2020 INCOSE New England Fall Workshop

Abstract Book

Program

Welcome and Introduction

Kiron Bhaskar, OTIS and INCOSE New England Chapter President

Keynote – Plenary: Keeping You Ahead of the Bear That's Chasing You

"There's a difference between jogging and being chased by a bear" *Grandma Sampson*

We are long past discussion about whether Systems Engineering (SE) is needed for today's complex products and into debates about how to integrate Model-Based SE (MBSE) with our product lifecycle processes. But our progress is very 'jogging-like' mostly due to cultural entropy and systemic breadth. Given this is an SE audience, we will dive into what's keeping you down and apply SE methods, tools, and techniques to accelerate the MBSE changes your organization needs to keep you ahead of the bear that's chasing you.

Mark E. Sampson, Systems Engineering Evangelist & INCOSE MBSE Working Group Chair

Siemens Industry Software

Presented on: Thursday October 15th, 8:45 to 9:30 AM

Biography

After graduating with a BS in Computer Engineering from BYU, Mark started his career at Texas Instruments where he quickly discovered how other domains effected his product's success prompting him to get a MS in Systems Engineering at USC and putting him on a career path around scaling systems engineering. Working with R&D, they developed one of the early systems engineering collaboration environments (SLATE) which resulted in 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 thru his SE Evangelist role. Mark was a founding member of the INCOSE N.Texas Chapter, has served in a variety of local and international-level leadership roles including INCOSE Technical Board overseeing modeling and tools strategies. He currently chairs INCOSE's MBSE Initiative which covers SE data exchange standards, SysML system modeling languages, and transforming systems engineering to a model-based discipline—which includes programs such as the popular annual INCOSE MBSE Workshops and the MBSE Lightning Rounds. Mark has published a number of articles on MBSE in various journals including INCOSE Symposia, Insight, IEEE Spectrum, and a number of blogs (google: Mark Sampson Siemens MBSE blog). In addition, Mark is an adjunct professor at SMU where he teaches graduate-level systems engineering courses. Mark lives outside Zion National Park in Southern Utah where he and his wife are experiencing raising a teenager.

Presentations

Track 1: Model-Based Systems Engineering (MBSE)

Envisioning Next-Generation Model-Based Agile Engineering

Mark Vriesenga, BAE Systems

Presented on: Thursday October 15th, 9:50 to 10:35 AM

The complexity of modern platform systems (e.g., commercial aircraft, spacecraft, and military vehicles) is exponentially increasing as we add new and advanced capabilities needed to sustain military and commercial market leadership. Modern commercial aircraft are aerodynamically unstable and controlled by hundreds of interrelated microcontrollers. Spacecraft dock at the International Space Station using artificial intelligence controllers, where humans are the “backup system." Military systems are moving toward cyber-assured autonomy and cyber-assured fire control on the battlefield. In each of these cases, new engineering challenges arise.

- Current Model-Based Engineering (MBE) tools and techniques perform well for representing bounded systems with low interaction among design elements. However, they do not perform well for representing complex systems with high interaction among design elements.
- System design under the 'constraint of complexity' frequently leads to product cost overruns and delivery delays.
- Most MBE methodologies do not provide techniques for directly designing safety and security into product designs, resulting is systems with exploitable vulnerabilities and hazardous operating modes.

Our analysis of MBE successes and failures from 2000 to 2020 suggests that we are at an inflection point, where future design challenges may exceed the design capabilities provided by today's MBE techniques.

This paper describes operational challenges, and associated requirements, leading to the development of BAE Systems next-generation Model-Based Agile Engineering (MBAE) methodology. We present five innovations that provide the theoretical underpinnings for our Agile Enterprise and Systems Architecting (Agile EaSA) methodology. Finally, we conclude with a brief description of success stories and recommendations for next-steps in MBAE capability development.

There is No Such Thing as Non-Model-Based Systems Engineering

Zane Scott, Vitech Corporation

Presented on: Thursday October 15th, 10:40 to 11:25 AM

Models are the basis of all communication and thinking. As we form ideas we think in models. As we communicate our ideas to others and absorb their thoughts, the communication is done in models. Successful communication rides on making those models match so that the ideas are accurately passed among us. The issue is not whether we use models but where those are kept. The presentation will address how we use models, where we keep and maintain them in order to promote efficient communication and how we can most efficiently and effectively communicate them.

Integrated SysML and Modelica Modeling Workflow

Brian Baillie, University of Connecticut

Presented on: Thursday October 15th, 11:30 AM to 12:15 PM

Efforts are underway to bridge the gaps that exist between systems models used in MBSE and numerical simulation models used for other forms of model-based engineering. Implementations of interface standards like the Functional Mockup Interface (FMI) provide a means for integrating executable models across disparate simulation platforms. Translation standards like the SysML Extension for Physical Interaction and Signal Flow Simulation (SysPhS) provide guidance for the direct translation of models and model components between modeling languages. The recent implementation of new standards-based translation features to Cameo Systems Modeler enables the development of closely integrated physics-based and simulation models.

This presentation will introduce methods for integrated systems and numerical modeling using Cameo Systems Modeler and Dymola. An overview will be provided of the leveraged standards and software capabilities. Bidirectional translation of model elements between the SysML and Modelica environments will be demonstrated. Integrated simulation using Dymola numerical solvers in conjunction with Cameo simulation and model evaluation features will be shown. Finally, a combined workflow for the development of closely integrated and directly translatable models that combine the strengths of both modeling environments will be presented. This integration accelerates the development of simulable models from a candidate system design, which in turn streamlines and improves the processes of validation, verification, and evaluation of design models by close, early integration with physics-based simulation.

Robust Simulation of Hybrid Mechanistic and Machine Learning Models

Matthew Stuber, University of Connecticut

Presented on: Thursday October 15th, 2:00 – 2:45 PM

An explosive resurgence in artificial intelligence has been underway for the last five years with applications emerging in almost every industry. As a subset of artificial intelligence, machine learning has found a natural home in model-based systems engineering as pure mechanistic models often exhibit computational complexity that makes their deployment prohibitive at the operating stage. Their input-output nature makes machine learning models attractive for real-time predictive modeling and optimization-based decision-making. However, pure data-driven machine learning models suffer from several disadvantages over mechanistic models. Namely, they are extremely expensive to train, they are highly sensitive to imperfect data, and they are entirely devoid of fundamental physical laws and causal relationships.

In this talk, we will discuss our recent approaches to addressing some of the primary disadvantages of pure data-driven machine learning approaches in model-based systems engineering. We will discuss our recent approaches in physics-informed machine learning for model-predictive control applications as well as our vision for and advances in enforcing high-level physical laws (e.g., continuity) upon machine learning models for verification and validation. Finally, we will discuss how our recent advances in the area of robust simulation can be used as a formal method for ensuring that a machine learning model rigorously satisfies imposed performance/safety constraints in the face of uncertainty.

MBSE Approach to Conducting Technical Reviews

Ben Talbert-Goldstein, Draper

Presented on: Thursday October 15th, 2:50 to 3:35 PM

Technical reviews are an essential part of the Systems Engineering process. Reviews give stakeholders an opportunity to assess the status of system development, and the likelihood that a design will meet system and program requirements. In a traditional, "paper-based" review, the entrance and exit criteria are satisfied with loosely coupled charts, diagrams, and slides. An MBSE approach to technical reviews provides a clearer and more direct way of showing that a review has served its purpose. When done correctly, this approach can also present a richer narrative of the SE process because the model provides a complete, coherent, and self-consistent view of the system, with clear traceability of all artifacts from stakeholder needs through to the final design solution. This paper introduces a new SysML profile and methodology that enables such an approach.

Designing for Safety in Model-Based System Engineering

Michael Hurley, BAE Systems

Presented on: Thursday October 15th, 3:40 to 4:25 PM

The advent of Model Based Systems Engineering presents an opportunity to Design for Safety in the same environment as the Systems Designers are developing and modeling functional architectures, eliminating the need for separate abstractions while left-shifting attention to safety. It is essential that this collaboration begin during the development of the system architecture, especially for autonomous systems, to ensure that safety constraints on system behavior are fully understood prior to system decomposition, and requirements allocation, into hardware, software, and firmware elements.

Newer approaches to Safety Design have emerged such as the Systems Theoretic Accident Model and Process (STAMP), and its derivative method, Systems Theoretic Process Analysis (STPA). STPA lends itself well to analyzing proposed control structures for their behavior given receipt of unsafe control actions, enabling establishment of safety requirements to prevent associated losses.

BAE Systems has developed a methodology for Safety Design that combines the STPA systems-oriented safety design technique with Model Based Systems Engineering. The method is used to ensure the system design will not behave in an unsafe way – derive, and verify compliance with, Product Safety requirements through modeling and simulation of the Logical/Functional Architecture.

This presentation will explain the method starting with an overview of how STPA is used to develop the Control Structure, examine potential Unsafe Control Actions and derive safety requirements in order to create a State Machine representation of the control algorithm for simulation, and verify the behavior remains within the constraints.

Track 2: Systems Architecting

Implementation of Human Systems Integration in a Mission Lifecycle

Jackelynne Silva-Martinez, NASA

Presented on: Thursday October 15th, 9:50 to 10:35 AM

NASA defines Human Systems Integration (HSI) as part of the overall systems engineering and acquisition strategy for space systems. NPR 7123.1C NASA Systems Engineering Processes and Requirements defines HSI: “An interdisciplinary and comprehensive management and technical process that focuses on the integration of human considerations into the system acquisition and development processes to enhance human system design, reduce lifecycle ownership cost, and optimize total system performance.” INCOSE also holds an HSI working group where the relationships between systems engineering practice and HSI practice are being developed as standards. HSI is an interdisciplinary integration of the human as an element of the system to ensure that the human and software or hardware components cooperate, coordinate and communicate effectively to perform a specific function or mission successfully. The presentation will include examples of the implementation of HSI activities within a space mission program using NASA/SP–2015-3709 NASA Human Systems Integration Practitioner's Guide. The authors will provide a guide on how to establish a Human Systems Integration Working Group (HSI WG) within an organization, which is established to fill the role of a Program or Mission HSI Team required as part of the Human Rating process. The HSI WG role should be described in the Program's HSI Plan, which defines how HSI activities will be implemented across the lifecycle of the mission, as required by NPR 7123.1C, NASA Systems Engineering Processes and Requirements, and NPR 8705.2C Human-Rating Requirements for Space Systems.

Using System Thinking in the Architectural Development of a Software Defined Radio

Eric Dano, BAE Systems

Presented on: Thursday October 15th, 10:40 to 11:25 AM

Software Defined Radios (SDRs) have rapidly proliferated the user community due to their flexible capabilities and the ability to missionize them near real time using various software loads. The key element of each SDR is the transceiver which will Analog to Digital Convert (ADC) incoming signals, host factory and user developed Field Programmable Gate Array (FPGA) cores for a diverse set of capabilities, and Digital to Analog Convert (DAC) outgoing transmit waveforms. This paper will serve as a case study that examines the derivation of a nominal SDR transceiver architecture. The transceiver element of the SDR was specifically selected because of its unique need to satisfy a diverse set of operational concepts, covering both civilian and military applications, in addition for the need to "architect in" significant modularity, growth and open standards to increase interoperability with the systems in which they will be hosted.

As with any complex system, the first step in the architectural development process is to reduce the architectural trade space by employing "system thinking" techniques to yield a flexible solution that meets the customer's needs for a configurable, reliable, high performance transceiver. System thinking techniques were used to examine all key stakeholder's views. Transceiver integrators, SDR end users, product maintainers, security, mission planning, and supportability elements were all considered, with the resulting functionality included in the functional decomposition of the SDR transceiver. Further considerations for the use of Open Architecture (OA) interface standards, optimal Human System Integration (HSI), and transceiver development tools will also be described in the context of how the architecture aligns with the characteristics of an elegant architecture.

The system thinking derived transceiver architecture yielded a high performance, highly modular/leverageable product that will successfully meet a diverse set of user CONOPs and needs well into the future. The architectural development detailed in this SDR transceiver case study, is a clear exemplar for successful architecture development, and is applicable to a wide range of products.

Architecting the Resilient Hospital Reference Model for Prolonged Power Outage

Howard Lykins, Resilient Hospitals Systems Engineering Team

Presented on: Thursday October 15th, 11:30 AM to 12:15 PM

Healthcare and Public Health, Energy, and Emergency Services" are some of the 16 critical infrastructures identified in Presidential Policy Directive-21. Our INCOSE supported Resilient Hospital Systems Engineering Team (RHSET) mission is to develop a Resilient Hospital Reference Model (RHRM) that hospital administrators and emergency planners can use for relevant decision support in the face of various threat scenarios to enhance current preparedness, protection, prevention, response, mitigation, and recovery planning. Initially RHRM will be targeted for prolonged power outages, with future extensions intended for broader spectrum of threats. Our overarching goal is to build a RHRM that has the capability to provide situational awareness, resource readiness, enhanced interoperability, assured communications, shareable knowledge, and assured compliance. We will employ current analysis, engineering, management, evaluation, and reporting techniques and tools, including Model-Based Systems Engineering (MBSE), to develop a generic architecture for resilient hospitals.

The project was initiated through a series of workshops with engagement of medical community stakeholders, applying the Lean Startup Method (LSM) to establish an Excel®-based foundation of knowledge that includes needs and capabilities. We have made it our top priority to keep the medical community stakeholders and users engaged with RHSET systems engineers throughout the development process. This level of collaboration requires trade-off between the ability to communicate MBSE concepts and engaging stakeholders with broad range of expertise but with varying technical understanding of MBSE.

In the early project phases, we are using OpCloud, a cloud-based modeling tool. OpCloud is based on the Object-Process Methodology (OPM) specification, and provides both graphical and textual description of the relationships between system objects and processes. This has allowed our healthcare stakeholders to be engaged in the critical stage of validating assumptions and refining the essential hospital resilience concepts. OpCloud can readily depict complex system architecture concepts and potentially be used in further development of the RHRM.

We are currently investigating appropriate capabilities and economics of other MBSE tools. We are exploring broad spectrum of MBSE tools which could extend the reference model to provide robust support for RHRM product design, development, implementation and operations, and further support evolution of future needs.

Our talk will present our mission and discuss how we combine LSM and Agile approaches in our MBSE development effort. We look to engage our attendees in a discussion regarding capabilities to build resilient system architecting for healthcare under prolonged power outage.

Lessons from the Stratosphere: Systems Engineering for Rapid Innovation

Brian Selvy, Vitech Corporation

Presented on: Thursday October 15th, 2:00 to 2:45 PM

Technology-centric companies that push the edge of the possible demand rapid innovation. Large, established organizations understand that it's necessary to maintain or expand their market position; smaller startups look to create disruption through the introduction of cheaper or better products or services with the objective of becoming the market leader. Unfortunately, systems engineering, in its traditional forms, is often perceived as being at odds with a culture and environment that embraces rapid innovation. Complaints can range from being too rigidly adherent to process to being too slow to deliver value to a team that is agile and nimble in their exploration of ideas and solutions. Brian Selvy will explore how these perceptions were overcome and how systems engineering was implemented to deliver value during his tenure as the Director of Systems Engineering at an early stage organization operating in the emerging stratospheric remote sensing and communications market. The presentation will explore ways in which tailored agile systems engineering methods were developed, incorporated into the culture, executed on programs, and updated based on regular feedback and reflection.

Concepts and Design Philosophy behind ISO/IEC/IEEE 42010 Systems and Software Engineering—Architecture Description

Rich Hilliard, nHansa, Inc.

Presented on: Thursday October 15th, 2:50 to 3:35 PM

ISO/IEC/IEEE 42010, 'Systems and software engineering—Architecture description', has been used by system, enterprise and software architects since its publication in 2011. It was based upon earlier work, IEEE 1471:2000, 'Recommended Practice for Architecture

Description of Software-Intensive Systems' -- the first formal standard on description of software and systems architectures.

Currently 42010 is undergoing joint revision by ISO and IEEE with active participation by a number of nations and liaison organizations (including INCOSE).

This presentation will offer the basic concepts and design philosophy of 42010, its usage, and what to expect when the revision is completed in 2021. Topics include: architecture descriptions, architecture description frameworks, viewpoints and model kinds, current usage of the standard and supporting tooling.

Impact of a System's Boundaries on Its Architecture and Requirements: Lessons Learned from Designing Energy Storage to Nuclear Systems for the Grid

Bao Truong, Malta, Inc.

Presented on: Thursday October 15th, 3:40 to 4:25 PM

Electricity is delivered to its end-users via a complex network, usually known as the grid. Traditionally, electricity is generated at central power plants (such as hydro-power stations, gas plants, coal plants, nuclear power plants, etc.) and then transported to the users via the grid. In the last two-three decades, with the concern of climate change, more and more solar power and wind power plants have been installed to provide electricity. These are usually more distributed resources, and as the fraction of solar and wind power increases it will cause additional challenges for the grid to maintain its stability. The use of energy storage systems can help alleviate these challenges. However, the grid overall will be more complex and will have additional demands on new systems connecting to it.

Design a system connected to grid requires understanding of how the grid interacts with such system and vice versa. Each of these interactions could have large impact on the system architecture, its requirements, and ultimately its design. This paper provides some lessons learned on the importance capturing these interactions early on and how that can save a lot of rework on the design of advanced nuclear power plants, energy storage systems and their combination. These energy systems are complex by themselves as standalone ones. Integrating them in to the grid, which is getting more and more complex, is even more challenging. The paper will first provide an overview of the different services an energy system can provide to the grid. Then it will focus on a few specific services, their associated requirements, and how those impact the architecture of advanced nuclear power plants, energy storage systems and their combination. For example, the promise of advanced nuclear plants to provide peaking service introduces many design challenges, including a completely different control architecture. For certain energy storage systems, providing peaking service is much easier. On the other hand, the promise of providing inertia to the grid, while easily done by nuclear plants, precludes many battery storage systems. The lessons learned here point to and confirm the need for a formal and rigorous systems engineering process very early on the life cycle of any energy system that is connected to the grid.

Training Sessions

Track A: Introduction to MBSE with SysML and Cameo Systems Modeler

Saulius Pavlakis, Dassault Systems

Conducted on: Friday October 16th, 8:30 AM to Noon

The training covers basic level of system behavior and structure definition using different SysML diagrams. SysML is the most popular and standard (ISO and OMG) systems modeling language. It is also one of the major MBSE (SE transformation to model based) enablers. However, language is not the only thing which is important in context of MBSE adoption, tools helping to create correct models fast, do analysis, data management etc. is also major component. Those two major aspects will be covered in this hands-on workshop.

Learning objectives:

1. Learn Cameo Systems Modeler user interface and main principles.
2. Learn SysML basics.
3. Learn how to start building system model in SysML with Cameo Systems Modeler.

Schedule:

1. Introduction to SysML
2. Introduction to MBSE with SysML
3. Introduction to Cameo Systems Modeler
4. Hand on building small model.

Trainer Bio:

Saulius (Saul) Pavalkis, PhD, Dassault Systems - CYBER SYSTEMS Industry Business Senior Consultant and MBSE Transformation Leader

- 18 years at Dassault Systems (No Magic) in model based solutions and R&D.
- Expert in systems modeling, simulation, MBSE ecosystem, interfaces / integrations, traceability, queries.
- Certificates: INCOSE CSEP, OMG OCSMP, No Magic lifetime modeling and simulation excellence award.
- Community author for simulation (youtube.com/c/MBSE Execution) and MBSE success cases (blog.nomagic.com). Author of multiple papers on MBSE.
- Representative at INCOSE CAB.
- Supporting MBSE adoption in A&D, T&M and other domains. Major clients: P&W, Boeing, NASA, BAE Systems, Raytheon Technologies, NGC, FORD.

Track B: Tutorial on Hetero-functional Graph Theory for Guiding Participants Systematically through MBSE and Graph Theory Using Smart City Example

Amro Farid, Dartmouth

Conducted on: Friday October 16th, 8:30 AM to Noon

Development in the smart city literature has predominantly focused on device connectivity & control, data acquisition, and governance structures. Though these topics are both complex and valuable, smart cities are much more comprehensive. Infrastructure systems enable smart cities by providing critical services such as electric power, natural gas, potable water, wastewater treatment, and transportation. These infrastructures, however, do not operate in a vacuum, as the literature converges from individual smart infrastructure systems to an interdependent smart city infrastructure system. Methodological tools for design and analysis of such interdependent systems have been lacking. Some have used graph theoretic approaches, which neglect the distinct functionality of these systems. Others have used model-based systems engineering techniques, but those do not lend themselves to quantitative analysis. Hetero-functional Graph Theory has been developed over the last decade and most recently, it has specifically been applied to interdependent smart city infrastructures. This workshop is a tutorial on Hetero-functional Graph Theory. First, it guides participants systematically through the fundamentals of model-based systems engineering and graph theory, using smart cities as examples. Thereafter, the workshop continues by providing the conceptual foundations of Hetero-functional Graph Theory, building on the discussion of MBSE and Graph Theory. The workshop concludes with a demonstration of Hetero-functional Graph Theory on a smart city infrastructure test case. The test case demonstrates the use of hetero-functional graph theory to model an interdependent infrastructure system consisting of a water distribution system, an electric power system, and an electrified transportation system.

Trainer Bio:

Amro M. Farid is currently an Associate Professor of Engineering at the Thayer School of Engineering at Dartmouth with a principal expertise in the application of control, automation & information technology to intelligent energy systems. He received his Sc. B. in 2000 and his Sc. M. 2002 from the MIT Mechanical Engineering Department. He went onto complete his Ph.D. degree at the Institute for Manufacturing within the University of Cambridge (UK) Engineering Department in 2007. He has varied industrial experiences from the automotive, semiconductor, defense, chemical, and manufacturing sectors. In 2010, he began his academic career at the Engineering Systems & Management department at the Masdar Institute of Science & Technology in Abu Dhabi, UAE.

Tracks A&B: Alternative System Architectures Automatic Trade-Study Analysis

Saulius Pavlakis, Dassault Systems

Conducted on: Friday October 16th, 12:30 to 4:00 PM

Trade-off study is a common task in a daily routine of a Systems Engineer. It is used to compare a number of alternative solutions to see whether and how well they satisfy a particular set of criteria. Each solution is characterized by a set of measurements of effectiveness that corresponds to the evaluation criteria and has a calculatable value or value distribution. Measurements of effectiveness of a given solution are evaluated using an objective function, and the results for each alternative are compared to select a preferred one. This hands-on workshop teaches how to perform an architecture-based trade-off study by using a new trade-study pattern, SysML as a modeling language, and Cameo Systems Modeler with Cameo Simulation Toolkit. Case Study: Satellite Solar Array Trade Study Based on Fire Sat Model from, "Architecting Spacecraft with SysML: A Model-Based Systems Engineering Approach.

Learning Objectives:

1. Learn how to setup trade-study: alternative architectures modeling, parameters normalization, and objective functions
2. Learn how to apply new automatic trade study pattern
3. Learn how to perform automatic trade study with variant from model and Excel

Schedule:

1. Introduction to trade-off studies and their types

2. Project organization for analysis
3. Introduction to automated trade-study pattern
4. Requirements verification to eliminate illegal configurations
5. Applying automated trade-study pattern and performing analysis

Trainer Bio:

Saulius (Saul) Pavalkis, PhD, Dassault Systems - CYBER SYSTEMS Industry Business Senior Consultant and MBSE Transformation Leader

- 18 years at Dassault Systems (No Magic) in model based solutions and R&D.
- Expert in systems modeling, simulation, MBSE ecosystem, interfaces / integrations, traceability, queries.
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