extremely efficient and capable product systems engineering. An integrated approach combining effective processes and practices allow us to yield greater benefits than each of these approaches alone. Along with efficient supporting tools, we are able to obtain the full benefits of Model-Based Product Line Systems Engineering (MBPLSE).

This hands-on tutorial will walk you through the essential practices of systems engineering, architectural design and MBSE in a PLE perspective. The tutorial will also give you an opportunity to demystify model-based approaches thanks to a practical methodology supported by an open MBPLSE solution.

Biography

Hugo Guillermo Chalé Gongora (Thales) - hugo-guillermo.chalegongora@thalesgroup.com

Hugo Guillermo Chalé Gongora is Product Line Engineering Director at Thales in charge of the development and deployment of PLE at Group level. He has over 18 years of experience in Systems Engineering and Product Line Engineering in Energy, Infrastructure, Automotive, Railway and, most recently, Aerospace and Defence, where he has worked both on the tailoring and on the application of SE, MBSE and PLE to the development of complex systems and products. Over the years, he has been particularly interested in safety-critical systems, formal methods, architecture description languages and autonomous systems. He holds a PhD on Energy & Thermal Systems, a Master on Energy Conversion and Internal Combustion Engines, and an Engineering Degree on Mechanical-Electrical Engineering. He is the author of several papers and has been the recipient of best paper awards on MBSE and PLE at the INCOSE Intl. Symposium, the CSDM Conference and the AFIS Conference. Guillermo is the Chair of the INCOSE PLE International WG, former founder and chair of the INCOSE Automotive WG and member of the INCOSE Transportation WG and the MBSE Initiative.

Stephane Bonnet (Thales) - stephane.bonnet@thalesgroup.com

Stephane Bonnet is the Design Authority of the Thales MBSE workbench for systems, hardware and software architectural design. He holds a PhD in software engineering. From 2008 onwards, he has led the development of Capella. In charge of Corporate MBSE and PLE coaching team, he dedicates most of his time to training and coaching activities worldwide, for Thales and other organizations. He accompanies systems engineering managers and systems architects implement MBSE/PLE approaches on operational projects, helping them define their engineering schemes, objectives, and guidelines. He is animating networks of experts from all Thales domains and business units to capture operational needs and orient the method and workbench evolutions and roadmaps. He is the author of multiple papers on MBSE and is a member of the SysML v2 Working Group.

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

Juan Navas is a Systems Architect with +10 years' experience on performing and implementing Systems Engineering practices in industrial organizations. He has worked on the design and the procurement of instrumentation & control systems and simulation systems for petrochemical plants, nuclear fuel cycle plants and nuclear power plants. He has lead projects to improve software and systems engineering performance following Model-Based Systems Engineering approaches. He accompanies systems engineering managers and systems architects implement MBSE/PLE approaches on operational projects, helping them define their engineering schemes, objectives, and guidelines. He holds a PhD on embedded software computer science (Brest, France), a MSc Degree on control and computer science from MINES ParisTech (Paris, France) and Electronics and Electrical Engineering Degrees from Universidad de Los Andes (Bogota, Colombia).

Overview of the INCOSE SE Handbook Version 4.0

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Presented on: Sunday, 08:00-17:00 in Grand Cypress Ballroom I

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

Abstract. Overview of the INCOSE SE Handbook Version 4.0

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This tutorial provides a useful overview of the INCOSE SE Handbook V4.0 using key excerpts from the official Technical Product approved by INCOSE Technical Operations in December 2016. Participants will benefit by learning how to apply the SE processes to realize systems, complex systems, and systems of systems, including key SE terminology, principles, processes, tailoring, what-to-do, and how-to-do SE to achieve project, organizational, and business success. The intended audience includes participants interested in learning and applying SE based on ISO/IEC/IEEE 15288, and who wish to increase their professional and/or personal value to their project and organization. Case studies, questions, answers, and group exercises are included to help participants apply the concepts being presented. The INCOSE Hampton Roads Area Chapter developed the Tutorial, and the INCOSE Training Working Group presented and recorded the webinars. It contains enhancements to the Handbook developed by creating additional figures using the information contained in this and prior versions of the Handbook. The complete Tutorial and its webinar recordings are in high demand and are available via INCOSE Connect for free electronic download by all INCOSE members, Corporate Advisory Board members and their employees, and Academic Council members and their students at <https://staff.incose.org/Library/Tutorials/training>.

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

Biography

John Clark (Old Dominion University) - clarkjo713@gmail.com

John O. Clark was the Corporate Systems Engineering Instructor and a Chief Engineer at Northrop Grumman Corporation (NGC) with over 50 years of experience applying Systems Engineering and Software Engineering. He is an internationally recognized Subject Matter Expert in SE. For NGC, he was the SE Associates (SEA) instructor and the founder of the INCOSE Community of Practice (CoP), Agile SE CoP, and NGC SE Handbook WG. John received the NGC Exemplary Performance Award for Multi-Sector Collaboration from Wes Bush and John Chino for developing the NGC SE Handbook. He received a BSEE from Penn State and a MSEE from the State University of New York, and currently is an adjunct instructor in the SE Master's Degree program at Old Dominion University in Norfolk, Virginia.

Quantitative Risk Assessment

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Presented on: Sunday, 08:00-12:00 in Magniola BC

Keywords. Risk Management;Project Management;Decision Making

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.

Biography

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Mark Powell has practiced Systems Engineering for over 40 years in a wide variety of technical environments including DoD, NASA, DOE, and commercial. His roles in these environments have included project manager, engineering manager, chief systems engineer, and research scientist. Mr. Powell began teaching in academia in 1980, and has been teaching Systems Engineering at the graduate level since 1989 at the University of Idaho, the University of Houston, Stevens Institute of Technology, and the University of Texas at Austin. Mr. Powell maintains an active engineering and management consulting practice in North America, Europe, and Asia. He is an active member of Sigma Xi, ISBA, AIAA, and helped to found the Texas Gulf Coast Chapter of INCOSE in 1991. Mr. Powell has served INCOSE as Chair of the Risk Management Working Group, and as Assistant Director for Systems Engineering Processes.

Tutorial#10

Systems Engineering MBSE implementation in your organization

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

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Presented on: Saturday, 13:30-17:00 in Grand Cypress Ballroom GH

Keywords. MBSE;Model Based Systems Engineering;Organization Change Management

Abstract. Model-Based Systems Engineering (MBSE) technology is accelerating while at the same time organization preparation to utilize the technology is lagging behind. Document-oriented organization processes and behavior changes are required to take advantage of the productivity improvements available through models—but where do you start?

This half-day tutorial/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 in your organization

Biography

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

Mark Sampson is the product evangelist preaching integrating systems engineering and requirements within the product-lifecycle management (PLM) business at Siemens—enabling systems engineering and requirements to participate/influence all aspects of product development. After graduating with a BS in Computer Engineering from BYU and a MS in Systems Engineering from USC, Mark started his career at Texas Instruments, survived a successful boot-strap startup, selling out to EDS, eventually ending up at Siemens with a breadth of 30 years' experience around applying Systems Engineering tools in a variety of industries and well-known brands—high tech, automotive, defense aero, medical devices, consumer products, and others. Mark is the co-chair of the INCOSE MBSE Initiative where he's involved with helping to transform engineering culture to MBSE—as a result he is a sought after speaker on MBSE in many organizations, universities, and government agencies.

Tutorial#25

Tactical Strategies for Overcoming Systems Engineering Dysfunction

Heidi Davidz (Aerojet Rocketdyne) - heidi.davidz@rocket.com
Eileen Arnold (ConsideredThoughtfully.com) - Eparnold5@aol.com
Dale Thomas (University of Alabama in Huntsville) - ldt0001@uah.edu

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Presented on: Sunday, 13:30-17:00 in Magniola BC

Keywords. Systems Engineering Execution;Systems Engineering Pathology;Systems Engineering Strategies for Overcoming Dysfunction;Systems Engineering Workforce Development;Lean Enablers;Competency

Abstract. This tutorial provides tactical strategies for effective SE execution in the face of dysfunction. Learn about the holistic perspective on SE dysfunction and SE situational awareness including examples of why more than one strategy for each dysfunction increases success, identify characteristic patterns of SE dysfunction, and acquire proven strategies to overcome dysfunction (regardless of how senior you are in your organization) to enhance SE success. Many SEs at different levels of the organization face dysfunction every day. Despite repeated efforts to enhance the quality of SE, deficiencies in SE execution continue to plague system development programs in many organizations. Developing competency at the individual level is important, but team and enterprise SE capability extends the organizational learning and resultant extension of company success. Even if capability is sufficiently developed at the individual, team, and enterprise level, that capability must be translated into execution to impact a program. Interventions to enhance SE at the individual level are often truncated by group dynamics or organizational limitations. Resources to systematically guide SEs in navigating dysfunction will be provided to help SE practitioners navigate confusion and disarray. As a soldier is trained for situational awareness and likely conflict, then equipped with tools to use in the field for anticipated conflict, the SE can also be trained for situational awareness and equipped with tools for likely conflict. As medicine has been gradually accumulating an understanding of causes, detection and treatment of diseased states, SE is beginning to accumulate an understanding of causes, detection and treatment of dysfunctional execution through work in SE pathology. The tutorial will include a handout, "Tactical Handbook for Overcoming Systems Engineering Dysfunction" which integrates research and INCOSE products, free to members. Participants can utilize this knowledge to develop a toolbox of strategies to overcome SE execution challenges. This will be an interactive tutorial that will include discussions of participant dilemmas and solutions, along with the opportunity to enhance the concepts for "real world" SE practice. (Aerojet Rocketdyne External Release Log #169-18)

Biography

Heidi Davidz (Aerojet Rocketdyne) - heidi.davidz@rocket.com

Dr. Heidi Davidz is a Principal Engineer in Systems Engineering (SE) at Aerojet Rocketdyne (AR) where she implements modern SE tooling on liquid rocket engine programs to enhance affordability while ensuring technical rigor. Previous roles at AR included the Model-Based Systems Engineering Project Lead, Discipline Lead of SE, Chief Process SE, Stennis Space Center Achieving Competitive Excellence Manager, and Test Operations Engineer, where she was a certified Test Conductor running hot-fire rocket engine tests. Prior to AR, she worked at The Aerospace Corporation in the Systems Architecture, Engineering and Cost Department where she provided support for NASA Headquarters and National Security Space projects. She was a Part Lead Author and later an Associate Editor for the Body of Knowledge and Curriculum to Advance SE (BKCASE) and SE Body of Knowledge (SEBOK).

Eileen Arnold (ConsideredThoughtfully.com) - Eparnold5@aol.com

Eileen Arnold; ESEP-ACQ, INCOSE Fellow, PMP is a co-founder and a principal systems engineer for ConsideredThoughtfully Inc., an online automated virtual career mentoring company start-up. Eileen has over 35 years of experience in aircraft electrical systems and weapons systems. She is a recipient of the Minnesota Federation of Engineering, Science and Technical Societies (MFESTS) Charles W. Britzius Distinguished Engineer Award in 2012. She holds credentials as an INCOSE certified Expert Systems Engineering Professional with a Department of Defense Acquisition extension (ESEP-Acq), is an INCOSE Fellow, and is a PMI Certified Project Management Professional (PMP). She has been an active INCOSE volunteer and author since 1996, holding a variety of international and chapter level leadership positions and a past IEEE Fallcon technical chair.

Dale Thomas (University of Alabama in Huntsville) - Idt0001@uah.edu

Dr. Dale Thomas joined The University of Alabama in Huntsville in 2015 as a full professor and was board-appointed as the Eminent Scholar in Systems Engineering. He has over 30 years' experience as an aerospace and systems engineer at NASA. After joining the UAH College of Engineering faculty, Dr. Thomas established the Complex Systems Integration Laboratory (CSIL) to explore advanced systems engineering with a focus on Model-Based Systems Engineering research. He also serves as the Director of the Alabama Space Grant Consortium and as Deputy Director of The UAH Propulsion Research Center.

The power of influence - how to lead without authority

Jennifer Nash Phd (Nash Consulting & Associates) - ExecSuccess@gmail.com

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Presented on: Sunday, 08:00-17:00 in Grand Cypress Ballroom GH

Keywords. Leadership Development;Professional Development;Soft Skills

Abstract. Systems engineers are trained in the technical capabilities needed to perform their jobs. But technical skills are not enough in today's VUCA (volatile, uncertain, complex and ambiguous) world. Today's organizations need systems engineers with interpersonal and professional leadership competencies to bring people together, lead without authority and get work done.

Despite the importance of and need for interpersonal and leadership skills, organizations as well as academic engineering degree programs frequently undervalue these capabilities and lack focus on this type of training. Many systems engineers therefore find themselves with a significant interpersonal skills gap and lack of know-how to effectively navigate this critical part of their job.

This unique leadership development tutorial offers INCOSE members the opportunity to fill this gap. Packed with experiential activities and grounded in principles of adult learning, each module introduces a distinct professional leadership competency: 1) influence - how to lead others without authority and 2) team dynamics. These two competencies are aligned to the INCOSE Systems Engineering Competency Framework and will be addressed at the Awareness and Supervised Practitioner levels.

Dr. Nash brings 25 years of experience in Leadership and Organizational Development to this tutorial. Tutorial attendees will receive CEUs for each module and will leave the tutorial with a strategy in hand to address bespoke challenges at work. These new capabilities will enable systems engineers to more effectively bring people together, lead others without authority, and take their performance to the next level.

Biography

Jennifer Nash Phd (Nash Consulting & Associates) - ExecSuccess@gmail.com

Dr. Jennifer Nash is an executive coach, management consultant, leadership development expert, speaker, researcher, professor and published author. She has worked with high potentials, senior leaders, and executives at distinguished organizations such as Deloitte, the University of Michigan, Ford Motor Company, Whirlpool Corporation, Magic Leap, Morgan Stanley, Westinghouse, BorgWarner, Ansell, SAP, Dana Holding Corporation, Goodwill and the State of New York, among many others. Prior to earning her PhD in Management, Dr. Nash worked for 25 years in executive and leadership roles for Deloitte Consulting LLP, Ford Motor Company, Kelly Services and Electronic Data Systems. She earned a PhD from Case Western Reserve University and an MBA from the University of Michigan. Jennifer is CEO of Nash Consulting & Associates, a global executive coaching and leadership development consultancy based in Michigan. She serves as an Executive Coach for the University of Michigan. Dr. Nash is a Certified Executive Coach, holds industry coaching credentials from multiple organizations and has instrument certifications in MBTI®, MSCEIT (Mayer-Salovey-Caruso Emotional Intelligence Test), and ESCI (Korn Ferry/Hay Group's Emotional and Social Competency Inventory).

Why the SEMP is not Shelfware: How to write a SEMP to ensure it delivers value to all.

Becky Reed (Reed Integration Inc.) - rreed@reedintegration.com

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Presented on: Saturday, 08:00-12:00 in Palm AB

Keywords. SEMP;Value;Management;Planning

Abstract. One of the key documents used to both plan and manage the development and execution of a complex system is the Systems Engineering Management Plan (SEMP).

Whilst contracts and organisational business management systems commonly call for this document, there is still a surprising lack of awareness and understanding as to the purpose and role of the SEMP within the wider project, confused in areas such as how it relates to other key planning documents, such as the Project Management Plan, System Integration and Test Plans and many other discipline-specific plans such as the Software Development or Hardware Development Plans. This problem is exacerbated when tender documents call for a draft SEMP to be submitted – with writers struggling in areas as to how much detail to provide to a potential Customer in advance of the detailed planning of the project.

This tutorial is designed to provide guidance for those struggling with writing of a SEMP. It covers the differing uses of a SEMP, key stakeholders for each use case and typical informing content. Along the way, the tutorial will tackle questions such as “What exactly is the SEMP purpose?”, “What topics should be addressed?” (including “What is the appropriate level of detail?”) and “How to I ensure my SEMP is both read and used as I intended?”

Instructors will be providing pointers to useful information sources and guidance from INCOSE best practice.

The tutorial will be highly interactive, enabling delegates to share their own experiences and ideas and enabling them to discuss their own specific challenges - within an environment designed to foster collaboration.

Biography

Ian Presland (Charterhouse Systems Ltd.) - ian@charterhouse-systems.com

After graduating from Bristol University with a BEng in Electronic and Electrical Engineering in 1980, Ian worked as an electronics engineer before moving into firmware, software and finally systems engineering where he has spent the last 25 years. His full lifecycle experience covers multiple sectors: aerospace, defence, automotive, transportation and learning and development and includes several senior leadership roles. In 2015, Ian left corporate life to establish an independent consultancy which now supports a variety of clients in the UK and internationally. He also lectures in Systems Engineering at Warwick University and for the University of California (Irvine). Ian is a Chartered Engineer, Member of the British Computer Society, Fellow of the IET, INCOSE ESEP and is the current INCOSE UK Professional Development Director. His other INCOSE activities include two terms on the INCOSE Certification Advisory Group and most recently as editor and co-author of the recently updated INCOSE Systems Engineering Competency Framework. In 2017, Ian was awarded an INCOSE Outstanding Achievement Award for his work in Certification and Professional Development.

Becky Reed (Reed Integration Inc.) - rreed@reedintegration.com

Becky Reed is the President and CEO of Reed Integration, Inc., a WOSB/EDWOSB, SDB headquartered in Suffolk, VA, with an additional office in the Washington, DC area and employees in 4 other states. With more than 25 years of engineering and leadership experience in aerospace, nuclear, environmental, and information technology industries, Becky is an internationally recognized authority on life cycle systems engineering and risk management and their applications in government and commercial markets. Her small business is an industry leader in technical and management consulting and training services and is a premiere provider of systems engineering training and CSEP exam preparation programs. A long-time, active member of INCOSE, Becky obtained her CSEP certification in 2004 and then became the 24th person in the world to achieve the credential of ESEP in 2010. She was awarded the INCOSE Outstanding Service Award in 2007 and is a member of the INCOSE Hall of Leaders.

Presentation

Presentation#67

A Definition Abstraction and Implementation (DAI) Process for System-of-Systems Engineering

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Presented on: Thursday, 08:00-08:40 in Grand Cypress Ballroom A

Keywords. System-of-Systems Engineering; Systems Engineering Process for System-of-Systems; System-of-Systems Definition-Abstraction-Implementation

Abstract. The design, development, and planning of a System-of-Systems (SoS) is a difficult task as it involves several systems, organizations, and complex dynamics between the constituent elements of the SoS. These factors make an SoS difficult to comprehend and model, and SoS solution synthesis becomes a challenging endeavor. Research and development of SoS Engineering (SoSE) processes to account for complexities involved in the design, management, and operations of the SoS has been an active area of research in Systems Engineering and significant progress is made in advancing the state-of-the-art of SoSE in the past decade. In this presentation, we will first review the current practices in SoSE—identifying their common themes and gaps—and then present a three phased SoSE process called the Definition-Abstraction-Implementation (DAI) process. The DAI process draws upon our decade long SoSE experience and critical lessons learned from a variety of government, industry, and academic SoS engagement experiences. The end goal of this work is to provide a domain-agnostic SoSE approach which incorporates both qualitative reasoning and quantitative analytics to create knowledge artifacts needed to support effective analysis for design and evolution of an SoS.

Current SoSE methodologies largely provide high-level processes and guidance that are aimed at orchestrating activities for a particular domain (defense, transportation etc.) and relies on adaptation of existing Systems Engineering processes to the SoSE context. In this presentation, we bridge multiple contexts of SoSE applications and present the development of an SoSE process that is domain-agnostic and motivated by practical observations from a myriad of research application experiences.

The DAI process starts with an initial scoping of the SoS problem definition and considers different evolution horizons of SoS. Once the general features of the SoS are identified, the DAI begins with a sequential but iterative application of Definition (D), Abstraction (A), and Implementation (I) phases. Each phase of the SoSE process is built using the INCOSE Input-Process-Output (IPO) diagrams which clearly highlights the requirements, inner working, and outcomes of each phase along with their individual contribution to the overall SoS solution synthesis. The objective of each of these three phases is summarized below.

The purpose of the Definition phase is comprehending the SoS problem space by identifying exogenous and endogenous variables, (which are not all technical in nature) and encompass economic and policy considerations. A major outcome of this process is the development of Resources, Operations, Policy, and Economics (ROPE) matrix which identifies different hierarchies of SoS considerations and stakeholders in these categories.

The abstraction phase uses informational artifacts collected from the Definition phase to construct sub-domains, and identifies appropriate inputs (e.g. resources, constraints) and outputs (e.g., measures of performance, effectiveness, -illities) associated with each sub-domain. The objective in this phase is to identify an appropriate domain decomposition of the SoS and to identify a problem definition germane to each sub-domain.

In the Implementation (I) phase, solution frameworks (methods, processes, tools) are adopted to generate an end SoS solution. In the presentation, we articulate the impacts that process choices in the Definition and Abstraction phases have on the construction of practical end solutions that are compatible with stakeholder considerations, and with the SoS in general.

It should be noted that the purpose of this presentation is to share on-going technical work with the audience and this presentation provides incremental improvements and developments to an earlier paper presented at the Council of Systems Engineering Universities (CESUN) 2018 conference with the title: A DAI Process for System-of-Systems Engineering – antecedents, status quo and path forward.

Presentation#36

A Systems Approach to Technology Development

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Presented on: Tuesday, 13:30-14:10 in Grand Cypress Ballroom GH

Keywords. TRL;Technology;Advanced Development;Early Development;Agile;Lean;Process

Abstract. Often, there is a substantial gap between what academia and industry call a mature technology. This can result in product development teams being burdened with unknown technology risks leading to project cost overruns, schedule delays, and product feature reduction.

Systems Engineering methodologies were applied to this problem at a medical device company which resulted in a new process for the pre-development of new technologies prior to project teams using them. This process was inspired by lean techniques, only adding work where there was value, and subtracting work where there was waste. This process also was inspired by agile techniques, setting the review cadence to 1 month, where projects could be killed, shelved or continued.

The process was implemented, refined and maintained successfully for about seven years. Over that time the budgeting process was also forced to become agile. The process also brought stakeholders together to discuss technology strategy, a forum that did not exist before.

Success was measured by the many technologies that failed before projects used them, the few technologies that successfully went on into successful projects, as well as the positive change in company culture that resulted. Now the global organization has changed to achieve these same outcomes in a more permanent, mandatory and comprehensive way.

A Systems Engineering Approach for Cancer Control

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Presented on: Tuesday, 15:30-16:10 in Grand Cypress Ballroom GH

Keywords. Systems engineering;Systems architecture;National policy;Systems integration;Cancer control;Population health;Human behavior;Complexity;Complex Adaptive Systems

Abstract. Cancer is unique in terms of its association with the words “complex” or “complexity”—as the collection of diseases challenges every layer of understanding on how to “control” them—from ethics to engineering, from evolutionary biology to economic policy and beyond. A systems engineering approach for cancer control is proposed as a guidance system for policies, integrating current resources and coordinating various processes across the continuum of cancer control—from risk awareness to prevention, early detection to treatment, and survivorship to palliative and hospice care—and improving accountability pertaining to progress and performance, and capitalizing on the available technologies of data aggregation and analyses. The demographic trends are expected to result in a dramatic increase in the number of cancer cases in the United States—currently with 1.7 million annual diagnoses and 606,000 deaths and growing—that could continue to overwhelm the nation’s medical, health, economic, and social services system.

The U.S. cancer control system is, like cancer itself, a complex adaptive system. Each entity in the system (e.g., advocacy, drug development, basic research, and clinical trials) attempts both to serve its own interests and to provide quality products and services to patients and participants in this system. Because the system has no central direction, the various stakeholders individually determine what the desired outcomes are, and these desired outcomes inevitably differ from participant to participant because of variable preferences and conflicting interests as well as widely differing notions of quality.

Multi-level modeling tools, each of which is a particular representation of a complex adaptive system, can provide a basis exploring the likely consequences of different cancer control strategies. To succeed, these strategies must appropriately link to and influence all levels of the system. The resulting systems architecture could provide a visual understanding of where pay-offs are likely in the processes and systems of cancer control, and what they are worth in terms of outcomes and costs. Using results from various publications on systems engineering techniques (e.g., cancer drug delivery, cancer survivorship as well as to clinical care and patient safety), and from using archetypes and functional models of integration and coordination—that serve as the basis for the recommendations in the forthcoming National Academies report on this subject to be released in June 2019—this presentation will summarize the essentials of an operational cancer control strategy for the United States. The key role of systems engineers and related professional societies in cancer control will also be discussed.

Presentation#30

Affordable Rocks (and Batteries): A lighthearted Dialogue About Value

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Presented on: Wednesday, 14:15-14:55 in Grand Cypress Ballroom C

Keywords. Affordable;Affordability;Value

Abstract. Affordable rocks? Sometimes, it can seem like all the fuss about affordability has gotten out of hand. We all buy things so we all know what it means for something to be affordable, right? Explore what affordability is (and isn't) plus some of the tools in the systems engineer's toolbox. Join us for a lighthearted, interactive dialogue about affordability and value. Learn why affordability tells us nothing about what we get for our money and why we should focus on value instead.

Applying Model Based Systems Engineering to Reduce Weapon System Development Cycle Time

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Presented on: Tuesday, 13:30-14:10 in Grand Cypress Ballroom A

Keywords. MBSE;System Architecture;Requirements

Abstract. Sandia National Laboratories (SNL) is the nation's premier science and engineering laboratory for national security and technology innovation, with missions in the strategic areas of: Nuclear Weapons, Defense Systems & Assessments, Energy & Climate, and Global Security. This presentation reports on techniques and results of implementing MBSE on programs associated with the nuclear weapons mission, and the defense systems & assessments mission. This presentation extends from work presented at INCOSE IW 2019, and includes information on mission team MBSE activities, as well as discussion on cross team / cross lab efforts to synergize MBSE people, process, and procedures.

In support of the nuclear weapons mission, in May 2018 a new initiative was championed by Sandia management to reduce the nuclear weapons development life cycle time using MBSE and other transformational approaches to systems engineering. With a similar timeframe, a new department was created within the defense systems and assessments mission area to focus on MBSE applications in both new and existing programs. For both mission areas, implementing MBSE initiatives into programs presents the following challenges: complying with security restrictions, including providing access to information on a need-to-know basis; modernizing existing designs; moving away from a document centric process; applying MBSE throughout the entire development cycle. The newly formed MBSE groups were established to promote an enterprise-wide reuse of model-based information and utilize the model as the single source of truth for product development teams. A key goal of the initiative is to reduce development cycle time which will allow Sandia to operate with increased agility to meet changing customer needs

Within the nuclear weapons mission, current MBSE efforts are utilized during Requirements Engineering (RE) and Verification & Validation (V&V) activities. In support of the defense systems mission, MBSE has been used for requirements engineering, functional and physical architecture, and is being introduced in V&V activities

Reuse of MBSE efforts on Functional Architecture have produced an observed reduction in the development process timeline: (1) Project A – intense 3-month activity involving many Subject Matter Experts (SME) to develop initial functional architecture. (2) Project B – Leverage project A functional architecture and refine for project B – 2-week activity with SME. (3) Ongoing Reuse: established a reference architecture that provides consistent top-level functions with consistent definitions enabling future modeling time focused on the challenging details rather than reestablishing the base architecture for the system for every project. (4) Leveraged reference architecture and understanding of A and B to build functional architecture for project C in a matter of days with SME review.

This presentation will elaborate on challenges met and solutions used to provide a common and integrated understanding of information captured through modeling to demonstrate the value of MBSE. We will present approaches taken, and lessons learned for both technical/tool transformation and cultural change agency. Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

Artificial Intelligence (AI) and Requirements Inspection and Evaluation

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Presented on: Wednesday, 14:15-14:55 in Grand Cypress Ballroom DEF

Keywords. Artificial Intelligence (AI);Systems Analysis;Requirements Analysis;Software applications;Information systems;Software Sizing;Function Point;Function Point Analysis;Automation;Natural Language Processing (NLP)

Abstract. Poor requirements have long been a problem across both industry and the federal government. Requirements engineers, business analysts, and estimators often face the challenge of parsing through hundreds and sometimes thousands of requirements in an effort to define system design needs or to accurately estimate the software development cost. This detail-oriented and often grueling process requires analysts to be highly experienced and also have a tremendous amount of tolerance for repetitive requirements parsing—and despite even the most meticulous analysis, mistakes are still an inevitability.

With artificial intelligence (AI), machines are now capable of “learning” processes and automating previously human-dependent functions. AI can serve to aid analysts in the understanding and parsing of requirements by identifying duplication in both language and meaning, and dramatically reducing the time and effort necessary to accurately analyze projects. Breakthroughs in AI, such as natural language processing (NLP), is making it possible to perform some requirements analysis.

This briefing provides an overview of select artificial intelligence capabilities and shows their applications to systems engineering and requirements analysis (to include Function Point Counting (FPA) process for software sizing). Also, to show the technology that NLP employs to search for low-quality requirements, and identifies keywords and objects to provide useful information.

Benefit Study on Digital Transformation for Integrated Project Planning and Control, Systems Engineering, and Safety and Mission Assurance Processes

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Presented on: Wednesday, 13:30-14:10 in Grand Cypress Ballroom C

Keywords. Digital Transformation;Benefit Study;Simulated Business Processes

Abstract. Agency-wide efforts have begun to transform the way NASA innovates, integrates, engineers, and manages its increasingly complex spacecraft projects through digital technologies. Evolving Project Integration, Innovation, and Collaboration (EPIIC) is a vision defined to transform the way projects manage information to support real-time decisions, capture best practices and lessons learned, perform assessments, and manage risk across a portfolio of projects. To characterize the relative benefits of the EPIIC vision, this study simulates the integrated Project Planning and Control (PP&C), Systems Engineering (SE), and the Safety and Mission Assurance (SMA) processes using a discrete event simulation (DES) process model.

PP&C consists of inter-related functions that supports developing the execution plans during the project's planning phase and subsequently assesses and evaluates progress against those plans during the control phase. Activities during both planning and control phases can be categorized into seven functions, such as Integration, Cost Estimation, Scheduling, and Risk Management. The PP&C handbook documents the process, including information exchanges, of how these functions interact with each other and with external teams. SE consists of the seventeen common technical activities (a.k.a., the V-engine) to be applied by NASA projects throughout all life-cycle phases. The SE handbook documents these activities in details, and is in the process of including information exchanges within the SE team and with other teams. SMA process is to ensure the early integration and implementation of safety, reliability, maintainability and quality assurance into NASA projects throughout life-cycle phases. Currently, the SMA community is in the process of its handbook preparation.

This benefit study focused on a single gate review during the planning phase, particularly the System Requirement Review (SRR). There are twenty-five PP&C activities performed by the seven PP&C functions, ten SE activities (not all 17 activities are required for the SRR) performed by the SE team, one SMA activity by the SMA team, and one project management activity by the project manager. These activities are iterative and generally occur at least once a month. A typical activity consists of three tasks, which are (1) Request - data collection through requesting the activity's inputs from its data owner; (2) Execute - activity execution by the activity owner; and (3) Revise - data products generation by the activity owner and route them to its data owner for revision approval. With the EPIIC vision, its process model will eliminate the Request task for any activity. It is important to note that this study captured various level of modeling resolutions for the disciplined specific activities due to the availability of documentation at the time of the study. For a single gate review event, it was discovered that the schedule benefit of the EPIIC over the current practice is only sensitive to the magnitude of the time durations for Request, Execute, or Revise tasks, and is not practically sensitive to the type of statistical distributions for these parameters. As the magnitude of the Execute's and Revise's time durations increases (relatively to the Request's time), the schedule benefit decreases and eventually converges to a theoretical minimum of 7.5% when the Execute's and Revise's times approach "infinity". Similar findings were discovered for the labor cost benefit with an exception that the theoretical minimum labor cost benefit of zero for the EPIIC over the current practice. This implies that as significant amount of times are spent to execute the activity and to revise its outputs (with respected to the data collection activity), there will be no labor cost saving to eliminate the Request task from the processes. It is anticipated that the schedule benefit will be much higher if the study includes iterative monthly processes leading up to the SRR, and will be significantly higher if it considers throughout life-cycle phases.

Product Lines

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Presented on: Tuesday, 11:30-12:10 in Grand Cypress Ballroom A

Keywords. Digitalization;Product Line Engineering;Reverse engineering;Knowledge Reuse;Variability Management;Knowledge -Based Requirements Engineering

Abstract. Have you ever thought about how often we start a new mission, program or project from an existing document, project, or even presentation?

In our experience, it is about 90% of the times and this also led us to think that something similar may happen in many engineering organizations.

It is precisely the idea of knowledge reuse one of the challenges that organizations need to overcome in order to build better systems or deliver better services, in less time, with less money and more efficiently. In this context, Product Line Engineering becomes an attractive methodology to manage systems development lifecycle.

Current digitalization trends are focusing on the improvement of existing development and manufacturing techniques. The systems that are being implemented today will be the legacy ones in 10 years time. That is why, it is necessary to move from static heterogeneous systems to Knowledge-Based Systems, in which assets such as curated data or actionable data revamp the efficiency of the development lifecycle.

The dynamism of the market for the development of such complex systems aims to improve the methods to formalize and certify system assets among all the stages in the product lifecycle. It is, at this point, when Knowledge-Based Requirements Engineering plays a key role to transform the practice of requirements engineering within an organization from traditional and hand-made activities to automation and reuse of existing information available in the different working products.

To demonstrate this approach, we introduce here an Use Case (UC) within the scope of the large European research project REVaMP2. This use case has been defined and implemented to automatically discover and manage commonality and variability in existing and not organized requirements specifications, to identify variability in product lines and variability models and to create reusable requirements structures that can be instantiated in future projects.

More specifically, the approach developed in this UC is based on the application of semantic technologies, ontologies and a knowledge repository, to manage and infer variability among different sort of assets. The implementation has been done on top of the RQS Suite providing a way to cope with key trends in the market for System's Knowledge management and analysis, with reuse and traceability as key processes to be improved in the context of variability management and product line management tools.

As result, the implementation has also demonstrated value to ensure the quality of new project assets and to ease processes such as verification and validation. To do so, the new capabilities have provided a systematic method to automatically assess completeness and consistency of the auto-generated requirements specification easing the identification of issues, minimizing risks and, mainly, providing a way to easily reuse specifications of existing working products.

In this presentation, the audience will get an overview of the main challenges that engineering processes are facing today in terms of increasing the degree of quality and reusability of their system artefacts making their engineering processes more repeatable and predictable. To do so, a complete description of the implemented use case and its evaluation will be presented as one of the main outcomes of the REVAMP2 project.

Developing Standards for Space & CubeSat Model-Based System Engineering (MBSE)

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Presented on: Thursday, 08:45-09:25 in Grand Cypress Ballroom A

Keywords. Architecture;CubeSats;CyberSecurity;Ground Stations;Frameworks;MBSE;Standards

Abstract. In the era of rapidly evolving threats that require faster cycle times for fielding and modifying warfighting capabilities, standards provide vendors and operators with the ability to focus on advanced technologies while building on known, time-proven standards. Col (Ret) Steven (Steve) A. MacLaird, Object Management Group's (OMG) SVP for Government & Industry Strategy will discuss the role open standards and Model-Based Systems Engineering (MBSE) play so future platforms can keep up with evolving threats and emerging technologies. Also covered in this timely session is how the OMG-managed programs advance multiple initiatives and products in horizontal and vertical trade spaces, cybersecurity, ontologies that benefit the military, industry, international partners and universities and how these initiatives reduce training and logistics across systems. Finally, you'll learn about current work being done already in the areas of business; engineering; ground stations for NASA, NOAA, and the US Air Force; Secure Networking Communications (SNC); Space; Systems Modeling Language® (SysML®) as well as on CubeSat Systems Reference Model (CSRM). The CSRM is intended for instruction and for designing and building a mission-specific CubeSats. CSRM outline and schematics to be discussed.

Doing Things Better, Doing Things Differently, Doing Different Things

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Presented on: Tuesday, 15:30-16:10 in Grand Cypress Ballroom DEF

Keywords. Engineering Support;Product Support;Asset Management;Transformation;Digital Twin;Maintenance Repair & Overhaul

Abstract. In-Service Support of UK military platforms is ripe for transformation, extending from maintenance & repair activities through to asset management and all the way back to the engineering activities and the governance regimes. This presentation highlights some of the findings from a recent task which has developed a multi-year programme of work to transform the area of “Engineering Support”, and will identify some techniques which may have wider applications.

The task itself was relatively straightforward in conception. Take the Ministry Of Defence (MOD) customer’s vision paper for “Engineering Support Transformation” (EST), test it and flesh it out through stakeholder workshops and technology surveys in order to develop a set of development themes and target architectures; then develop a programme of work to define, prove and deliver the various themes and architecture elements over a series of incremental tranches. In practice there were a few more twists and turns along the way.

Do you like your changes regular, large or extra large?

From the very outset of the project we had a 3-level model of change in mind: “Do things better”, “Do things differently” and “Do different things”. This provided a much needed challenge function to ensure that we looked beyond the obvious and considered changes that would be truly transformational.

Doing things better is all about small scale improvements or activities which modify the current “as-is” situation. Examples include reviewing existing policies and standards, setting up a technical governance structure, or adopting a coherent set of maintenance planning applications based upon condition-based maintenance regimes.

Doing things differently focuses on taking an existing practice or capability and finding a different way to achieve the same effect, usually with a performance improvement or other expected benefits. Examples include adopting COTS standards (such as the ASD series) in place of existing military standards, developing common collaborative approaches to contractor support solutions, or providing remote technical support using audio-visual links and access to digital asset data.

Doing different things is where the genuinely disruptive changes occur, potentially bringing in new capabilities or achieving different effects. Examples include using “Big Data” techniques to conduct fleet-wide analysis using a decentralised “brain-of-brains”, employing Digital Twin technology applied down to individual platforms (whether as genuine digital twins, or some form of “digital sibling” or “digital cousin” at the type or class level), or adopting Asset Management practices as defined in ISO 55000 to provide a business-focussed wrapper around the maintenance, repair, overhaul and supply chain activities.

This 3-level model also helped enormously with constructing the programme of work at the end of the task as it helped with identifying where proof-of-concept studies would be needed to demonstrate some of the more novel technical innovations. This model almost certainly has wider general utility in transformation programmes and will be one of the central anchoring points for the presentation.

We engaged with our stakeholders through a variety of means.

Questionnaire on Survey monkey
Workshops with MOD Users, MOD Acquisition, Industry and SMEs
1-2-1 sessions
MOD User Forums

Industry Supplier Forums
Wider engagement up to senior levels within MOD.

This presentation will focus on the workshops, explaining how we used a mixture of briefings, rich pictures and semi-structured post-it note based analysis, across two parallel streams, to identify pain points, future aspirations, enablers, blockers and potential solutions (categorised into interventions and innovations) across three contexts (Maintenance Repair & Overhaul, Asset Management, and Engineering Governance) and across three environments (Air, Maritime, Land) which each brought their own unique perspectives.

Defining the Vision

The various stakeholder engagement and research activities all contributed to refining the set of elements which would be needed to deliver the overall vision. These were captured in a set of target architectures and mapped onto the various interventions and innovations needed, leading to a set of thematic workstreams. The target architectures captured not only the Engineering Support aspects, but also the dependencies on other parts of the wider Defence Support Network transformation programme. In each case, a systems-of-systems approach was followed to identify loops and dependencies.

Building the Programme of Work

A set of 11 development themes was identified, covering these areas:

- A Culture of Collaboration
- Engineering Governance
- Engineering Policy
- Engineering Standards
- Commercial Enablers
- Information Systems and Data Management
- Exploitation of Health and Usage Data
- Digital Platforms and Assets
- Enhanced Maintenance and Repair Activities
- Asset and Fleet Management
- Design For ...

In keeping with the 3-level model, the themes were defined according to a common pattern based upon 5 stages – understand, proof-of-concept, option analysis, policy definition, and implementation. Not all stages were needed for each theme, and in some themes there were multiple parallel understand and proof-of-concept tasks, recognising the need to engage with multiple communities or explore multiple technical options.

At the time of writing, the EST Programme of Work is still being finalised. The task itself will be completed at the end of March, and the final version of the programme will be summarised as part of the presentation.

Conclusions

It has proved possible to use this approach to devise a thematic approach to the programme of work which should deliver across the full EST Vision. A key element will be ensuring that Engineering Support governance is properly defined within the wider Defence Support Operating Model, as this is needed as a key enabler for many of the interventions and innovations to be progressed – as is always the case in these situations.

In our wider research, it has become apparent that current developments in the built environment, where Building Information Modelling (BIM) is being combined with Asset Management techniques, may provide a useful benchmark for the digital transformation of military assets, facilities and their management approaches. This is of particular interest as the digitisation of support engineering appears to be a confluence where MBSE, BIM, Systems Engineering, Asset Management and product standards such as the ASD series and AP233 / ISO13030 / STEP may all come together – enabling the design of better support solutions at the interfaces between products, services, processes and facilities.

Presentation#66

Health Impact Assessment of Subcritical Pulverized Coal Fired Power Plants in Luzon Using Life Cycle Assessment

Keywords. Coal Fired Power Plants;Health Impact;Life Cycle Assessment

Abstract. – In the Philippines, coal comprises 32.2% of the country's installed capacity and the department of energy forecasted that by 2040 it can grow as much as 42%. Coal combustion in power plants produces air emissions, such as carbon dioxide, oxides of nitrogen, particulate matter (>2.5 microns in diameter) (PM 2.5) and oxides of sulfur that negatively affect human health. It is important to consider the balance between meeting energy demand and effect on human health.

The study estimated the health impact from coal power plants in Luzon since about 75% of the coal based generation capacity in the Philippines is located in Luzon. Two existing coal generation technologies were considered. Subcritical pulverized coal (SCPC) was considered since it comprise almost 65% of the total dependable capacity of coal. Coal source was also considered in the study since the Philippines is promoting local coal use for energy generation through the use of some incentives.

The goal of the study is to analyze and compare the health impacts of SCPC in Luzon. It also aims to inform the public and decision makers regarding the health impact caused by electricity generation technology, specifically coal, for them to make more informed decision for making or revising existing policies. Stratified sampling method was used to determine which power plants should be included in the study. Power plant specifications were gathered from DOE and Energy Regulatory Commission (ERC). From the power plant specifications the coal consumption for each coal power plants were obtained. Life cycle inventory was estimated based on the coal consumption of the power plants and the existing life cycle data or emission factors for each of the life cycle stages considered - mining, transportation and energy conversion.

SCPC was estimated to have an average health impact of 1.82×10^{-6} DALY/kWh. This translates to 46,084 DALY/year of power plant operation. This result can be used to calculate the cost of health intervention needed to avert this health impact and compared to the overall benefit of the presence of the coal fired power plants. This would help the decision makers crafting policies for sustainable development. Energy conversion stage imposes the highest health impact and PM 2.5 has the highest impact among air emissions considered. Having a more efficient way in operating the power plants would reduce the health impact imposed by SCPC on the population in Luzon. Reducing the particulate matter emissions in the combustion phase through emission control technologies significantly reduce the health impact of coal fired power plants. The Philippines wanted to utilize its coal resources. However, it was also found that in a health impact perspective, imported coal has an advantage over local coal due to its lower ash and sulfur content.

implementation of a Product Line Engineering approach

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Presented on: Wednesday, 16:15-16:55 in Grand Cypress Ballroom A

Keywords. Product Line Engineering;Systems Engineering;Model Based Systems Engineering;Unmanned Aerial Systems;Variability;Commonality

Abstract. Product Line Engineering (PLE) is an approach that provides an efficient way to build and maintain portfolios of systems and equipment that share common features and capabilities, as well as to efficiently manage variants and versions. One of its practices is to put in common the development assets and to reuse those assets for addressing stakeholders' needs, rather than developing bespoke solution which later on will be difficult to reuse. The expected benefits of the PLE approach are manifold: lower development and recurring costs, reduced time to market and better quality of the product, among others.

The implementation of a PLE approach in an organization encounters several challenges related to the impacts on the existing organizations, their roles and responsibilities; the tools that are required to implement it; the business context which may be favorable or not to this implementation; the quality, maturity and ownership of the existing building blocks (i.e. the reusable items); and the heterogeneous profiles of the people that will implement the approach.

Regarding this last challenge, the Systems Engineering (SE) approach has proven to be a key tool for addressing it. Indeed, SE practices promote an interdisciplinary approach for both technical and management tasks, aiming at delivering solutions satisfying the stakeholders' expectations and constraints. They are well adapted for a PLE implementation, as it impacts a high number of technical and management processes, requiring the collaborative effort of several disciplines of engineering and beyond.

We have been developing a set of Model-Based Systems Engineering (MBSE) practices to support the implementation of the PLE approach. MBSE promotes the use of models as a semi-formal support to improve communication and reduce ambiguities among heterogeneous populations. In the case of architectural models, they also provide the means to represent, discuss on, perform trade-offs and review the reference architectures of the product and its building blocks.

During this presentation we will provide an overview of the MBSE practices that support a PLE implementation and in particular the definition of the architectural design of a product:

- Analysis of the operational context of the Product Line – expectations and constraints of the stakeholders coming from diverse market segments
- Analysis of the product needs – definition of the capabilities of the product, its key requirements and the key interfaces with the stakeholders
- Variability & Commonality analysis – identification of the those capabilities and constraints that are common to the different market segments, and of those that shall be addressed in a variable way
- Variability impact analysis – definition of how the logical and physical architecture of the product is tailored according to the product needs

These MBSE practices, as well as how they contribute to the effective implementation of a PLE approach in an industrial organization, will be illustrated through an example: the definition of the architectural design of an Unmanned Aerial System (UAS) addressing several market segments and stakeholders.

Machine Learning for Project Management Functions

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Keywords. Machine Learning;Lessons Learned;Content Analysis

Abstract. At NASA, we are transforming our processes to fully leverage evolving digital technologies. The vision of this transformation is not only to view digitized records virtually across diverse organizations, thus improving design efficiency, collaboration, and safety, but also to streamline our processes to take advantage of new digital tools to optimize operational flows. One application being realized as a result of these transformation efforts is an intelligent data interface that rigorously integrates systems engineering and project management lessons learned information in near real-time. The application is a Microsoft Excel add-in application with an easy installation process on the user's desktop or laptop. The add-in application provides a user interface to accept text input (in various forms from a keyword, a sentence, a paragraph, to an entire document) in an active cell of any worksheet and then output the relevant historical lessons learned information via a customized side panel.

The add-in application encompasses a corpus of lessons learned documents in a plain text format, a trained Doc2Vec (based on a single-hidden layer neural network) model, and the user interface functions. An Expert User periodically updates the lessons learned corpus via the application's user interface. As additional lessons learned are added, the Expert User must then retrain the Doc2Vec model by tuning several training parameters. After validation of the newly trained model, the Expert User can package this add-in application and deploy it to general users. The general user then installs this new version on his or her machine and is able to proactively activate the application, search through the lessons learned corpus in a near real-time, and, using hyperlinks, access the full lessons learned documents. There are two potential primary benefits of this application over today's practice. First, this application offers a proactive search capability of NASA's lessons learned database. Today's practice is passive in nature, meaning that the users must go to the lessons learned source and perform the laborious search themselves. Second, the application's search Doc2Vec algorithm is based on content analyses, while the lessons learned website's search is based on keywords. As such, the recommended documents from the website are often deemed irrelevant by users. Additional benefits of the application, are that it can be shared with, and reused by several users many times and can be applied beyond the lessons learned corpus to any generic database. Additionally, it can be extended as an add-in to multiple programs in the Microsoft Office suite.

Along the way, the development team encountered a few deployment challenges in this project. For instance, the lessons learned documents data format needed to be standardized as well as cleaned before the Doc2Vec model's training step. Additionally, while training the application, tuning the parameters was a particular challenge. The ever-present IT security was also a challenge. In this presentation, the team will demo the application, discuss our challenges and solutions, and share our progress to date including any lessons learned for this project.

Manufacturer to Industry Partner: A review of the Inauguration of Systems Engineering within an Organization

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Presented on: Tuesday, 15:30-16:10 in Grand Cypress Ballroom I

Keywords. Processes;Partner;Leadership

Abstract. For any Original Equipment Manufacturer (OEM) in Defense Industries, requirements management is rooted into the Organizational structure. Architecture, Development, Validation, Traceability, and Verification are ingrained in the Systems Engineers within the Organization and the Systems Engineering process is well established. However, Program Risk sharing has changed the industry in such a way that OEMs are no longer looking for “Suppliers” but instead seek “Industry Partners”. These Industry Partners no longer just Build-to-Print (BTP) but now have Design Authority and share in some of the risks associated with this new responsibility. In this risk sharing role, the additional responsibilities must align and supplement the parent responsibilities of the OEM.

Companies who are deep rooted into their manufacturing trade are now faced with the cultural shift to work as a Valued Partner and create an Infrastructure which allows for the management of this new found role. They must work to launch processes and have tools in place to allow them to perform with the goal to provide all the data required for requirements closure at the OEM level.

For Spirit AeroSystems, the primary product is Structures and Structures Technology. Within these disciplines, requirements management is often managed organically and adding additional rigor imposed by an external group raises the question “Does it add value”? Structures technology at this level is atomic and decomposition of the system is not necessarily required.

For the new Functional Organization at Spirit AeroSystems, called Systems Engineering, the team had a different kind of holistic problem to solve. Systems engineering was required to manage the complexity, change, and risks Spirit AeroSystems now faced as an industry Partner. It is within this context the Systems Engineering team had to redefine the System and the focus was on the social aspect of the problem as it relates to design and manufacturing of the product. The dynamic behavior normally seen within the technical realm was not the necessary construct for the team but instead, the dynamic behavior normally managed by Systems Engineering was within the Organization relationship and interactions itself. The ability to add rigor and discipline to a product for which previously never had the need as a BTP product, now required this level of disciplined Systems approach.

This presentation will walk through the journey of the development of Systems Engineering methodologies now utilized at Spirit AeroSystems. New processes and tools had to be inaugurated and as the team learned more about how the organization handled these new processes and tools, they learned to be flexible and adapt to meet the greater need of creating a structured process that met the needs of all those integrated into the process while still supporting the performance of a good quality product within the schedule and budget constraints provided by the OEM.

The opportunity for Systems Engineers to form this new operating environment did not occur without its setbacks along the way and when faced with unintended consequences, the team developed significant lessons learned they used to become more efficient as the development of the product progressed. The quick maneuvering and actions taken by the team reduced unnecessary risks that may have resulted early in the establishment of the processes and tools. The team spent a significant amount of time reviewing patterns that created barriers contributing to ineffective systems engineering and took positive action to counter the challenges.

The presentation will walk through from start to finish the dynamics we faced during the development of the processes we put in place as well as the growth and understanding of the Systems Engineers role in this new space. Processes in Requirements Development, Verification, Interfaces, Test, and Affordability were all developed in order to support the OEM through the development program and production programs as well as protect the interests of Spirit in this new role.

Leadership had to strategically review the long-term effects of creating a Systems Engineering function and provide a vision for the company which would sustain from one project to another. Will Systems Engineering be effective at Spirit AeroSystems? Will the requirements discipline put in place insure the company will prosper and become successful as an Industry Partner? In order to visualize the end, you need to be able to understand the beginning.

Mastering the impacts of modes and states on the system: model-based method and tool perspectives

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Presented on: Wednesday, 13:30-14:10 in Grand Cypress Ballroom GH

Keywords. mbse;mode;state;method;model;systems

Abstract. Management of modes and states is a wide, complex, and often underestimated part of systems engineering. As systems and missions become more complex, the potential combination of modes and states across system, subsystem, and component levels becomes exponential and difficult to master. This presentation proposes a methodological approach for studying and integrating the impact of modes and states on the architecture definition. It establishes the concepts of configuration and situation as keys to analyzing these impacts. The presentation illustrates this approach with the use case of a nano-satellite and demonstrates how the approach is supported by a modeling tool.

Modes and states are amongst the most ambiguous and the least understood concepts in systems engineering. Several aspects have to be considered:

- The specification of the expected functional behavior of the system in different contexts
- The supervision of the expected functional behavior of the system and the detection of possible failures
- The combinatorial of the modes and states of the system and of its components
- The possible dynamic reconfigurations to be performed during system operation, in particular in reaction to failures
- The startup and stopping of the system and its components
- Etc.

Challenges are numerous:

- Being able to prove that the system expected behavior can be reached in all possibly realizable combinations of modes, states, at system and subsystem level.
- Being able to study the reconfigurations of the system while it operates.
- Using modes and states as a support to perform analyses on the system. For example, in the domain of satellite launchers, the mass, power and communications profiles vary significantly according to the flying phases, and the modes of each subsystem

Overview of the approach

1. Specification of modes and associated atomic configurations. The first step consists in defining the expected behavior to face the different contexts the system will face. This includes all or parts of the following:

- Identification of the different contexts required simultaneously: for example, operational mission or training, fully operational or maintenance, autonomous or remotely piloted by an operator, etc.
- For each context, formalization of one mode machine specifying all possible transitions
- The content of each mode is then detailed in an atomic configuration that primarily describes the functional and non-functional content (required capabilities, functions, scenarios and functional chains to be played, etc.) but might also include some structural content (components, interfaces, physical connections, etc.).
- The triggers and conditions for all possible transitions between modes within a mode machine can then be specified, and if possible, related to elements such as functional exchanges or execution of functions.

2. Specification of states and associated atomic configurations. The different simultaneous state machines that can impact the content and behavior of the system (presence or absence of components, health status of physical components, environmental conditions, etc.) can be defined following the same patterns as the ones used for the definition of modes. Atomic configurations are also used to primarily describe how specific states translate in terms of

structural content and associated properties.

3. Identification of "superposition" situations. Once the expected behavior of the system is specified, it has to be confronted to the situations that can influence or harm it during its operating time. Each situation identifies the required superposition of modes (logical combination of modes in each mode machine) as well as the states likely to occur in this situation (typically feared states like attack, failure, external disturbance, etc.). A situation is a combination of distinct modes and states, all currently active in their own context.

4. Definition of global configurations of interest. Unlike atomic configurations, global configurations are not directly associated to any specific mode or state. Instead, they are used to capture an expected system behavior of interest. There are multiple reasons why a specific system behavior (scenario, functional chain, etc.) can be of interest: because it corresponds to a particularly critical point of the system, because it is a customer specific request, because it is a minimal behavior to be preserved whatever the operating conditions, etc.

5. Computation of the global configuration corresponding to each situation of modes and states. Each superposition situation of several modes aggregates constraints coming from the atomic configurations associated to each mode. These atomic configurations have to be combined, which might bring contradictions (for example, a function can be required in a mode and rejected in another, a functional chain can become incomplete because of rejected functions, etc.). The following step of the approach is therefore to build the global computed configuration, merging all atomic configurations associated to the modes involved in the considered situation. The merging rules have to be refined (this is the topic of an ongoing work), but a simple union is a good starting point. The internal consistency of this resulting global configuration can then be analyzed. Inconsistencies mean either the modes machines or the atomic configurations have to be reworked.

6. Confrontation with expected global configuration of interest. Optionally for each given situation, if global configurations of interest have been defined, it is possible to compare them to the global computed configuration and detect inconsistencies.

7. Analysis of the computed global configurations for situations mixing modes and states. From a technical or conceptual standpoint, situations involving states could be managed the same way as situations involving only modes. However, it is generally recommended to treat them incrementally, in a second step.

8. Adaptation of the architecture. If the delta between the expected behavior and the result of the analysis is not acceptable, a compromise has to be sought, if possible by reworking the architecture to restore the expected behavior. This can take several forms, including:

- Functional reallocation (for example to move critical functions in a less vulnerable component)
 - Introduction of degraded modes (for example triggering a dynamic reconfiguration of resources), introduction of redundancy
 - Improvement of configurations associated to certain states (using for example more reliable components)
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MBSE 2.0- The Next Steps for MBSE

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Presented on: Tuesday, 16:15-16:55 in Grand Cypress Ballroom I

Keywords. MBSE;future;metamodel;connected

Abstract. Model-based systems engineering (MBSE) is a term that has become "loaded" with meanings- many not intended in the original concept of MBSE - some of them even contradictory with it and with each other. As originally conceived, MBSE was the practice of basing the systems engineering (be that design, redesign or improvement) on a common, shared model of the system design. But the loading down of the term has resulted in confusion in engineering enterprises about what MBSE is and how it is practiced.

This presentation points the way to a path forward- to an MBSE 2.0 where the hurdles and missteps are behind us. In doing so, we don't reject the journey and the progress that has brought us to this point in time. Instead, we embrace them in all their richness - the strengths and successes to reinforce, the challenges to address and resolve. This involves understanding that a broad vocabulary consisting of representations that will communicate to a wide audience of customers and not just to a narrow segment accustomed to one way of representing systems. It requires connecting to a variety of analytical models (e.g.- physics-based performance models) without thinking of them as the systems architecture model that makes systems engineering truly "model-based."

The path forward described here is a return to sound systems engineering principles and practices while incorporating and embracing the enrichment derived from the contributions of the sister disciplines of traditional engineering, software development and the advancing world of artificial intelligence. This is a practical reflection with pragmatic guidance to help us deliver against today's challenges while plotting a path to the greater digital engineering future. Moving towards MBSE 2.0 today allows us to mine the best of systems engineering's fundamentals and the learning of its future.

Meeting the Challenge of Tomorrow

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Presented on: Monday, 13:30-14:10 in Grand Cypress Ballroom I

Keywords. Future;non-traditional;opportunity

Abstract. INCOSE's Vision 2025 "A World in Motion" calls for, "Applying systems engineering to help shape policy related to SOCIAL AND NATURAL SYSTEMS" and lays out socio-economic and physical environment challenges. At the recent IW 2019 the Leadership Strategy Sessions included a session on the "Grand Challenges" that focused on this expansion of system engineering's reach beyond its traditional applications. Some of the challenges prioritized by the session participants included clean water and sanitation, a zero carbon footprint, consistent power availability and conflict management.

It is, however, much easier to say that systems engineering should bring to bear its tools and methods in these non-traditional areas than to actually bring that about. There are significant obstacles impeding the way. This presentation will address the nature of a number of those obstacles and their etiologies as well as strategies for overcoming them.

In particular the presentation will examine the issues of visualization and translation. It is a fundamental principle of change that we cannot go anyplace where we can't visualize ourselves as being. This is a large chunk of the problem that first generation college students have to overcome. Without any family history of college attendance or closely related examples potential students have difficulty imagining themselves as successful in the college setting. In order for systems engineering to expand its horizons systems engineers must learn to visualize their discipline as applied to the field of expansion.

Systems engineers also face the obstacle of translating what systems engineering does, how it does it and how that can be helpful to domains where even the name "systems engineering" has never been heard. This means that they must learn the language of the new domain and communicate in it. The arrogance of insisting that the domain learn to speak systems engineering will doom even the most helpful effort to failure from the outset.

In response to these challenges, systems engineering must develop strategies for addressing and overcoming them. This presentation will discuss such strategies as learning to think about systems problems and solutions at the conceptual level in order to visualize the wider field of opportunities for system solutions and learning the language of the domain in order to be able to communicate and gain acceptance in non-traditional domains.

A World in Motion challenges us to expand our horizons to make systems engineering even more relevant and useful in today's ever-changing world. This presentation plots a path and packs a bag for beginning that journey.

Presentation#11

Modeling and Optimization of Interconnected Systems to Improve Economic and Sustainability Considerations: Applications to Energy Systems and Process Operations

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Presented on: Monday, 11:30-12:10 in Grand Cypress Ballroom I

Keywords. process systems engineering;mixed integer programming;carbon management;planning;energy systems

Abstract. The quest for pollution prevention, coupled with increased pressure and demand for environmentally sustainable processes and products, have spawned new rules and regulations in the process industry. This talk will present methodologies that enable engineers to identify creative strategies for the operation, design, integration, and supply chain management of interconnected processes in a sustainable and cost effective way. These strategies involve the selection of system components, interconnections of units, operating conditions, infrastructure development decisions, or even interactions along supply chains or the ecosystem at large. Novel mathematical programming models that are able to propose optimal solutions to effectively account for sustainability and capture the complexity of the various operations will be presented. Several illustrations dealing with energy production systems, integrated petroleum and petrochemical facilities, energy hubs, and eco-parks will be discussed

Presentation#39

Practical tailored MBSE process “Nissan-7”

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Presented on: Thursday, 08:45-09:25 in Grand Cypress Ballroom DEF

Keywords. Tailored MBSE process;Automotive;New engine development;Layered concept

Abstract. The latest power train technologies such as downsizing turbo engines, continuously variable transmission (CVT) and hybrids are increasing in complexity and scale of required development effort. As a solution, Nissan has started to use a Systems Engineering focused approach the development methodology. Requirements for automobiles will continue to increase. The automobile systems are also becoming more complicated as the requirement increases. As a solution to this challenge, many automotive companies are applying Model Based Systems Engineering (MBSE) for complexity system design. It is necessary to involve all engineers related to system design into systems engineering activities. “All engineers” involved in system design include not only system engineers but also performance designer, mechanical engineers, software engineers and calibration engineers. Therefore, new capabilities are required for facilitating widespread understanding and discussion of the whole system. To achieve this, a unique Nissan MBSE process was developed that uses processes, views and matrices in a more practical and efficient way in systems engineering. This presentation describes Nissan's practical MBSE approach through development of a new variable compression

ratio turbo (VC-T) engine.

<Key points of Nissan's MBSE>

Many domain engineers are involved in automobile development. We need to develop together with "All engineers" who are not specialists in system design. Nissan's MBSE has 3 key points. They have realized that "All engineers" can participate in system design. Not only system engineers but also mechanical engineers, software engineers, and calibration engineers are required to participate in the case of power train design.

1. Layered concept: Requirement is flow downed with step-wise refinement.
2. Tailored process "Nissan-7": Simplified procedures which are understandable for "All engineers".
3. Quick Verification and Validation (V&V) in design phase: Expanded the verification area by using CAE before making a prototype.

1. Layered concept.

Nissan's layered concept has 3 layers. Power train, Unit and System layers in conventional unit development case. System layer defined parts and control requirements. Layered concept has 3 objectives.

- i. Engineers receive requirements from the layer above, and own layer is defined by decomposition
- ii. Requirements are passed to the lower layer following iterative analysis
- iii. Layered verification and validation is realized by layered design.

The benefit is it can be executed before assembling a prototype engine. "All engineers" can verify at any level.

2. Tailored process "Nissan-7"

Essential diagrams were selected from standard SE diagrams. But "All engineers" cannot participate in the design with the standard SE diagrams alone. Therefore we created 2 original diagrams. Nissan-7 is realized challenge extraction more viewpoints involve with hardware and calibration engineers. Nissan-7 is realized challenge extraction more viewpoints involve with parts and calibration engineers.

Explanation of the original diagrams.

Operational view: General SE diagram doesn't define such as the diagram. This diagram show multi system behavior. It is an effective diagram for Nissan engineer's discussion.

Trade off matrix: This diagram can clearly define the requirement specification of parts. This matrix can be define parts requirements by each parts set points that satisfy the functionality and reliability requirements for each scene and determining the trade-off study result.

3. Quick V&V in design phase

In order to execute MBSE, we defined a collaboration process between the Nissan-7 diagrams and system simulation models. The representation of the MBSE diagrams is SysML. In order to prevent rework, it is important to confirm the target achievement level in the design phase. We confirmed it by assuming the consistency of the realization logic to the request.

<Procedure of MBSE in Nissan Power train>

We are designing in 3 layer in case of Engine development and 4 layer in case of HEV development. Engineers receive requirements from the layer above, and own layer is defined by decomposition. Passing requirements to the lower layer following iterative analysis. The system granularity is defined by layered concept. Engineers can control the complexity level by layered concept. Nissan is managing design responsibilities according to that layer definition. Our organization responsibility is basically decided by the layer concept.

"All engineers" are participate system design. It was difficult for all of them to understand the essential SE diagrams. We have developed 2 diagrams for "All engineers" to understand.

Nissan is also develop while ensuring the consistency between description model and analysis model. The achievement level of requirements is evaluated using an analytical models that ensures consistency in design phase.

Raising the Bar on SE: Lessons Learned Improving the Practice at a Navy Research Center

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Presented on: Wednesday, 10:45-11:25 in Grand Cypress Ballroom A

Keywords. systems engineering;education;competency;leadership;effectiveness;culture shift

Abstract. The presenter will discuss an almost 5 year effort to improve the skills and capabilities of the SE workforce at a Naval Research and Development (R&D) center. Specific topics to be addressed will include:
Identifying the SE workforce – Due to historical precedent, many employees considered SEs had little to no academic training in the SE discipline. With the exception of a handful of senior level positions, the title “system engineer” was used by a significant portion of the workforce not actually performing SE duties. Methods for identifying those who were truly functioning as SEs will be discussed.
Reaching SEs - As a product-aligned organization, those performing SE tasks were scattered throughout the organization. This posed additional challenges for contacting them and facilitating development, collaboration and mentoring of junior level SEs. Specific actions taken to address this will be presented and their effectiveness discussed.
Motivating SEs – Creative ideas for motivating practicing SEs to improve their skills and share their knowledge despite the extreme demands to execute project work will be presented.
Inspiring SEs – To help identify future leaders in the SE discipline, specific opportunities to expand their perspective and improve their leadership skills were identified and advocated for. The results of these effort will be discussed, to include perspectives from both the organizational leadership as well as the SEs themselves.
Conclusion – A retrospective look at the effort will conclude the presentation, discussing how it became evident the task at hand was not just a policy and training change, but a significant culture shift which could have benefited from additional considerations.

Presentation#20

Requirements Efficiency: Questionnaire Results

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Presented on: Tuesday, 14:15-14:55 in Grand Cypress Ballroom DEF

Keywords. requirements engineering;requirements management;survey

Abstract. Efficiency in requirements engineering and management (REM) for complex hardware systems is desirable to reduce program impacts, such as schedule and budget. We investigated REM state-of-the-practice to capture insights, recommendations, and best practices on REM topics, including requirements approaches and processes, architecting, configuration management, and change control. Twenty-one at-will participants contributed responses to closed- and open-ended questions. The results were synthesized and provided to help us and others understand where our practices are current; what trends, approaches, or processes in REM might be beneficial if implemented or introduced; what challenges might be avoided; where efficiencies might be realized; and which practices are still maturing or evolving in industry and academia, so that we can stay abreast of these developments.

Presentation#65

Smart system assets development: Use your knowledge!

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Presented on: Thursday, 08:00-08:40 in Grand Cypress Ballroom B

Keywords. Requirements Engineering;Ontologies;Aerospace standards;System Design;Verification and Validation;Requirements Quality

Abstract. One of the biggest challenges in the development of complex systems in the Aerospace industry is to ensure the correct implementation of the system capabilities. The verification and validation tasks will therefore ensure that system requirements represent a solution that meets the operational needs of the stakeholder's expectations and that the requirements are developed further in a correct way towards the SW and HW development. During the requirements definition process, stakeholders provide the services needed in a defined environment and assign those needs to SW or HW components respectively. During this process, to define and evolve system and SW/HW requirements, the complexity is an ever-increasing element in the system and SW/HW life cycles. The consequences of the decisions made at early stages of the development, as it is the requirements definition, imply an increment of the costs to extract defects in later stages. The abovementioned aspects for the requirements definition and development, are part of the processes defined within the systems and SW/HW engineering activities to reduce the risk of failures in projects. Therefore, there have been developed several techniques focused on the improvement of the textual requirements definition activities. As it

is the case of the INCOSE Guide for Writing Requirements, which aims to draw together advice from existing standards such as ISO 29148 and the authors and reviewers into a single, comprehensive set of characteristics, rules and attributes (Requirements Working Group. INCOSE, 2017). When it comes to the application of such guidelines and standards, it is important to align the industry objectives and the techniques defined in theory. Most aerospace projects follow the ARP standards for systems & safety engineering (ARP4754A, ARP4761) and the RTCA DO standards for SW/HW engineering (e.g. RTCA DO-178B/C, RTCA DO-330/331/332/333, RTCA DO-254).

On the other hand, the process for specification of the system requirements is very complex due to the complexity of the systems to be developed, which leads to a hierarchical elicitation and refinement of requirements by the different parties acting at the different levels of the supply chain (Aircraft Manufacturer, System Provider, Equipment item Provider, provider of components of equipment items, supplier of certain tasks). The providers at the different levels (except the highest one) have all to use the requirements from the next higher level to specify and design their specific part of the overall system. In turn, all providers (except the lowest tier) have to specify the requirements for the next lower level. This complexity makes crucial for the success of the projects a high quality of the requirements at all levels and regarding all aspects, which in aerospace domain especially means crucial for the safety and reliability of the systems.

The study presented was developed in the context of a Proof-of-Concept in AES with the collaboration of The REUSE Company technology and consultants, where the main purpose was to measure the quality of SW/HW requirements specifications based on the characteristics and rules defined by INCOSE, international standards and organizational guidelines to assess how well-formed are both SW and HW requirements. Further, the aim was to improve the process and means for requirements definition and the formulation of SW/HW requirements.

To tackle the PoC main purpose, there are sub-objectives to overtake before we got any conclusion. In the definition of textual requirements, the characteristics and attributes provide a sort of reference to develop the qualitative (and quantitative) indicators that ensure the good quality of textual requirements.

On the other hand, the accuracy of the quality results achieved according to the defined guidelines to ensure the correctness of requirements, will depend on several aspects intrinsic to natural language, due to the ambiguity of the language itself. To minimize the impact of this ambiguity in textual requirements, there exist the advantage of using common syntaxes for requirements, which also needs to focus on the specific vocabulary and how those terms are used by the different subsystems and elements, as breakdown structures, system architectures or interfaces, among other pieces of information. Both syntax and vocabulary, with their relationships, can be managed by using patterns and the definition of ontologies. The definition of such ontologies, will help us to reduce manual efforts to assess the quality of our requirements, the counterpart is that if we want to have tools to help us in this activity, we need to transfer them our knowledge, and the organizational know-how, to have a similar analysis.

The scenario to define both the ontology and the set of characteristics for textual requirements, start to grow in scope and efforts to cover complex systems, then the reuse of the organizational know-how and the system knowledge become interesting solutions to define the optimal process to develop requirements within an organization. The application and analysis of knowledge in the scope of the PoC have been part of the main activities, applied to two different projects in AES. One of them a new project, the other project is an ongoing project, this scenario within the PoC let us distinguish between different knowledge configurations to (i) cover the actual needs of each project and (ii) reduce the efforts to create both ontologies by reusing all common elements. The results from both processes imply to measure how suitable are each of those documents to be tailored within AES current SW and HW requirements engineering, and at the same time to evaluate the impact on its application to production environments.

Systems Engineering on Legacy Systems

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Presented on: Tuesday, 16:15-16:55 in Grand Cypress Ballroom DEF

Keywords. Sustainment;Legacy;Systems;Aerospace;Defense

Abstract. What are legacy systems? Why would you want to work on legacy systems? How can you build a successful engineering career in legacy systems? What are some strategies for working on legacy systems? In this presentation, we will explore these, and many other, questions.

As engineers, we are the problem solvers of the world. We apply our creativity and technical expertise across many domains. We build state-of-the-art aerospace and automotive vehicles. We develop innovative ways to bring food and water to more people around the world. We produce ingenious technologies for delivering health care. We produce greener technologies and develop more efficient infrastructure.

Legacy systems play a critical role in the systems we work on every day. Rather than thinking of legacy systems as "obsolete" or "outdated", think of them, simply, as older systems that are still in use today. These legacy systems are still in use, because they fulfill their missions better than anything else in their domains. As a younger engineer, you can benefit greatly by working on legacy systems. As an older engineer, you can continue learning, growing your career, and mentoring the next generation of engineers.

As we discuss legacy systems, we will present strategies for working on legacy systems. These strategies include gathering documentation, seeking mentoring, developing architectures, performing modification programs, sustaining the system, and replacing the system. We will show how applying these strategies can lead to a successful engineering career.

Systems Engineering Principles

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Presented on: Wednesday, 11:30-12:10 in Grand Cypress Ballroom I

Keywords. Systems Engineering Principles;Systems Principles;Systems Engineering Hypothesis;Engineering Discipline;Sociology;System Science;System Integration;Transcendent;Lifecycle

Abstract. Systems engineering exists to develop a solution to meet a need. This is the motivation of systems engineers in accomplishing their work. But how do system engineers accomplish this expansive challenge? To address this, a set of systems engineering discipline principles and hypotheses articulate the basic concepts that guide systems engineering. The INCOSE Systems Engineering Principles Action Team reviewed various sources of systems principles and systems engineering principles identified in literature. Principles are accepted truths that apply throughout a discipline. These truths serve as a guide to the application of the discipline. Systems engineering principles then are accepted truths that apply throughout the discipline of systems engineering, guiding the application of systems engineering. In reviewing the various principles, a set of criteria was identified which govern the definition of a systems engineering principle. These criteria indicate that, system type, the context in which the system is developed and operated, or a life cycle phase do not narrowly define systems engineering principles. Systems engineering principles transcend these system characteristics and inform a worldview of the discipline. Principles are not "how to" statements, which are embodied in the processes, but provide guidance in making decisions in applying the systems engineering processes. Principles should have a strong reference basis supported by literature, or widely accepted in practice (keeping in mind that this success must transcend the system characteristics mentioned above), or both. Principles are focused, concise, and clear in well-constructed principles statements. This presentation provides the definition of a set of systems engineering principles and hypotheses based on the results of this Action Team.

The Application of Systemic Thinking to Understanding the Interoperability Challenges of Integrated Live Virtual & Constructive Training

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Presented on: Tuesday, 11:30-12:10 in Grand Cypress Ballroom I

Keywords. Systems Thinking;LVC;Distributed Mission Training;Mission Rehearsal;Modelling and Simulation;Interoperability.

Abstract. The ever evolving Defence operational context in conjunction with increasing complexity of Defence assets is driving a need for greater integration across Defence Services in order to ensure safe and effective delivery of required capability outcomes. This operational context is driving a greater need to interoperate efficiently and effectively, across Services and platforms, and perhaps even more importantly, in the ability to train and rehearse as a joint force to demonstrate preparedness prior to actual operations in an integrated Live, Virtual and Constructive (LVC) construct.

Defence forces today have the ability to conduct very efficient and effective individual procedures training for specific platforms - such as with high fidelity Full-Flight and Mission Simulators for specific aircraft types. However, the same cannot be said for team and tactics training (such as across the crew on a specific platform), and even less so for joint and combined distributed mission training (DMT) or Mission Rehearsal (MR). This inability to effectively train as a joint force presents significant risks to defence operations and in successful achieving defence outcomes.

This presentation will apply a first-principles systems thinking approach to define an interoperability effectiveness framework, from a human-centric perspective towards achieving common situational awareness in an integrated LVC context. It will build on defining core principles of Systems Thinking, Modelling & Simulation (M&S), and categorise M&S across the LVC context. This will be followed by highlighting the challenges of moving from the traditional high-fidelity platform-centric procedures context to team and tactics training and onto DMT and MR. It will present an example common functional architecture for simulations with particular regards to modularity and openness, highlighting where applicable standards exist and opportunities for future standards development. The overarching intent being to highlight the risk to Defence as a result of the extant training gap in the team, tactics, DMT and MR context, and towards improving the understanding of the challenges, so as to improve the definition and delivery of training capability over and above the traditional individual focus towards team and tactics training and on to DMT and MR.

Presentation#29

The Dawn of Intelligent Systems

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Presented on: Wednesday, 13:30-14:10 in Grand Cypress Ballroom DEF

Keywords. Intelligent Systems;Artificial Intelligence;Machine Learning;User Experience;Design

Abstract. The challenge that confronts all engineers, and systems engineers in particular is the design of increasingly complex systems that are both more intelligent and autonomous, but are also better able to collaborate with the humans that use them.

Fulfilling the vision of such Intelligent Systems takes more than just throwing in the latest machine learning algorithm or slapping a conversational interface on an existing product. It takes engineering systems to function as intelligent partners and collaborators with humans.

In this talk we will cover:

- ? What makes a system intelligent?
- ? How systems can deliver an intelligent customer experience (or not)
- ? Why human-machine partnerships, not artificial intelligence, is the future
- ? Principles for engineering Intelligent Systems

Presentation#61

The Future of Assurance and Certification of Cyber-Physical Systems exists today: the AMASS platform.

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Presented on: Tuesday, 14:15-14:55 in Grand Cypress Ballroom A

Keywords. assurance;certification;traceability;verification;model quality;interoperability;platform

Abstract. System assurance and certification are amongst the most expensive and time-consuming tasks in the development of safety-critical systems. They require the execution of complex activities such as the management of compliance with hundreds or thousands of criteria defined in safety standards and the management of a large volume of evidence artefacts throughout a system's lifecycle to justify system dependability. The challenges arising from system assurance and certification are further growing as a result of the evolution of safety-critical systems towards open, interconnected, networked systems such as "the connected car". This has brought a "cyber-physical" dimension with it, exacerbating the problem of ensuring safety as well as other dependability concerns, e.g. security. As a result,

new approaches for system assurance and certification are necessary.

The AMASS (Architecture-driven, Multi-concern and Seamless Assurance and Certification of Cyber-Physical Systems) project (<http://amass-ecsel.eu/>) has created and consolidated the de-facto European-wide open tool platform, ecosystem, and self-sustainable community for assurance and certification of Cyber-Physical Systems (CPS) in the largest industrial vertical markets including automotive, railway, aerospace, space, and energy. The ultimate goal of AMASS is to lower certification costs for CPS in face of rapidly changing features and market needs. This has been achieved by establishing a novel holistic and reuse-oriented approach for architecture-driven assurance (fully compatible with standards such as SysML), multi-concern assurance (for co-analysis and co-assurance of e.g. security and safety aspects), and seamless interoperability between assurance and engineering activities along with third-party activities (e.g. external assessments and supplier assurance). The software application that implements the approach is referred to as the AMASS Tool Platform.

In this presentation, some relevant results of the AMASS project will be presented. More specifically, the contributions of the The REUSE Company (TRC) to link (a) system assurance and certification with (b) knowledge-centric systems engineering and quality analysis. In more concrete terms, these solutions enable the following activities:

- Extended requirements quality analysis, thanks to the provision of new metrics and measurement procedures to assess the correctness, consistency, and completeness of requirements specifications.
 - Model quality analysis, by extending the capabilities to assess requirements specification to assess other system artefacts with a graphical and structured representation, such as SysML diagrams and Simulink models.
 - Quality evolution analysis, which allow quality managers and engineers to get a detailed picture of how the quality of a system artefact or set of artefacts has changed during a project as the artefacts or the quality measurement means used vary.
 - Checklist-based V&V, in order to extend automatic quality analyses with manual ones, supporting the configuration and tailoring of these analyses, and integrating their results in the overall quality view of a project.
 - Generic tool interoperability with the OSLC KM technology for a wide variety of system artefact types and formats, including SysML diagrams created with different tools, Simulink models, physical system models created with FMI/FMU, and MS Excel.
 - Extended and enhanced ad-hoc tool interoperability, e.g. for DOORS Next Generation, PTC Integrity, and Rhapsody.
 - Automated traceability management, thanks to the features of the Traceability Studio tool to configure traceability projects, capture trace links, assess and suggest links, and conduct change impact analysis.
 - Evolution management of system and certification information represented as an ontology, so that a user can first represent e.g. safety standards or a safety-critical system's design as an ontology and next manage such representation by copying information from an ontology into another, merging them, or defining versions of the ontologies.
 - Data exchange between TRC tools and the AMASS Tool Platform, on the hand to analyse system artefact information managed with Platform, e.g. SysML diagrams, and on the other hand to enable the import of quality analysis results into the Platform as a part of the assurance evidence data of a project.
 - Advanced search of system assurance and certification information, by exploiting the semantics-based search features of the TRC tool suite in order to improve information finding for assurance reuse.
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The Systems Engineering Advisor - Exploring Augmented Intelligence for SE

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Presented on: Tuesday, 16:15-16:55 in Grand Cypress Ballroom GH

Keywords. Systems Engineer;Augmented Intelligence;Automation;Future of Systems Engineering

Abstract. Imagine yourself as lead system engineer on a future program, faced with a difficult set of trades and decisions on a path forward to a complex solution. As you converse with a set of mechanical, electrical and software engineers on your options, a new member of the team - DAISY - joins the conversation. DAISY is a Digital adviser using Augmented Intelligence for SYstems engineering. She is the latest technological advancement in the Artificial Intelligence community, specifically designed to automate many of the mundane data exploration and engineering calculation tasks driving long schedules into historical engineering development programs. While the team explores different creative design solutions, DAISY runs millions of scenarios, searching for a solution that optimizes the product within a broad range of program lifecycle constraints. Your meeting ends not with a set of actions to run more engineering simulations and candidate design trades, but with a set of potential solutions in hand that can be immediately proposed to program management. DAISY is a new type of Augmented Intelligence - an engineering assistant developed to automate many of the data and computationally intensive activities of a typical engineer.

How realistic is DAISY, what technologies will produce her, and how will these impact the life of today's systems engineers? These are questions being explored by the International Council on Systems Engineering (INCOSE) Future of Systems Engineering (FUSE) team. Studies on the future of AI predict automation of many data and knowledge intensive tasks, but less support to tasks relying on creative intelligence, social intelligence, and physical manipulation and perception of design. These are core skills of the systems engineer. DAISY's ability to perform Systems Engineering tasks will free up systems and other engineers to focus much more time on product innovation and team collaboration. DAISY will automate many product evaluation and evidence building tasks, creating higher quality systems in much less time. DAISY will continuously look out across product lifecycles to create scenarios that lead to more holistic decisions. DAISY will work for any and all domains and industries from aerospace and defense to medical and transportation. But DAISY will not be replacing systems engineers in the near future, just enabling and assisting them. This is why the INCOSE FUSE team is investing time in the study of future DAISY-like SE Advisers.

This presentation will discuss the concept of an SE Adviser using augmented intelligence, the technologies that might enable it, the technological challenges and research needed to achieve it, and the impact it will have on our profession. It will include a possible technology roadmap toward realization of DAISY-like capabilities in future systems engineering tools.

Presentation#31

Top 10 Ways Engineers Undermine Their Own Success

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Presented on: Monday, 15:30-16:10 in Grand Cypress Ballroom GH

Keywords. Soft-skills;Leadership;Systems Engineering

Abstract. This session will explore areas that engineers commonly struggle with in their career development and effectiveness. The recurring feedback comment “you need to work on your people skills” has become cliché for engineers, and while often accurate it is not a very helpful comment for an engineer. This presentation explores some common example problem areas in a humorous “Top Ten List” format; and then offers some constructive recommendations for how engineers can avoid these clichés in their career development.

This presentation is in the category of “soft skills” and is generally applicable to anyone interested in improving their effectiveness on project teams – as team member, a team leader, or a manager of engineers.

The current list of areas to discuss are the following. This list is subject to review and refinement between now and the conference.

10. “But, I’m right...”
9. “But, that’s stupid...”
8. “I don’t have time to hold their hand...”
7. “We don’t do things that way...”
6. “Why don’t they just trust us...”
5. “The data will demonstrate our results...”
4. “No one understands what I am saying...”
3. “It won’t work if we do it that way...”
2. “Here’s something that you don’t know...”
1. “But, that’s already done...”

Note: This presentation was given at GLRC2018 and at the January meeting of the North Star Chapter.

Presentation#52

Using the Model-Based System Architecture Process (MBSAP) for Utilization Management in Outpatient Imaging

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Presented on: Tuesday, 14:15-14:55 in Grand Cypress Ballroom GH

Keywords. Model-Based System Architecture Process;Outpatient Imaging;Healthcare;Utilization Management

Abstract. A significant source of waste in healthcare is non-utilized time slots due to patients that never show up for

their scheduled exam. The total cost for a medium-sized outpatient imaging center that attempted to proactively prevent same-day missed appointments (no-shows and patients who call to cancel the same-day) still came to approximately \$1.5 million in 2017. After four years of running experiments to try and change patient behavior to reduce the occurrences of same-day missed appointments, it became obvious that a different solution was required. The system needs to be changed.

The goal is to build a system that optimizes utilization without dependency on modifying patient behavior. The Model-Based System Architecture Process (MBSAP) provides a comprehensive and visually understandable framework for system development in an industry unfamiliar with Systems Engineering methods. Examples of the components of MBSAP that can be used to develop this system for outpatient imaging centers are outlined in the following paragraphs.

An initial Domain diagram for the Utilization Management Systems shows three primary domains – an Exam Status System, a Radiology Information System and a Predictive Model. Each of these domains have unique parts and user interactions.

An Enterprise Domain diagram shows how this system could fit into the greater system of healthcare. An automated utilization management system would be even more effective if the overall healthcare enterprise could be changed to provide a central information repository. A central information repository would be used to collect and distribute patient orders and information. Obviously, there are security issues and HIPAA considerations but the benefits of this type of system (improved healthcare accessibility for the whole community) potentially outweigh the cost of managing the security considerations.

A Reference Architecture Diagram shows how the architecture could be used in any business that schedules appointments, has regular cancellations, high demand and a desire to proactively manage their utilization.

Use Case Diagrams can be created for staff functions. For example, front office receptionists will need to be signaled if a patient does not check in by their scheduled table time to reach out to the patient and obtain a reason for missing their appointment. This information could be fed to the predictive model to improve accuracy of workflow directives.

An Activity Diagram can show the process for modifying scheduler workflows if the patient's cancellation probability is high and an actionable cancellation reason has been identified. It can also show the process for the scenario where the patient's cancellation probability is high and an actionable cancellation reason cannot be identified. In this scenario, the predictive model will send the RIS system a trigger to allow the exam time to be double-booked, but the scheduler's workflow will not change.

A Sequence Diagram with timing can show how the requirement to not exceed current scheduling cycle times can be met.

Security Features identified during the development of the system can be identified and allocated to Domains. This system may require the constant transfer of patient data between three subsystems so the security administration required to fulfill HIPAA requirements would have to be rigorous.

A Quality Attribute for the security of this system should be HIPAA compliance violations and can be measured by tracking data access and user activity. Specific assessment factors include frequency of data access, unexpected data access and unusual frequency of user logins.

This presentation will cover the benefits of using MBSAP in healthcare and provide components of the initial conceptual architecture for an automated utilization management system in outpatient imaging. MBSAP has been invaluable in developing the initial concept and providing a visual baseline that all stakeholders are able to understand and build upon.

Why a Systems Engineering Competency Framework is not enough. Enablers for successful organisational framework roll-out.

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Presented on: Wednesday, 15:30-16:10 in Grand Cypress Ballroom A

Keywords. Competency;Framework;Tailoring;Effective deployment;Enablers

Abstract. In July 2018, INCOSE released the new Systems Engineering Competency Framework document. This is a significant publication, representing the first output from INCOSE's International Competency Working Group and the result of six years of collaborative effort.

The new framework permits any systems engineering role in any organisation to be characterized as a combination of multiple competencies, each at differing attainment levels, with the competency areas and attainment levels defined and agreed by the foremost authority in Systems Engineering in the world. The new framework will provide an excellent benchmarking mechanism for both individual and organizational capability in the discipline and should provide the ideal starting point for career planning and development for systems engineers worldwide. However, the published framework does not exist in isolation from the rest of the organisation in which it is deployed. It relies upon a series of critical enablers to be successful. Failure to understand and address these will impact the potential and actual value deliverable from deploying the framework, reducing the impact of the investment made by an organisation.

This presentation identifies 12 critical enablers for successful framework rollout and highlights the potential impact they could have on the success of a framework deployment if not addressed adequately beforehand. These range from the obvious, such as tailoring the framework appropriately to reflect both business and purpose, to less obvious such as working with HR, Project and Finance stakeholders to facilitate personnel project movements identified from the assessments performed. The presentation makes a series of key recommendations for any organisation considering implementing a competency framework.

These recommendations are based upon the authors experiences rolling out differing variants of the UK Chapter Systems Engineering Framework (the immediate predecessor of the newly released framework) indifferent types and size of businesses across the globe.

Those attending the session should leave with an understanding of the topics to be considered and resolved organizationally before rollout is considered, in order to ensure deployment is effective, together with a series of pointers as to what makes a successful organizational implementation.

Women in Engineering – Not a Damsel in Distress!

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Presented on: Monday, 16:15-16:55 in Grand Cypress Ballroom GH

Keywords. Diversity;Inclusion;Gender;Engineering;Team Setup;Team Roles

Abstract. More women in engineering are featured in the media today increasing their visibility as role models. However they are often asked the same questions – “why engineering?” and “how does it feel?”. On one hand these questions can highlight the motivation behind studying engineering and enhancing their image as a role model for young girls. On the other hand they seem to highlight yet again the shortage we have of women in engineering, making her looking like something out of the norm. Is she portrayed then as an inspiration for young girls or as a “Damsel in distress”? We found inspiration at an event for the International Women in Engineering Day where a senior woman engineer provided a memorable answer to the second question - “how does it feel?” Her answer was: “I don't know, I have always worked in engineering so I can't compare with other environments”. Besides these questions women also have to overcome the myth of women that they need more help or focus when working in engineering projects than others. The percentage of women in engineering is better than ever with some countries doing better than others so being a woman in engineering should no longer seen as the exception.

Engineering is all about using ingenuity, innovation, and systematic approaches to solve challenging problems. This has nothing do with being a man or a woman. Life experience and academic research shows us that bringing a wide range of skills, knowledge and thinking styles to bear on a problem is an effective way to accelerate and improve the intended outcomes. By contrast, a team of people with the same cultural background, life experiences, education, and thinking style could well be relatively less effective and more prone to identifying predictable solutions. This subject is richly referenced.

The UK Royal Academy of Engineering (2015) has demonstrated that “the business benefits of a more diverse workforce ... potentially include positive impact on an organisation’s financial performance, greater innovation and creativity, increased employee productivity and retention, improved customer or client orientation, and increased customer or client satisfaction”.

William A Wulf, President of the US National Academy of Engineering has identified (2002) the drivers for diversity in engineering as equality, numbers, but most of all quality of the engineering performed.

When forming a team, an effective team leader will want to ensure that the team members work well together by having a diversity of viewpoints and approaches.

Dr Meredith Belbin developed an approach for selecting teams with a high probability of successful performance. He identified nine different team roles as part of a study of team performance at Henley Business School in the late 1960s. Most people have three preferred roles, three manageable roles and three least preferred roles. During the course of a project, all nine roles will be required but the mix and the need for each role varies during the lifecycle of the project. The key to a successful team is self-awareness, including recognizing when the role you are being asked to perform may not play to your strengths.

Of the nine roles, one of the most common in large organization is the “Shaper”. These people are “movers and shakers” and are driven to achieve. They are more often found at the higher levels of management. Having an excess of Shapers in a team can lead to conflict. One of the less common team roles in large organizations is the “Plant”, who displays creativity, innovation and problem solving skills. In an Engineering organization, there is a high probability that there will be excess of “Monitor Evaluators”, who thrive on analytical tasks.

Interestingly, Dr Belbin's study and subsequent investigations showed that there was little to no bias in preferred roles associated with race or gender, although an organization, via its recruitment approach, may create a bias towards one or more of the team roles.

As a discipline, Systems Engineering is applied in a wide variety of contexts - the systems we engineer range from micro-electronics to aircraft, from abstract systems to smart cities. As systems engineers we may be working in a customer, a prime contractor/integrator, a supplier or product manufacturer, or a government body. These activities take place all over the globe, often as part of consortiums or complex partnered programmes involving multiple organisations, countries and cultures. Therefore, it is reasonable to assert that the Systems Engineering workforce and culture should be at the forefront of diversity and inclusion given its transdisciplinary and integrative role across other disciplines and activities.

As the global authority on systems engineering, INCOSE needs to be at the forefront of diversity and inclusion in order to achieve its vision "A better world through a systems approach" and mission "To address complex societal and technical challenges by enabling, promoting, and advancing Systems Engineering and systems approaches".

So what? - We need to help "normalise" Women in Engineering, so that they are not regarded as heroines, trailblazers or role models but simply as engineers. This is a change journey because clearly women are under-represented in the engineering workforce at present.

How do we get there?

- Continue to raise awareness of the gender balance challenge in all our interactions and constantly ensure we look through a "diversity lens" (not just limited to gender)
 - Ensure that our society (INCOSE) makes steady improvements in its diversity, and inclusivity, encourages a healthy balance in leadership gender, and as far as possible makes it feel that being a woman systems engineer is simply a normal experience.
-

Invited Content

AI in Systems Engineering

Thomas Shortell (Lockheed Martin) - thomas.m.shortell@lmco.com
John Artus (Lockheed Martin) - john.g.artus@lmco.com
Tom McDermott (Stevens Institute) - tmcdermo@stevens.edu

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Presented on: Thursday, 10:00-12:10 in Grand Cypress Ballroom I

Abstract. As Artificial Intelligence and Autonomy change the world, Systems Engineering will change but the true question is whether AI/Autonomy is bringing doomsday to the world or will AI/Autonomy work and positively affect humans in the world? This session will debate the insertion of AI and Autonomy into Systems Engineering considering both systems of interest and how systems engineers use the the life cycle processes. The debaters will discuss many engineering, ethical, and legal questions of the use of AI and autonomy in SE including autonomous cars, defense systems, medical systems, and critical infrastructure and cyber security. The debate will include whether the current set of mindsets, methods, processes, and tools are equipped for the use of AI and autonomy in today's world. The debaters will debate questions requested by the audience as time permits.

An Approach for Implementing MBSE in Aerospace Organizations

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

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Presented on: Monday, 13:30-14:10 in Poinciana

Keywords. SE Fundamentals

Abstract. For the last 10+ years, Lockheed Martin Space has been pursuing the use of model-based techniques for use executing systems engineering process. Over that timeframe, we have collected a number of observations and learned a number of lessons that have shaped our approach to supporting the practice of model-based systems engineering (MBSE) across our enterprise. This presentation will take a look those observations and lessons, describe how they've impacted our approach to implementing across our organization, and have impacted our future directions for MBSE.

Biography

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

Chris Schreiber is a Systems Engineering Senior Manager for Lockheed Martin Space with responsibility for the Systems Engineering Modernization department, focused on supporting Space Systems programs with Model-Based Systems Engineering, Agile Systems Engineering, and Augmented Reality capabilities. For the past 9 years Chris has been focused on developing and deploying MBSE practices, training and infrastructure at Space Systems. He has led a number of Model-Based Engineering and Systems Engineering pilots, IRADs and implementations, including Systems Engineering efforts for Lockheed Martin's Digital Tapestry Initiative. Chris is active in a number of industry associations as a member of INCOSE and OMG, co-chairing the Model & Simulation Committee 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.

Being Agile: Systems Engineering for Continuous Lifecycles

Tom McDermott (Stevens Institute of Technology) - tamcdermott@att.net

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Presented on: Monday, 15:30-16:10 in Poinciana

Keywords. SE Fundamentals

Abstract. “Continuous development and deployment” at the “speed of relevance” should be a core tenet of all systems today and the enterprises that acquire provide them. This presentation discusses the relationships between systems engineering, agile practices, and continuous lifecycles for development and operations (DevOps). “Traditional” systems engineering is often characterized as too slow and inefficient while many agile programs are said to fail due to lack of good systems engineering. How do traditional and agile system engineering practices converge? What do systems engineers need to know in the adoption of agile and DevOps practices? These questions are rooted in the foundations, history, and emergence of systems and software engineering as separate disciplines. We will explore this history and the paths to convergence necessary to make continuous development and deployment a natural aspect of systems engineering.

Biography

Tom McDermott (Stevens Institute of Technology) - tamcdermott@att.net

Tom McDermott is the Deputy Director of the Systems Engineering Research Center (SERC) at Stevens Institute of Technology. His primary work focuses on the development of innovative methods and tools to facilitate multi-disciplinary analysis and learning in complex systems. He teaches system architecture, systems thinking and decision making, and engineering leadership. He has over 33 years of background and experience in technical and management disciplines, including 15 years at the Georgia Institute of Technology and 18 years with Lockheed Martin. Tom was previously Director of Research at the Georgia Tech Research Institute, where he led the organization to an unprecedented and continuing period of sustained growth and impact. At Lockheed Martin, he led the core processing system development and then the entire F-22 avionics team to a successful first flight.

Embarking on a Grand Challenge

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Presented on: Monday, 10:00-12:10 in Grand Cypress Ballroom GH

Abstract. Grand challenges (GCs) “represent the greatest obstacles to attaining universal well-being” (Ref: Wikiversity). They are “ambitious but achievable goals that harness science, technology and innovation to solve important national or global problems, and that have the potential to capture the public’s imagination” (Ref: White House). One such GC is Clean Water that everyone can relate to. Focusing on this one GC will enable INCOSE to participate at a global level on a complex systems problems that we can apply a systems approach, engage with a variety of stakeholder groups with a similar purpose and embark on a collaborative, learning journey. What better way can INCOSE demonstrate its vision of “a better world through a systems approach”.

This session will kick off with a presentation and discussion on possible heuristics principles for such complex problems and associated mental models/filters to be considered. This is the start of a cyclic learning journey that embraces “all industries and members with an interest in systems”. It should itself help us all in making sense of the complexity we face in our own industries and contexts.

With these principles in mind, an interactive phase will follow, focusing on the Grand Challenge, Clean Water. During this phase we will probe for ideas, concepts, exacting and balancing science, processes and practices with holism and passion.

Information and material gathered in this session will contribute to our initiative in GCs and support our endeavours in advancing a systems approach to a GC, in particular Clean Water, collaborating with external teams on this complex problem. We invite all those who appreciate the need to join us in this journey.

Enhancing the Value of Architecture Models

James Martin (the Aerospace Corporation)

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Presented on: Tuesday, 16:45-17:05 in Grand Cypress Ballroom C

Keywords. MBSE; Lighting round

Abstract. It is not uncommon to have spent considerable effort in creating a number of architecture models that end up spending most their time on the shelf. How can we ensure that this does not end up being the case? This talk will focus on how to do "problem framing" up front to identify the intended uses and users of the models, the questions that these models can help to answer, and the views that will help convey the answers that the models can provide to better understand the architectural trade space. This Problem Framing approach has been shown to greatly increase the value of architecture models and resulting in greater appreciation of the architecture being pursued.

Biography

James Martin (the Aerospace Corporation)

James Martin is a Principal Engineer with the Aerospace Corporation, helping government clients develop and evaluate large, complex enterprise and system architectures. Dr Martin also helps them implement MBSE and Digital Engineering tools and techniques to ensure a more effective modeling and analysis effort on various kinds of projects and programs. James has a PhD in Enterprise Architecture from George Mason University and has been using this Problem Framing approach for the last fifteen years in many customer engagements. Dr Martin currently leads the Systems Science Working Group, is a Fellow member of INCOSE, and has been awarded the INCOSE Founders Award for his contributions to the SE discipline.

Framing (and modeling) the Problem: Eliciting needs and deriving requirements

Alejandro Salado (Virginia Tech) - asalado@vt.edu

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Presented on: Monday, 11:30-12:10 in Poinciana

Keywords. SE Fundamentals

Abstract. Correctly framing the problem to be solved is a necessary condition to perform rational engineering. Without a proper formulation of the problem to be solved, success in engineering becomes a game of pure chance. Identifying preferences, eliciting needs, and deriving requirements are some vehicles by which systems engineers can unveil what the true problem or opportunity is. With such explicit framing of the problem, predictions on the success of the engineering endeavor using verification and validation become possible. Unfortunately, formulating engineering problems is arguably amongst the most difficult tasks in engineering. Yet, an engineer often completes his/her education without being formally exposed to these concepts. This introductory talk on problem formulation will cover fundamental concepts in problem formulation and problem modeling, will provide a few tricks to clearly distinguish between needs and requirements, as well as between verification and validation, and will point to methods that are effective in supporting the activities of need elicitation and requirement derivation.

Biography

Alejandro Salado (Virginia Tech) - asalado@vt.edu

Alejandro Salado is an assistant professor of systems engineering at Virginia Tech with 10+ years of experience developing space systems. His research focuses on applying decision analysis to V&V and on improving problem formulation through modeling. He is a recipient of the NSF CAREER Award and the Fulbright International Science and Technology Award. Alejandro holds a BSc/MSc in electrical engineering (Polytechnic University of Valencia), an MSc in project management and a MSc in electronics engineering (Polytechnic University of Catalonia), the SpaceTech MEng in space systems engineering (Delft University of Technology), and a PhD in systems engineering (Stevens Institute of Technology).

From Apollo to the Space Shuttle and All Industries: The Trace-Elements of the Transformation of Systems Engineering

Dr. Larry Kennedy (CEO Quality Management Institute, Co-Founder Systems Engineering Quality Management Working Group)

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Presented on: Monday, 13:30-14:45 in Grand Cypress Ballroom C

Keywords. techops

Abstract. Fifty years ago, Apollo Astronauts first set foot on the lunar surface with the declaration that it was "one giant leap for mankind." It certainly was a leap forward in technologies as well as the public awareness of the prowess of systems engineering when it functioned in sync with the objectives of the mission. So, since then, what have we done, what have learned and what have we lost?

The quality of Systems Engineering has both improved and deteriorated even though the problems of development and deployment are relatively the same as always - people and processes that are supported by the tools of the discipline, etc. - all with the demand of satisfying a set of requirements described by a customer or customers. There have been triumphant announcements regarding the advancement of our ability to make outcomes more certain and our processes more measurable. And there has also been an increased emphasis on time to market, responsiveness and opportunism. But the statistics too-often do not support the promised results.

In this session, we'll discuss the "trace-elements" of the transformation of systems engineering culture over the past fifty years and the "lessons learned." We'll examine the efficacy of list-managing software, analytics and AI. And, we'll envision a promising future by building upon our competencies with carefully crafted "intelligent systems."

FuSE, SE Transformation, and Digital Engineering

Bill Miller (Stevens Institute of Technology) - wdmiller220@gmail.com
Troy Peterson (System Xi) - tpeterson@systemxi.com
Kevin Robinson (Shoal Group) - kevin.robinson@shoalgroup.com
Heinz Stoewer (Space Associates) - heinzstoewer@spaceassociates.net
Monica Nogueira (SAE International) - Monica.Nogueira@sae.org

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Presented on: Thursday, 10:00-12:10 in Grand Cypress Ballroom C

Abstract. Digital Engineering poses opportunities and challenges to be an enabler for Systems Engineering Transformation and the Future of Systems Engineering. As Digital Engineering matures, the opportunities and challenges are ...

- Systems community being able to determine what is needed for the Systems Engineers of the future to perform Digital Engineering
 - Digital Engineering providing an adequate foundation for the Future of Systems Engineering
 - Development, integration, and use of models adequately informing enterprise and program decision making; and embracing models as the basis of engineering
 - Digital Engineering providing an enduring, authoritative source of truth; managing data as an asset
 - Digital Engineering providing sufficient technological innovation to facilitate the transformation of the engineering practice
 - Systems Engineering establishing a supporting infrastructure and environments to perform Digital Engineering activities, collaboration, and communication across stakeholders
 - Limits of a “Digital Twin”
 - Culture and workforce adopting and supporting Digital Engineering across the lifecycle
 - Ability to manage the modeling environment (models, data, interfaces, etc.) in a changing, dynamic environment (change of models, systems and stakeholder interactions)
- Panelists will provide perspectives on their uses and needs for Digital Engineering and their beliefs on whether it is sufficient to meet future needs. “Are we currently on a path to provide digital engineering for yesterday rather than for tomorrow?”
-

Invited Content#SEFun#7

How to talk about SE without scaring people

Courtney Wright (V1 Decisions) - Courtney.Wright@v1decisions.com

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Presented on: Monday, 16:15-16:55 in Poinciana

Keywords. SE Fundamentals

Abstract. Courtney Wright is INCOSE's Certification Program Manager, an instructor of SE professional development courses for non-engineers, and the recipient of many eye rolls from her teenaged children. All three audiences have heard her talk extensively about systems engineering, with varied levels of interest. She is not scary.

Biography

Courtney Wright (V1 Decisions) - Courtney.Wright@v1decisions.com

Systems Engineering is so interesting to you that you came to Florida in the heat of Summer to hear other people talk about the subject. Not everyone shares your love and understanding of SE. During this presentation, we'll talk specifics and generalities about sharing systems engineering topics with others, particularly non-engineers. We'll discuss what you should never say; what you should always say; how to tell you're losing your audience; and how to bring them back.

Improving our Definitions of System and Systems Engineering

Patrick Godfrey (Systems-Thinking) - patrick.godfrey@systems-thinking.co.uk

Dorothy McKinney - dorothy.mckinney@icloud.com

Hillary Sillitto - hillary.sillitto@blueyonder.co.uk

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Presented on: Monday, 13:30-14:55 in Grand Cypress Ballroom B

Abstract. The INCOSE Fellows' Initiative on System and Systems Engineering Definitions was established in 2016, to: review current INCOSE definitions of SYSTEM and SYSTEMS ENGINEERING; and recommend any changes necessary to align the definitions to current practice and to the aspirations of INCOSE's 2025 Vision. The recommendations were approved by the INCOSE BoD in January 2019 and will be launched as an official INCOSE publication at IS19. This presentation presents the final outputs from the initiative and the process used to bring this effort to a successful conclusion.

The three key recommendations - for improved definitions of systems engineering, engineered system, and a general definition of system - will be presented, with contextual explanations. The presentation will also provide an overview of the definitions of other specific system types and categories of importance to the systems engineering community. The full set of information, with contextual explanations, is available both as a document and as an on-line resource.

Invited Content#SEFun#5

Introduction to Systems of Systems

Mike Ryan (University of New South Wales) - M.Ryan@adfa.edu.au

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Presented on: Monday, 14:15-14:55 in Poinciana

Keywords. SE Fundamentals

Abstract. This presentation will provide a brief introduction to the nature of system-of-systems (SoS), as distinct from the nature of systems(-of-elements). Based on the INCOSE SoS Primer and the final draft of ISO/IEC/IEEE 21839, the presentation provides definitions of SoS and of systems, and then goes on to explain the four main types of SoS: directed, acknowledged, collaborative, and virtual. The presentation makes some observations regarding the differences and similarities in design of SoS and design of systems. In particular, an appropriate design perspective (a systems-centric perspective) is shown to be useful in designing SoS.

Biography

Mike Ryan (University of New South Wales) - M.Ryan@adfa.edu.au

Dr. Mike Ryan is the Director of the Capability Systems Centre, University of New South Wales, Canberra. He lectures and regularly consults in a range of subjects including communications systems, systems engineering, requirements engineering, and project management. He is a co-chair of the Requirements Working Group in the International Council on Systems Engineering (INCOSE). He is a Fellow of Engineers Australia, a Fellow of the International Council on Systems Engineering, and a Fellow of the Institute of Managers and Leaders. He is the author or co-author of twelve books, three book chapters, and over 250 technical papers and reports.

Invited Content#MBSELR#0

MBSE Lightning Round - Introduction

Mark Sampson - mark.sampson@siemens.com
Troy A. Peterson - tpeterson@systemxi.com

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Presented on: Tuesday, 10:00-12:10 in Poinciana

Keywords. MBSE; Lighting round

Abstract. Building on last year's MBSE Lightning Round 1, leading MBSE practitioners and researchers will gather for fast-paced/TED-like presentations on a variety of Model-Based Systems Engineering topics--distilling MBSE lessons, critical implementation issues, and future directions into a series of 18 minute talks with in depth Q&A/discussions on the topics following the presentations.

Invited Content#MBSELR#0

MBSE Lightning Round - Introduction

Mark Sampson - mark.sampson@siemens.com
Troy A. Peterson - tpeterson@systemxi.com

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Presented on: Tuesday, 13:30-14:55 in Poinciana

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Invited Content#MBSELR#0

MBSE Lightning Round - Introduction

Mark Sampson - mark.sampson@siemens.com
Troy A. Peterson - tpeterson@systemxi.com

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Presented on: Tuesday, 15:30-15:45 in Grand Cypress Ballroom C

Keywords. MBSE; Lighting round

Abstract. Building on last year's MBSE Lightning Round 1, leading MBSE practitioners and researchers will gather for fast-paced/TED-like presentations on a variety of Model-Based Systems Engineering topics--distilling MBSE lessons, critical implementation issues, and future directions into a series of 18 minute talks with in depth Q&A/discussions on the topics following the presentations.

Invited Content#MBSELR#5

MBSE Lightning Round - Q&A

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Presented on: Tuesday, 17:05-17:30 in Grand Cypress Ballroom C

Invited Content#MBSELR#3

MBSE—a Major Force for Enabling Digital Enterprises

Heinz Stoewer (Airbus)

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Presented on: Tuesday, 16:25-16:45 in Grand Cypress Ballroom C

Keywords. MBSE; Lighting round

Abstract. MBSE has advanced well beyond pilot projects, enabling new perspectives. These could involve the “integration” of all engineering disciplines and the simultaneous “correlation” with advanced PLM methodologies. Provided a holistic set of databases and a set of “end-to-end” seamless supporting tools can be realized these three elements together could become the backbone for digital enterprises of the future. This presentation will outline options and hurdles for such a journey. It is in part based upon a panel discussion held at the January 2019 “Fourth MBSE Symposium and Workshop” at NASA JPL, Pasadena

Biography

Heinz Stoewer (Airbus)

• Degrees in Technical Physics, Business, Systems Management, Germany/USA • Airbus, Germany, Project Engineer European launcher upper stage; Head Programmatic Unit • Boeing, USA, System Engineer space launchers, Project Manager “post Apollo” and NASA Space Tug/USAF Orbit to Orbit Shuttle • European Space Agency, first Programme Manager Spacelab, Europe’s first human space project; later Founder of ESA’s Systems Engineering and Programmatic Dept. • Delft University of Technology, Netherlands, first Professor/Chair Space Systems Engineering, Founder international MSci programme in Systems Engineering; all part-time • Managing Director Science and Application programmes, German Space Agency; Member ESA Council, European Union Space Advisory Group, et al • Founder/President Space Associates GmbH • Member Supervisory Council of OHB SE, Europe’s 3rd largest Space Prime contractor • Advisor Systems Engineering Airbus • Member Advisory Board Dutch National Space Agency (NSO) • Fellow, Life Member, Past President INCOSE • Distinguished Visiting Scientist NASA JPL • Member International Academy of Astronautics (IAA); emeritus member Board of Trustees and as chair of its Engineering Section • Lecturer/guest professor/keynote speaker universities, industry, governments • >90 publications; multiple national & international honours, e.g. German Parliament, NASA, IEEE 2018 Simon Ramo Medal

PM-SE Integration Workshop

Tina Srivastava
Randy Iliff

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Presented on: Monday, 15:30-16:55 in Grand Cypress Ballroom C

Keywords. techops

Abstract. This is an interactive workshop to internalize some of the key principles arising from research into integrating the disciplines of program management and systems engineering to achieve improved program outcomes. Development effort is "different" than production. That difference arises any time "new" requirements must be added to the effort and creates a unique set of technical and management constraints. This powerful activity reveals the essential interaction between definition (SE) and execution (PM) of work, as well as providing insight into the unique nature of development effort. The workshop will also highlight key activities of the INCOSE-PMI Alliance and the PM-SE Integration Working Group.

Professional Development for Systems Engineers; Evolving today's engineers to meet society's changing needs

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Presented on: Monday, 13:30-14:55 in Grand Cypress Ballroom GH

Abstract. This panel will bring together SE leaders from industry, government and academia to discuss paths to success, the skills they found particularly valuable along the way, and how to develop those skills in themselves or others (whether via a leadership or mentoring role). For example, many SEs have found success as specialists in one area or two areas. Many others choose one or more depth areas and add on skills at a lesser depth as needed to advance. Although there are probably many paths to success, this kind of dichotomy in career paths give us the "T-shaped" rather than the "I-shaped" person. The panel members will address these how they dealt with identifying and filling skills gaps based on the roles they chose or were requested to fill. Attendees will gain value by hearing success factors from our panelists, as well as the ability to ask their targeted questions regarding their individual needs. The moderated discussion will allow the Panel Leaders to glean professional development offerings that create the most value for the evolving INCOSE population.

Systems Engineering Complexity in Context

Sarah Sheard (Carnegie Mellon University Software Engineering Institute) - sheard@sei.cmu.edu

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

Keywords. SE Fundamentals

Abstract. Complexity is often blamed for systems engineering problems, but rarely with a precise definition of complexity. A paper cataloging complexity for the purpose of adjusting systems engineering cost estimates (Young, Farr, and Valerdi, 2010) identified more than 30 relevant types. Which of these types should systems engineers consider?

This talk defines complexity and identifies what entities within systems engineering problem spaces can be complex. It shows where in the system space these many varied types of complexity can arise. The presentation describes how a system being developed, the project developing the system, the environment, and cognitive challenges interact and can result in complexity.

The systems engineer should be able to recognize complexity, bring together various tools to identify and manage it, and measure the remaining risks to the project.

Biography

Sarah Sheard (Carnegie Mellon University Software Engineering Institute) - sheard@sei.cmu.edu

Dr. Sarah Sheard has been a systems engineer for over 30 years, beginning with satellite hardware and now working with software engineering. She is the Principal Engineer, Systems Engineering at Carnegie Mellon University's Software Engineering Institute. Her work has explored process, measurement, software and systems process improvement, and complexity science. Her current focus ranges from the interface between systems and software engineering to causal learning. She leads the INCOSE working group addressing the System and Software Interface. A Fellow of INCOSE she received her doctorate studying complexity in complex systems in 2012 from Stevens Institute of Technology.

Invited Content#techops#3

Systems Engineering: Cracking the Code of Digital Transformation

Troy Pedersen

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Presented on: Monday, 11:30-12:10 in Grand Cypress Ballroom C

Keywords. techops

Abstract. While complex systems transform the landscape, the Systems Engineering discipline is also experiencing a transformation to a model-based discipline. In alignment with this, the International Council on Systems Engineering (INCOSE) is seeking to strategically accelerate this transformation. The approach is to build a broad community that promotes and advances model-based methods to manage unprecedented change, empower digital transformation and prepare companies for what's next to speed innovation. More specifically, to leverage the discipline of Systems Engineering and practice of model based systems engineering (MBSE) as the core capability to digitally transform for advantage.

Invited Content#techops#1

The Systems Engineering Competency Framework

Cliff Whitcomb
Lori Zipes

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Presented on: Monday, 10:00-10:40 in Grand Cypress Ballroom C

Abstract. In 2014, INCOSE leadership tasked the Competency Working Group to develop an INCOSE systems engineering competency framework (ISECF). The INCOSE Competency Framework was released as a technical product in July 2018. The ISECF can be used to produce competency models tailored to the needs of the customer organizations. The ISECF is not a competency model – it is meant to be used as a guide to the creation and development of competency models used by organizations. The ISECF was developed based on a number of existing competency models, including the INCOSE UK Systems Engineering Competency Model, the DoD Better Buying Power 3.0 Implementation Plan, the Defense Acquisition University Competency Model, the US Navy Systems Engineering Career Competency Model, the INCOSE Systems Engineering Handbook Fourth Edition, and the Systems Engineering Professional Certification Program. The ISECF is now being followed up by the development of a systems engineering assessment guide that is based on the ISECF. The assessment guide is to be used as a basis for organizations to develop assessment plans for systems engineers. This presentation will summarize the ISECF, explain the development of the companion assessment guide, and describe the way forward for future work in the competency area.

Using System Architecture Models to Populate Structured Requirements

Ron Carson (Seattle Pacific University)

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Presented on: Tuesday, 15:45-16:05 in Grand Cypress Ballroom C

Keywords. MBSE; Lighting round

Abstract. How good do you want your requirements to be when they are created? When they mature and are being verified? How can we ensure high-quality, verifiable requirements when they are first written? In this presentation we explain how to use a system architecture model to populate and analyze structured requirements templates so as to help ensure high-quality, verifiable requirements from the beginning. Elements of an architecture model are mapped to a requirements template. Then simulation and analysis of the model is used to validate the model and requirements. Using an industry requirements quality measurement model we show that this can enable higher quality and more valid requirements compared with not using the system architecture model.

Biography

Ron Carson (Seattle Pacific University)

Dr. Ron Carson is an Adjunct Professor of Engineering at Seattle Pacific University, an Affiliate Assistant Professor in Industrial and Systems Engineering at the University of Washington, a Fellow of the International Council on Systems Engineering and a certified Expert Systems Engineering Professional (ESEP®). He retired in 2015 as a Technical Fellow in Systems Engineering after 27 years at The Boeing Company. Dr. Carson is the author of numerous articles regarding requirements analysis and systems engineering measurement, and is the developer of numerous industry systems engineering training courses. He has been issued six US patents in satellite communications, and two patents regarding "Structured Requirements Generation and Assessment". Dr. Carson has a PhD from the University of Washington in Nuclear Engineering (Experimental Plasma Physics), and a BS from the California Institute of Technology in Applied Physics.

Using the Viable System Model to Focus on the Human Aspects of Problems.

Bob Kenley (Purdue's School of Industrial Engineering)

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Presented on: Tuesday, 16:05-16:25 in Grand Cypress Ballroom C

Keywords. MBSE; Lighting round

Abstract. There once was a university course full of engineers who were assigned to teams and asked to develop system solutions for complex organizational problems that were chock full of human considerations. The earnest students had somewhat low empathy quotients and relatively high systemizing quotients. They and their project partners discovered to their amazement that there is a formal systems model that allows even the most geeky among us to uncover and appreciate the human context of an organizational situation before taking the deep dive to come up with system solutions.

Biography

Bob Kenley (Purdue's School of Industrial Engineering)

C. Robert Kenley is an Associate Professor of Engineering Practice in Purdue's School of Industrial Engineering, where he has been developing courses and curricula to support the educational objectives of the Purdue Systems Collaboratory. He has over thirty years' experience in the industry, academia, and government as a practitioner, consultant, and researcher in systems engineering. He has a high systemizing quotient and has published geeky papers on systems requirements, technology readiness assessment and forecasting, Bayes nets, applied meteorology, the impacts of nuclear power plants on employment, and model-based systems engineering and agent-based modeling for systems of systems. He is an expert system engineering professional (ESEP), a Fellow of INCOSE, and is working to improve his empathy quotient. Robert Clark Stevens was born and raised in a small Quaker meeting in central Indiana and had always been taught to seek truth and value the contributions of all people. In grade school, he knew there was an overlap between his schoolwork, percussion studies, and Scouting, but couldn't quite describe it. As an undergraduate in Mechanical Engineering and in Theatre Design and Production at Purdue University and during his years as a Process Engineer, he began to put words to the interconnections between all things. Now as a master's student in Systems, Industrial Engineering, and Business Administration at Purdue, Robby is learning to understand and improve complex systems. He is President of Purdue's "systems" student organization and spends his free time with his friends, but mostly their dogs.

What is Systems Thinking and how do I do it?

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

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

Keywords. SE Fundamentals

Abstract. This presentation will explain the fundamentals of Systems Thinking and how to apply it. Duncan will explain why Systems Thinking is critical to effective systems engineering. Using personal examples from Defence, Rail, Information Services and Business Transformation, he will introduce a series of simple yet powerful techniques. These will include: how to understand situations from multiple perspectives; how to understand the interactions between different elements; how basic systems concepts can be used to predict behaviour; and, the relationship between systems thinking, systems engineering, critical thinking and basic numeracy. Finally Duncan will help participants understand how to start their journey as System Thinkers.

Biography

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

Duncan Kemp is Chief Systems Engineer and SE Fellow at the UK Ministry of Defence. Duncan's current role is leading and building the MODs Internal SE consultancy, which he has grown from scratch to a team of 35 over the last three years. Previous roles have included Chief Systems Engineer for Rail at the Department for Transport, the Command, Control, Communications and Computing Chief Architect at MOD, and MODs acquisition policy lead. Duncan has over 17 published papers on a range of Systems Engineering topics, including 4 best papers. He is a Chartered Engineer and Fellow of the Institution of Engineering and Technology.

What makes a competent System of Systems engineer?

Alan Harding
Beth Wilson

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Presented on: Monday, 10:45-11:25 in Grand Cypress Ballroom C

Keywords. techops

Abstract. Systems of Systems (SoS) are now an established part of our systems engineering vocabulary - referring to that class of system where its elements have varying degrees of managerial or operational autonomy (Maier 1988). While a SoS is itself a system, it is recognised that this reduction in control over their development and operation requires different methods to realise and operate them, and to participate in them. In July 2019 INCOSE published its Systems Engineering Competency Framework. This framework, based on earlier work in UK, covers all of the competencies that are generally required across the discipline of systems engineering. The collected experience of the INCOSE SoSWG suggests that the activity of engineering/managing a system of systems, or of engineering/managing a system in a SoS context does require different competencies in the systems engineers who are involved. This presentation will explore three perspectives (typical SoS Engineering (SoSE) roles; what review of the SoSE pain points tells us about competencies for SoSE; and the insights we can gain from the maturing ISO standard ISO/IEC/IEEE DIS 21840 (guidelines for the utilization of ISO/IEC/IEEE 15288 in the context of System of Systems (SoS)). This presentation will summarise these three inputs, synthesise them into an overview view of competency for the application of systems engineering to SoS, and an indication of future work in the area.

Workshop

Systems Literacy Workshop

Peter Tuddenham (president of the International Society of Systems Sciences)
James Martin (chair of Systems Science Working Group)

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Presented on: Sunday, 08:00-17:00 in Grand Cypress Ballroom C

Abstract. Systems Literacy is a coordinated ongoing action to create a greater awareness and understanding about “Systems” in our lives, in the world, nature, society, science and art, in schools and universities, in engineering, and beyond. It is anticipated that building greater awareness and understanding of Systems will help individuals and groups develop an ability to make informed decisions and communicate using systems approaches. This Systems Literacy initiative builds on previous “literacy” work over the past 20 years facilitated and/or contributed to by the College of Exploration and by many other Literacy projects. These are combined with several previous systems literacy projects and the many “systems” education programs around the world. These range across many disciplines and many related topics, including cybernetics, complexity, complex adaptive systems, systems thinking, network literacy and network thinking, pattern literacy, developments in neurosciences, and many others.

The aim is to create a broader awareness and understanding of the science (and art) of systems. To achieve that we are building a collaborative learning system for systems literacy that coherently and systemically includes as many individuals, groups, societies, associations and other organizations from around the world who are concerned with systems research, education, theory, methods and applications to map, understand and describe big ideas, principles and concepts of systems.

The 2019 Annual Meeting and Conference of the International Society for the Systems Sciences will have a focus on Systems Literacy. The outputs and outcomes from that meeting in June will be presented at the INCOSE Symposium workshop in July.

The USA is implementing the Next Generation Science Standards (NGSS) in K-12 education. One aspect of the NGSS is a set of cross-cutting concepts that students consider in their science and engineering education. This Systems Literacy project takes those 7 cross-cutting concepts and supports their intent and application with richer systems content and contribution from systems engineers.

This workshop will consider the work so far and design ways to make it relevant to systems engineers at all stages of their education and career.

Key Reserve Paper

Key Reserve Paper#26

A Modified Variable Neighbourhood Search Heuristic for the Multi-Mode Resource Constrained Project Scheduling Problem with A Case Study

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Presented on Tuesday breaks and Lunch

Keywords. Project Scheduling;Resource Constraints;Multi-mode RCPSPs;Neighbourhood Search;Heuristics

Abstract. This paper provides a fast near-optimum solution to the Multi-Mode Resource Constrained Project Scheduling Problem (MRCPSP), for projects with activities that have known deterministic renewable and non-renewable resource requirements. Multi-modes allows any activity to execute one of many alternative combinations of resource usages and durations, while each activity needs to pick the most feasible one. This type of setting is more prevalent for real-life project schedules, which necessitates systematic methodologies and advanced solution approaches in harmony with real-world implementations. This study proposes a Modified Variable Neighbourhood Search Heuristic (MVNSH) algorithm as an advanced optimization technique for scheduling projects. To validate our approach, exhaustive computational tests were carried out by using relevant benchmark instances. The MVNSH algorithm has been shown to be faster and more accurate than many existing heuristic methods. This research also contributes to developing a practical decision support system for resolving real-life constraints in multi-mode resource-constrained projects.

An Integrated Quantitative Approach to Acceptance Testing and Related Decisions

John MacCarthy (University of Maryland) - jmaccart@umd.edu

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Presented on Wednesday breaks and Lunch

Keywords. System Validation and Verification Testing; Value of Testing; Acceptance Testing; Acceptance Decisions; Design of Experiments; Test Design; Test Confidence and Power; Decision Trees

Abstract. This paper provides an integrated, analytical framework (and associated tools) for determining the scope of an acceptance test, designing acceptance tests, and for making acceptance decisions. A decision tree model is developed that may be used to determine the value of different acceptance test designs. Hypothesis testing models are developed that may be used to determine the performance threshold for testing, given a desired confidence of failing a bad system (test "Power"), and the design margin required to have a given confidence of passing a good system (test "Confidence"). These two models are then integrated into a single model that may be used to establish a test design (in terms of an acceptance threshold and the number of measurements) that achieves a desired test Power and Confidence. Finally a decision tree model is developed for the system acceptance decision based on the results of a given acceptance test.

Comparing Implications of 'Robustness' and 'Optimality' for Decision Support under Uncertainty

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Presented on Tuesday breaks and Lunch

Keywords. Decision support;planning;uncertainty;scenario;exploratory modelling;robustness

Abstract. Conventional simulation-optimisation approach in decision support under uncertainty aims to find optimal decisions which can meet decision objective(s) under reference scenarios with well-characterised uncertainty. However, futures often emerge with unexpected circumstances which cannot be predicted in our pre-specified reference scenarios, and their uncertainty cannot be fully characterised a priori. This article uses robust optimisation based on simulation models as an alternative approach to address such uncertainties of decision support. To show how the two approaches work and how better robust optimisation can be, we formulate a fleet mix problem under uncertainty and implement it in two experiments to compare the results. We conclude that robust optimisation could lead to decisions with probably lower performance than conventional optimisation at imagined future scenarios. However, the advantage of robust optimisation is that the results have better performance in overall and are more reliable over a wide variety of scenarios in the future.

Framework for Improving Complex System Performance

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Presented on Tuesday breaks and Lunch

Keywords. complexity;Complex System Governance;Requisite Variety;Systems Theory

Abstract. This paper introduces a framework for improvement of complex system performance. Complex systems are besieged with conditions marked by increasing uncertainty, emergence, and ambiguity. Additionally, demands for increased productivity, resource efficiencies, and performance improvement make new approaches paramount for modern systems engineers. In response, a framework to improve complex system performance is developed. Following an introduction, the paper pursues four objectives: (1) introduction of Complex System Governance (CSG) as a foundation to describe essential system functions, (2) suggest system 'pathologies' as an explanation for deep system performance issues, (3) exploration of system performance improvement as a function of 'requisite variety' to compensate for deep system issues, and (4) introduce a framework for complex system performance improvement using system pathologies as 'unabsorbed variety'. The paper closes with some challenges for further development of the framework for deployment and application guidance for practitioners.

Graph-based Assessment and Analysis of System Architecture Models

Leonard Petnga (University of Alabama in Huntsville) - leonard.petnga@uah.edu

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Presented on Wednesday breaks and Lunch

Keywords. Multigraph;MBSE;Model Quality Assurance;Graph Algorithms;Graph and Data Analytics;SysML

Abstract. We conceptualize, develop and prototype a semi-automatic graph-based framework for quality assessment (i.e., completeness, consistency, correctness) and probing - at all stages of development and maturity - architecture models developed in the System Modeling Language (SysML). Relevant data is extracted via partial model transformation, then organized and stored in a labeled property graph. Analytics powered by graph and big data algorithms enable the System Analyst to gain deep insight into the model and answer increasingly complex and diverse questions. Multigraphs and description logics formalisms provide solid theoretical foundations for our approach while graph database, semantic web and machine learning technologies support its implementation. We demonstrate the capability of our approach in an analysis of requirements in a publicly available spacecraft architecture model.

Interactive Knowledge Architecture - An intuitive tool for effective knowledge sharing

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Presented on Wednesday breaks and Lunch

Keywords. Knowledge Management;Architecture;Stakeholder Interaction

Abstract. This paper focuses on sharing knowledge in early phases of system development. It introduces an interactive documentation tool called the Interactive Knowledge Architecture. The tool works as a knowledge base of the problem domain. We created the tool using Human-Centered Design principles. The lack of an early common understanding of the problem domain can result in increased project costs. We have experienced that we need to focus on the human aspects of project execution to successfully achieve a common understanding among the project team members and customers.

This paper presents the results of implementing the Interactive Knowledge Architecture in three system development projects. To study the tool's ability to meet the human aspects, we used an action research approach. The results of this research imply that the Interactive Knowledge Architecture offers a usable, accessible, and desirable way to document and share knowledge.

System Resilience: Application Domain Perspectives

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Presented on Wednesday breaks and Lunch

Keywords. system resilience;civil systems;military systems;natural systems;cyberspace systems;organizational systems;capability;adversity;timeframes;systems of systems

Abstract. Experts in many domains are studying the concept of resilience, that is, the ability of a system to maintain required capability in the face of an adversity. The purpose of the paper is to explore how resilience related considerations vary among different application domains. Domains examined include civil systems, military systems, cyber space, natural systems, and organizational systems. One factor in how domains differ is how the system reacts or adapts to an adversity, which may be natural or human-made or internal to the system itself. Domains differ with respect to the timeframes in which the system engages the adversity. The system of systems context can either be a hindrance or a benefit to resilience. Recovery can be accomplished through architectural and design techniques suitable for the system and the scenario at hand. This paper concludes that resilience as described in all domains are contextually appropriate manifestations of resilience.

The challenges in implementing future interoperable joint C4ISR systems

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Presented on Thursday breaks and Lunch

Keywords. Ultra large scale systems;C4ISR;Interoperability;Mission Ssystems

Abstract. The unprecedented scale of ultra large scale (ULS) systems spans into various dimensions like lines of code, amount of information processed, number of interdependent hardware and computational components, number of people involved etc. The characteristics of ULS systems due to their scale pose different challenges which could only be addressed by a multi-disciplinary research rather than the traditional software engineering approaches. In this paper, we focused on proposing solutions against challenges in implementing the future interoperable joint Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) systems. For this purpose, we examined the main research topics to address the challenges in ULS systems. We discussed two main capabilities to enable the vision of future interoperable joint C4ISR. One of these capabilities is the effective and secure use of information across components of the system, while the other one is real-time fusion of the available information with the local context

The Digital Twin Throughout the SE Lifecycle

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Presented on Monday breaks and Lunch

Keywords. Digital Twin;MBSE;SysML;Simulation;Augmented Reality

Abstract. A digital twin is much as it sounds: a digital representation of a specific asset in the field, including current and past configuration states, considering serialized parts, software versions, options, and variants. Condition data is also represented including sensor readings, alerts, and operating environments. A digital twin has significant implications for service, operations, analysis, design, etc. especially when visualized as a Computer Aided Design (CAD)-sourced graphic in 3D virtual or augmented reality. Using this immersive and real-time information, engineers can inspect and verify the asset being serviced, designed or operated to get precise product information. However, the digital twin does not spring into life fully formed straight from the CAD model. It requires an informed system engineering approach to ensure that the integration between physical and digital is fit for purpose. Model-Based Systems Engineering (MBSE) models can be used in conjunction with the digital twin to improve operational models, predict and analyze faults, perform best-fit analysis and eliminate inappropriate system configurations, etc. This paper will look at various aspects of the digital twin and how it can be used in conjunction with MBSE.

The Drone System I: Context-Level Architecture

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Presented on Tuesday breaks and Lunch

Keywords. Unmanned Systems;Autonomous Systems;Model-Based Systems Engineering;SysML;System Architecture;System Availability;System Reliability

Abstract. This paper is the first of two papers that together provide an example of how to use the systems engineering processes outlined in the INCOSE Systems Engineering Handbook and ISO/IEC/IEEE 15288:2015 to develop a SysML system architecture from a user's statement of need and then to develop a mathematical system model for system reliability, availability, and maintainability that may be used to perform system design and cost-effectiveness trade-off analyses. This paper focuses on the development of a SysML architecture for a drone system that provides surveillance and delivery services.

The Need for an Information-based Approach for Requirement Development and Management

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Presented on Tuesday breaks and Lunch

Keywords. requirements; requirement statement; requirement expression; requirement development; models; MBSE; templates; ontology; integrated dataset; shareable data and information model

Abstract. In many organizations, the quality of the individual requirement statements and sets of requirements is often poor, not having the characteristics of well-formed requirement statements and sets of requirements. Correctness, completeness, consistency, ambiguity, feasibility, implementation, leveling, etc. are common issues. This puts a heavy burden on the design team to address and correct these issues. Given these issues, it is common for modern systems engineers to even question the need for text-based requirements. This paper discusses why text-based requirements are still important, their role in the overall systems engineering lifecycle activities, and identifies key issues in the current approach many organizations practice concerning requirement development and management (RDM) – especially how RDM relates to current model-based design and systems engineering approaches.

Transforming the Engineering Organization with Systems Engineering and Quality Management

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Presented on Tuesday breaks and Lunch

Keywords. Quality Management;Systems Engineering;Systems Thinking;Development Processes;Organizational Transformation

Abstract. Never have the challenges of complex product and systems development been greater. Rising complexity coupled with the need for fast development cycle times and lower development and support costs have driven development efforts into a Faustian dilemma. Is it better to become highly agile by forgoing documentation, process and discipline—or to labor under the burden of restrictive, formal processes which use much needed time for non-development activities like planning, design and documentation? As some development organizations sell their quality souls for expediency, while ignoring the eventual price they may pay, others stay the course, hoping their ponderous processes do not leave them vulnerable to disruptive start-ups and new business models. Is there a better path? Yes, modern development concepts properly deployed and implemented in a values-based quality management environment provide a choice of chaos versus quality.

Usage of Digital Twin Technologies during System Modeling and Testing in Vessel Traffic Services System Project

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Presented on Monday breaks and Lunch

Keywords. Digital Twin;Systems of Systems;System Modeling and Testing;Vessel Traffic Services;Radar Systems;Automatic Identification System;Communication and Control

Abstract. Design and Integration of a Vessel Traffic Services (VTS) System with the implementation of a newly VTS software is a highly complex project with some challenges on interfaces and timing. The involvement of directives of command operation center personal and information from shiplader as stakeholder as well as different systems as automatic identification system, radar systems, electro optical systems, physical security systems beside the traffic services system makes is difficult manage the overall system design. A system of systems approach with MBSE techniques and usage of tools as designing with digital twin technology helps to simplify overviewing system design and checking interface definitions on the left side of the Vee model before implementation and integration process starts. A software intensive system with involvement of electrical and mechanical engineering including structural engineering for measurement of tolerances of cameras installed on towers gives an opportunistic theme for digital twin modeling of devices.

Validating a System Architecture Model (SAM) for a Department of Defense (DoD) Acquisition Program Using a Phased Approach

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Presented on Monday breaks and Lunch

Keywords. Safety Critical Function; Model-Based Systems Engineering; MBSE; System Architecture Model; Model Validation; Safety; Mitigation

Abstract. One of the benefits of taking of Model-Based Systems Engineering (MBSE) approach to capturing information such as system design, requirements, and verification information within a digital, object-oriented System Architecture Model (SAM) is it eliminates the risk of manually creating a set of text that must be maintained separately for consistency. Digital definition of this information eases configuration management and allows reuse, so that engineers can focus more on the technical challenges of system development and less on the tedium of document management. To ensure the SAM accurately reflects system description, uses consistent terms, and content is not duplicated, the model must be validated.

This paper recaps the journey taken by a legacy DoD Acquisition Program transition of safety critical functions from a document-centric to a model-based environment, but the focus will be on model validation.

Sponsor - Exhibitor

A journey in the Arcadia-Capella model-based engineering tool

Stephane Bonnet (Capella) - stephane.bonnet@thalesgroup.com

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Presented on: Tuesday, 13:30-14:00 in Regency 6

Abstract. This presentation stages a set of focused demonstrations of the open MBSE solution Arcadia-Capella. From the operational analysis down to the specification of subsystems, the rationale for each Arcadia engineering perspective is explained illustrated using a Unmanned Aerial System (UAS) example: what are the engineering objectives, main tasks, which choices are made, which ones are left opened.

This journey in the Arcadia-Capella model-based engineering approach is the opportunity

- To focus on how the Capella tool actually helps engineers conduct the architectural design
- To demonstrate some of the original, value-added core features of Capella: automated synchronization of perspectives, replication of building blocks, advanced diff and merge, etc.
- To demonstrate some of the most recent new features of Capella, and in particular the profiling (PVMT) and filtering add-ons.

Advancing MBSE for Government Applications and Facilitating Collaboration with Industry and Academia

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Presented on: Tuesday, 11:30-12:00 in Regency 6

Abstract. Model-Based Systems Engineering (MBSE) is an emerging paradigm for improving the efficiency and effectiveness of systems engineering through the pervasive use of integrated descriptive representations of the system to capture knowledge about the system for the benefit of all stakeholders. Over the past several years, The Aerospace Corporation has engaged in numerous pilot, experimental, infusion, and collaboration efforts to advance the state of the practice of MBSE, both internally and in direct support of and collaboration with its key mission partners. This presentation will provide some insight into some of the many ways Aerospace is endeavoring to address some of the key needs and challenges in MBSE, and some of the lessons learned and best practices that have been obtained over the past several years.

An open platform approach to Systems Lifecycle Management

Pawel Chadzynski (ARAS Corp.) - pchadzynski@aras.com

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Presented on: Wednesday, 10:45-11:15 in Regency 5

Abstract. Managing a systems' lifecycle is seen as one crucial component for the real-world application of Model-Based Systems Engineering (MBSE) practices and tools. To fully benefit from the introduction of systems modeling, companies must ask themselves how to avoid the creation of yet another silo and bridge the gap to the other engineering domains. Instead of investing in outdated legacy PDM tools, many businesses already took an open platform approach that allows for easy configuration and integration with a variety of tools used to describe the System of Interest. In this presentation you will learn what it takes to establish full lifecycle traceability with the ARAS PLM platform without spending all of your budget in a never ending migration project.

Eight Practices for Building Really Big Systems using Lean-Agile and SAFE Agile

Harry Koehnemann (Scaled Agile Inc.) - harry@scaledagile.com

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Presented on: Monday, 14:15-14:45 in -

Abstract. Many engineering organizations are finding success adopting Lean-Agile principles and practices. As these organizations build and deploy ever-larger applications—in increasingly complex, connected, and unpredictable environments—they face significant challenges not directly addressed by Agile. These systems often require multi-year roadmaps, coordinating 1000s of developers and suppliers, and integrating hardware and other long lead-time items. How does agile help them specify these large systems, plan the work, organize the people, measure progress, manage risks, and ensure verification, validation, and compliance? This talk explores eight agile practices that provide guidance applying Lean-Agile principles to the construction of very large systems. We will discuss how to scale agile teams to very large systems, continually refine specifications, plan at multiple levels, manage supply chains, and 'continuously' integrate large systems.

Eight Practices for Building Really Big Systems using Lean-Agile and SAFE Agile

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Presented on: Monday, 14:15-14:45 in Regency 6

Abstract. Many engineering organizations are finding success adopting Lean-Agile principles and practices. As these organizations build and deploy ever-larger applications—in increasingly complex, con-nected, and unpredictable environments—they face significant challenges not directly addressed by Agile. These systems often require multi-year roadmaps, coordinating 1000s of developers and suppliers, and integrating hardware and other long lead-time items. How does agile help them specify these large systems, plan the work, organize the people, measure progress, manage risks, and ensure verification, validation, and compliance? This talk explores eight agile practices that provide guidance applying Lean-Agile principles to the construction of very large systems. We will discuss how to scale agile teams to very large sys-tems, continually refine specifications, plan at multiple levels, manage supply chains, and ‘continu-ishly’ integrate large systems.

Engineering Collaboration and Tool Interoperability in MBSE

Christoph Bergner (MID AG) - c.bergner@mid.de

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Presented on: Monday, 11:30-12:00 in Regency 6

Abstract. Traceability and interoperability between MBSE and RE tools are great challenges today. Building on 35 years of experience in working with model-based content, MID presents powerful solutions:

1. Smartfacts

Easy Access to Models: Publish any model and provide easy and web-based access to models from Enterprise Architect, MagicDraw, Matlab Simulink, Rhapsody and more.

Engineering Collaboration: Comment, chat and carry out reviews in the context of mod-els.

Cross Tool Link Management: Build OSLC-based links between engineering artifacts independent of authoring tool. A seamless integration into IBM Jazz allows to link almost any model with IBM Jazz.

2. Toolbus

Migration of Models: More than 70 reading and writing adapters allow to migrate native model files and repositories from one modeling tool format to another one.

3. Innovator

Browser-Based Modeling allows to leverage the power of modeling without local de-ployment and provides a seamless integration experience with web-based platforms like IBM Jazz.

Feature-Based Product Line Engineering for the Enterprise

Drew Stovall (BigLever Software) - dstovall@biglever.com

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Presented on: Wednesday, 15:30-16:00 in Regency 5

Abstract. This session will introduce Feature-based Product Line engineering (PLE), the subject of an up-coming ISO standard sponsored by INCOSE. It will address the important concepts that underlie Feature-Based PLE: the Feature Catalog, Bill-of-Features, Shared Asset Superset, PLE Configurator, and resulting automatically generated, product specific, and ready-to-deliver assets. The presentation will spotlight how the PLE Factory provides a highly efficient and automated means of production for all of the products in a product line – relieving the burden and costs of separately maintained products. The session will explore the use of features as the “lingua franca”, or common language, for expressing product differences across all phases of the engineering lifecycle, as well as across an entire enterprise into areas such as product marketing, portfolio planning, supply chain, manufacturing, sales and service.

How AI contributes to improved quality, efficient resource use and time to market of requirements creation.

Stella Liu (Watson IoT, IBM) - Stella.Liu@ibm.com

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Presented on: Tuesday, 16:15-16:45 in Regency 6

Abstract. A foundational Systems Engineering element to any product is requirement creation. Requirements are the core of any product providing the overall product description and operation. Product complexity continues to increase as interaction and utilization with other external systems and data expands as part of the product operation. As a result, requirements created for these systems grows with the complexity of the system. The systems engineer operates in an ever-changing environment contending with globalization, disparate systems and the mix of junior and senior engineers making peer review and requirement process standardization difficult. Current requirement creation solutions miss requirement mistakes due to misunderstanding of word context, ambiguity, or the miss-use of quality indicators. The objective of this session is to describe and illustrate the benefits creating requirements with a system utilizing AI. The implementation demonstrates how AI analyzes the requirements and using the INCOSE Guideline removes ambiguity, errors, while providing recommended modifications.

How AI contributes to improved quality, efficient resource use and time to market of requirements creation.

Stella Liu (Watson IoT, IBM) - Stella.Liu@ibm.com

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Presented on: Monday, 13:30-14:00 in Regency 5

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How Systems Engineering Could Have Prevented the Aral Sea Human Disaster

Robert Halligan (Project Performance International) - rhalligan@ppi-int.com

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Presented on: Wednesday, 10:45-11:15 in Regency 6

Abstract. Visiting Karakalpakstan, an autonomous Republic on the territory of Uzbekistan, had a profound affect on me. Karakalpakstan is the home of The Aral Sea Disaster; its 1.8 million people are the victims. The Aral Sea, once one of the largest inland water bodies in the world, shrank and dried, leaving a dry sea bed laden with salt, pesticides and carcinogenic chemicals to be carried away by the winds and deposited on a helpless population. Daytime temperatures have increased by 4 to 8 degrees Celsius, with similar reductions in night time minimums. Medical problems far exceed those of the rest of the former USSR, particularly rates of infertility, anemia, tuberculosis, kidney and liver diseases, respiratory infections, allergies and cancer. In this presentation, I look at what led to this enormous environmental disaster, the systems engineering principles that were violated, and the lessons for application to socio-technical systems.

Increase the supply chain quality through a knowledge-based approach

Elena Gallego (The REUSE Company) - elena.gallego@reusecompany.com
Christer Fröling (The REUSE Company) - christer.froling@reusecompany.com
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Presented on: Tuesday, 15:30-16:00 in Regency 6

Abstract. This presentation will show why important topics like Requirements Quality, Knowledge management and Traceability are of great importance in the application of procurement. Today, many organisations struggle with procurement, and the examples of poor quality, high cost, late deliveries or lawsuits are many. The cost of poor procurement practices can be measured in millions of dollars in all sectors and in every country. Poor information quality in the bid documentations not only means that the bidder does not get a clear view on the thought need, but it also means that the acceptance process of verification and validation becomes cumbersome and the tracing is a nightmare and late guesswork. To have an efficient and effective procurement process is not all about the technical Systems Engineering processes in ISO15288, but also in a high degree the agreement and project supporting processes of information and knowledge management. We will show the importance of creating a common understanding through a common syntax, semantics and having a clear view on the procurement context as well as how to develop a correct set of procurement documents that captures the complete need without having built in a lot of errors and inconsistencies.

Increasing Engineering Competitiveness with PLE & MBSE

Robert Hellebrand (pure-systems GmbH) - robert.hellebrand@pure-systems.com

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Presented on: Monday, 15:30-16:00 in Regency 6

Abstract. Product Line Engineering and Model Based Systems Engineering are both mature strategies to deal with the growing complexity in system development. While MBSE focuses on easing the communication between engineers during development and maintenance of a system, PLE deals with the challenges that arise if engineering assets of a complex system shall be reused across a product family. Learn how pure::variants can be used to realize a systematic reuse approach for MBSE assets held in Rhapsody, Magic Draw and Capella that can also be holistically applied to other engineering assets like requirements, test cases and code.

Innoslate The Future of MBSE

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

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Presented on: Monday, 10:00-10:30 in Regency 6

Abstract. See how SPEC Innovations' flagship software, Innoslate, is the future of Model-Based Systems Engineering and Enterprise Architecture. Innoslate is a modern and innovative solution for even the most complex system of systems problems.

Cloud computing technology provides Innoslate with the capability of large scalability, collaboration, and model-based reviews. Innoslate takes advantage of artificial intelligence to perform advanced natural language processing. You'll save time and reduce risk by having traceability automatically detected and requirements quality improved.

Unlike other MBSE solutions, all the models in Innoslate are data-generated. Innoslate makes model-based systems engineering simple with drag droppable diagrams that can be easily edited within the diagram and automatically updates the database. You can test your models with the Discrete Event and Monte Carlo Simulators. Then keep track of tests and evaluations in Test Center.

Want to save time and reduce risk? Join us to see how Innoslate is the future of MBSE.

MBSE 2.0: How Concurrent Systems Engineering Can Help Your Organization

Mark Malinoski (Vitech) - mark.malinoski@vitechcorp.com

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Presented on: Wednesday, 10:00-10:30 in Regency 6

Abstract. Concurrent model-based systems engineering is becoming critical to a successful engineering outcome. It requires that systems engineers and subject matter experts collaborate on design solutions. In order to facilitate this, it is necessary to realize a practice and toolset based on a proven systems-metamodel that enables the design team to instantiate their system model in an enterprise-class database. With a robust API that connects with the tools and processes of subject matter experts and other engineering disciplines, concurrent model-based systems engineering becomes indispensable in addressing the engineering challenges of our time. This is the power and promise of MBSE 2.0.

New Frontiers in Model Visualization

Liana Kiff (Tom Sawyer Software) - lkiff@tomsawyer.com

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Presented on: Wednesday, 13:30-14:00 in Regency 6

Abstract. As digital engineering becomes the industry standard for how designers simulate, explore, and develop solutions, Model-Based Engineering has established itself as an essential foundational element. While SysML, UPDM, BPMN, and other models remain standard, organizations need to create an environment where they can construct and consume models efficiently. That means leveraging the strength of language-compliant modeling tools that feature flexible and responsive system visualizations.

This presentation will cover how integrated, model-based visualization platforms are revolutionizing workflows to enable digital engineering as well as increase productivity and improve the quality of communication.

Proposed Master of Science in Systems Engineering Leadership

Donald Gelosh (Worcester Polytechnic Institute) - dsgelosh@wpi.edu

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Presented on: Tuesday, 10:45-11:15 in Regency 6

Abstract. There is a generally held belief that if you are a Systems Engineer, then you must also be a leader. Professional skills are as important to success as a Systems Engineer as Systems Thinking and Engineering skills. Come join us and participate in a facilitated discussion about this newly pro-posed master's program at WPI. In this session, you will learn about the proposed Master of Science in Systems Engineering Leadership program and you will have the opportunity to provide your feedback. As practitioners in these crucial disciplines, your opinions and thoughts about Systems Engineering and Leadership are important to us. We hope you can join us for this session.

SE Scholar

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Presented on: Wednesday, 14:15-14:45 in Regency 6

Social system engineering supported by Nomadic mindset

Jargalsaikhan Dugar (TUS Solution LLC) - jargalsaikhan@tussolution.mn

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Presented on: Wednesday, 15:30-16:00 in Regency 6

Abstract. Nomadic people usually live in a harsh, fast-changing environment. For them, disruption or change is inevitable. To survive in such environment, Nomads must have an adaptable and innovative mindset so-called Nomadic mindset. However, there are common weak points for Nomadic people such as unorganized thinking, unsustainable team spirit. The system engineering methodologies compensate for these disadvantages perfectly. This synergy between Nomadic mindset and System engineering allowed us to create a social system that's capable of:

- Generating compiled, good quality data in real-time;
 - Adapting to the fast-changing environment in a timely manner;
 - Enforcing stakeholders to develop their skills continuously.
- Such systems are becoming a necessity to survive in today's disruptive world.
-

Syndeia: Building the Digital Thread

Dirk Zwemer (InterCax) - dirk.zwemer@intercax.com

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Presented on: Tuesday, 10:00-10:30 in Regency 6

Abstract. Enterprises store system data distributed across many software tools and repositories, but want a single authoritative source of truth giving every team member access to the data they need, when and how they need it. This idea has many names, but we will call it the Digital Thread. Syndeia, the MBSE interoperability platform from InterCax, lets organizations

- Build and maintain the Digital Thread, by federating the domain models with a network of connections between model elements,
- Use the Digital Thread to access and share data across these connections,
- View the Digital Thread, to monitor system development and document the system in real time.

We will demonstrate these use cases using a microservice-based architecture called Syndeia Cloud accessible by multiple users from Syndeia tool plug-ins, stand-alone clients, and external applications through an open REST API. Applications working with OpenMBEE and graph databases will be featured.

True North Enterprise Calibration - Empowering and Enabling your Digital DNA

Todd Egan (Institute for Process Excellence) - Todd@ipxhq.com

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Presented on: Monday, 13:30-14:00 in Regency 6

Abstract. A corporation's data is its DNA: The genetic code of its past learnings, present behaviors, future potential. The lack of management of an organization's data limits their ability to learn from past experiences, build on existing foundations of knowledge, and squanders opportunities that could define their future. More essential than individual success in each discipline is the digital connection between the enterprise disciplines; the connected ecosystem tissue, the CM2 Digital DNA

Otherwise its merely digitalizing the workgroups, speeding up the silos, but retaining the barriers between reinforcing the traditional organizational and data structures. When companies realize the value of elevating configuration management out from the shadow of engineering, they begin to see the real benefit of connected systems that are promised by technology but never achieved by technology alone.

UConn UTC Graduate Education Programs in Advanced Systems Engineering

Amy Thompson (University of Connecticut UTC Institute for Advanced Systems Engineering) - amy.2.thompson@uconn.edu

George Bollas (University of Connecticut UTC Institute for Advanced Systems Engineering) - george.bollas@uconn.edu

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Presented on: Tuesday, 16:15-16:45 in Regency 5

Abstract. Our academic mission is to train the engineer of the next decade; the one who is not constrained by disciplines and who bridges the gap between theory and application. The UTC-IASE aims to produce these "2020 engineers" at a substantial capacity by adoption of a bold, scalable, interdisciplinary, and modular approach to graduate STEM education that focuses on the application of theory, modern computational methods, and state-of-the-art software. The convergence of computation, communications and control enable cyber-physical systems (CPS) to possess learning and predictive capabilities, capable of adapting to changing situations. Motivated by the increasing complexity of advanced products and the digital revolution, the UTC-IASE trains engineers in urgently needed CPS-related disciplines that are pivotal to innovation in the globally competitive economy. This session presents the details of our Master's of Engineering degree and Graduate Certificate in Advanced Systems Engineering, which we deliver online to working professional engineers and scientists.
