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Systems Engineering for Earth's Future

Uniting Technology and Grand Challenges through Systems Engineering

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Book of Abstracts

Table of contents

Keynote - Plenary

Keynote-Plenary#K1

System engineering and society

Bernie Fanaroff (Former Director Square Kilometer Array (SKA) South Africa) - bfanaroff@ska.ac.za

Presented on: Monday, 15:00-16:00

Abstract. I will look at how system engineering helped to make the design and construction of the MeerKAT radio telescope spectacularly successful, showing convincingly that the best science and technology can be done in Africa. I will also talk about the use of SE in South Africa's National Ventilator Project and the challenge of increasing the successful implementation of the National Infrastructure Plan.

Biography

Bernie Fanaroff (Former Director Square Kilometer Array (SKA) South Africa) - bfanaroff@ska.ac.za
Dr Bernie Fanaroff was the Director of the Square Kilometer Array (SKA) Project Office through 2015 and as strategic advisor for the SKA South Africa Project from 1 January 2016 to December 2017. Dr Fanaroff began his academic career in 1965 as an undergraduate at the University of the Witwatersrand, where he obtained a BSc and a BSc (Hons) in Theoretical Physics. He later obtained a PhD in Radio Astronomy from Cambridge University in 1974. It was at this time that Fanaroff, together with a British astronomer, Julia Riley, made a breakthrough in the classification of radio galaxies and quasars when they identified two classes of radio sources which now bear their names – Fanaroff-Riley class I and class II sources, or FR-I and FR-II as they are now universally known. Dr Fanaroff's paper on the Fanaroff-Riley classification has been cited well over 2000 times. Upon his return to South Africa, Dr Fanaroff dedicated 19 years to the struggle against apartheid as an organizer and national secretary for the Metal and Allied Workers Union, which became the National Union of Metalworkers of South Africa (NUMSA) in 1987. After the first democratic election in 1994, Dr Fanaroff was appointed as the Deputy Director-General in the Office of President Nelson Mandela, and as the Head of the Office for the Reconstruction and Development Programme (RDP). He also served as the Deputy Director-General of the Department of Safety and Security, the Chairperson of the Integrated Justice System Board and the Inter-Departmental Steering Committee for Border Control. After a distinguished career in public service, he was asked by the previous NRF CEO, Dr Khotso Mokhele, and the previous Director General for Science and Technology, Dr Rob Adam, to set up the South African SKA Project Office (SASPO) at the beginning of 2003, with the vision of bringing the largest radio telescope in the world to Africa. Together with Dr Mokhele and Dr Adam, and renowned scientists Dr George Nicolson and Prof Justin Jonas, Dr Fanaroff worked towards the vision of not just hosting SKA, but becoming a leading partner in the development of cutting edge technology for the SKA telescope and playing a leading role in SKA Science. As Director of the SKA SA Project, Dr Fanaroff led the conceptualisation, development and construction of the South African SKA precursor, the 64 dish MeerKAT telescope array, which was completed in March 2018 on schedule, on budget and within the prescripts of the PFMA. This project included the construction of the prototype telescopes XDM and KAT 7 and the infrastructure to establish to huge observatory site at Losberg in the Karoo. A key part of the project has been the development of the SKA South Africa's highly-respected Human Capital Development programme. Despite his retirement at the end of 2015, Dr Fanaroff has continued to work as an advisor to the SKA SA project, as well as an advisor to the Ministry of Science and Technology. He has been appointed co-chair of the BRICS (Brazil, Russia, India, China and South Africa) Working Group on Information and Communication Technologies and High Performance Computing, and as member of the Advisory Committee of the Breakthrough Listen project. He is also a founding member of the Academy of Science of South Africa (ASSAf); a Fellow of the Royal Astronomical Society; and was a Visiting Professor at Oxford University.

Keynote-Plenary#K2

System Engineering of Low-Cost Earth Observing Systems

Jakob van Zyl (Hydrosat, Inc.)

Presented on: Tuesday, 15:00-16:00

Keywords. keynote

Abstract. Remote sensing of the Earth as a system has long been the exclusive domain of large government programs. These investments have created a wealth of scientific knowledge and led to significant advances in technologies that could simplify the implementation of future space missions. But there is an inherent mismatch in expectations between broad scientific missions and focused commercial efforts. In the former, performance is of paramount importance, while in the latter cost plays an outsized role.

In the last decade, several start-up companies have emerged to provide some of the data that these government satellites used to provide. In most cases, these commercial satellites are very low cost, partly because either they do not provide the same exquisite quality of the scientific satellites, or they provide only a small subset of the data either in their spatial or spectral coverage. A key difference of course is the fact that commercial satellites have to have a business case that closes. As a result, non-essential observations are eliminated. In addition, often these commercial systems built on decades of government investment in technology.

In this talk we shall examine these differences and focus on the systems engineering behind the Hydrosat constellation of low-cost thermal infrared satellites. It is well established that the difference between the land surface temperature (LST) and the ambient air temperature provides a direct measurement of plant water stress. Today, the best available resolution for daily LST is 750 meters to 1 km; far too coarse a resolution for global agricultural applications. Hydrosat will launch a constellation of small satellites to image the entire globe in the thermal infrared to provide a global map of LST every day at a spatial resolution of 70 meters. We shall discuss how these parameters came about and discuss the system engineering that translates these parameters into a space constellation.

Biography

Jakob van Zyl (Hydrosat, Inc.)
As a Principal for Physical Sciences, Jakob oversees the diverse portfolio of investments across the spectrum of physical science disciplines; each holding the promise of providing fundamental advancements to everyday life. His responsibilities include the end-to-end cycle of technology development and transition–from the identification of cutting-edge, new technologies with high impact potential to working daily with new companies as they transition from a possible incubation to a Series A investment. Prior to joining Kairos, Jakob spent 33 years at the Jet Propulsion Laboratory in Pasadena, California where he started as a researcher in 1986. He joined the JPL Executive Council in 2002 where he served as the Director for Astronomy, Physics and Space Technology, the Associate Director of JPL responsible for Project Formulation and Strategy, and the Director for Solar System Exploration. He was instrumental in the development of innovative technologies during his time as Associate Director, including the first deep space small satellites to launch and operate all the way to Mars (2018) and the demonstration of a small helicopter for increased mobility on Mars, to be launched in 2020. He concluded his career at JPL with the spectacularly successful landing of the Insight lander on Mars in November 2018. Jakob is the coauthor of the texts Introduction to the Physics and Techniques of Remote Sensing: Second Edition and Synthetic Aperture Radar Polarimetry. He has contributed to eighteen other books and published more than 60 papers in peer-reviewed journals and gave numerous keynote speeches at technical conferences. Besides being a Principal, Physical Sciences at Kairos Ventures Investments, he is also the CEO and co-founder of Hydrosat, a data analytics and space remote sensing startup company and a Senior Faculty Associate at Caltech where he teaches the graduate course Physics and Techniques of Remote Sensing and an Extraordinary Professor at the University of Stellenbosch in South Africa.

Keynote-Plenary#K3

Water Supply Systems : A Broad Overview

Dr. Ronnie S. McKenzie (Former Chairman, Water Loss Group, International Water Association)

Presented on: Wednesday, 15:00-16:00

Biography

Dr. Ronnie S. McKenzie (Former Chairman, Water Loss Group, International Water Association)
Ronnie is well known as a specialist in the fields of Water Demand Management, Hydrology, Water Resource Planning and Systems Analysis, with more than 30 years of experience in these fields. He has been involved in the analysis of many large water resource systems, particularly in Southern Africa where he is currently based. He was a key member of the Vaal River System Analysis team which pioneered the water resources systems analysis techniques now used throughout South Africa and many other parts of the world. Other major projects in which Ronnie has been involved include the Orange River System Analysis, the Namibian Central Area Water Master Plan and the verification of the Lesotho Highlands hydrology for royalty calculation purposes. He has developed and presented more than 100 papers, courses and workshops in many parts of the world, and was responsible for introducing the internationally recognised Burst and Background Estimate (BABE) water demand management techniques to South Africa and numerous other countries. Ronnie also developed Leakage Benchmarking software for the South Africa Water Research Commission as well as the Australian Water Supply Association and the New Zealand Water and Waste Association. In the past few years, Ronnie has initiated several large leakage reduction projects throughout South Africa including the Khayelitsha Advanced Pressure Management Project and the Sebokeng/Evaton Advanced Pressure Management PPP, both of which won several national and international awards for technical excellence (SAACE, SAICE, IWA and IMESA). He was responsible for the development and presentation of many training courses in Water Resource Systems Analysis and Water Demand Management and has personally presented more than 50 courses throughout South Africa as well as in Ethiopia, Brazil, Australia, Puerto Rico, USA, New Zealand, Namibia, Botswana, and Lesotho. He is a fellow of the SA Institution of Civil Engineering, IWA and WISA and is a past Chairman of the IWA Water Loss Specialist Group.

Paper

Paper#65

(MBSE)2: Using MBSE to Architect and Implement the MBSE System

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

Keywords. MBSE;System Architecting;Problem Framing

Topics. 5.3. MBSE;

Abstract. Model-Based Systems Engineering (MBSE) is being applied in a new way at the enterprise level for the benefit of all its major programs and business units. For an enterprise to successfully implement MBSE, it must integrate models, datasets, tools, and infrastructure with appropriate processes, methods, and standards into a comprehensive, integrated MBSE “System”. This paper describes a methodology that uses MBSE principles and methods to architect this MBSE System, focusing on the descriptive models that serve as the foundation for MBSE. The methodology has been named (MBSE)2 since it uses MBSE to architect and implement the MBSE System. This (MBSE)2 methodology is illustrated with example models of the MBSE System, showing how these models can be used to inform the architecting process, monitor agile implementation of models, and facilitate model-based execution of SE reviews and audits.

Paper#105

A Capability Engineering Lifecycle Framework Based on Insights from Australian Defence

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Paper not presented

Keywords. Systems of systems;Capability engineering;Defense

Topics. 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 6. Defense;

Abstract. The Australian Department of Defence is actively pursuing initiatives to improve the integration and interoperability of the defence force and this paper reports on research findings produced in support of this effort. The paper opens with a description of the Australian Defence capability development context together with recent initiatives to provide greater military capability for the available budget.
Within this context, the problem the researchers set out to address is how best to co-ordinate the ongoing force Integration and Interoperability (I2) activities that evolve and deliver defence capabilities so that these capabilities can be integrated together at short notice and deployed.
System of Systems Engineering (SoSE) approaches have been found to be effective for this class of problem and the paper provides a short review of the most promising candidates.
The methodology needs analysis that follows concludes that a range of different SoS approaches will be needed to cover the entire problem space and the paper then proceeds to describe a framework that provides a new way of looking at the defence Integrated Capability Realisation (ICR) SoSE challenge across two dimensions.
The first dimension is the time horizon of the planned capability increment: from the present to around four years; four to eight years; eight to twelve years; and longer than twelve years.
The second dimension covers the types of activities that are traditionally performed to evolve defence forces such as future force planning, program co-ordination and planning, project capability definition, acquisition, and force generation.
The paper describes how this framework provides a simple method to understand which SoSE approaches are the most applicable to given ICR subtasks and also proposes an overall approach to self-organise overall Defence ICR efforts.

Paper#5

A Framework of International Competencies for Systems Engineers

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Paper not presented

Keywords. Global Systems Engineering;International Engineering Competencies;Systems Engineering Education;Cross Cultural Teaching Elements

Topics. 1. Academia (curricula, course life cycle, etc.); 5.10. Diversity (cultural boundaries, diverse engineering teams, training underserved groups, etc.); 5.9. Teaching and Training;

Abstract. In the course of their career, many systems engineers are likely to interact with engineers of other nationalities as they collaborate on large, complex projects and system of system problems. These partnerships are necessary to support international goals, such as those for sustainable development. System engineers may even work onsite in other countries where they must adapt to different styles of doing business. This requires a set of global skill sets for cooperating and decision making, as well as basic social skills for interacting with the local community. These global skills can be included in a graduate level system engineering curriculum by integrating a set of "international competencies" that includes cognitive style differences, culture awareness, communication, ethics, and teamwork. The competencies were identified through a literature review of suggested global engineering skill sets; these five themes consistently appeared throughout the literature. The Graduate Reference Curriculum for Systems Engineering (GRCSE) was then reviewed to link these competencies to established systems engineering learning outcomes and System Engineering Body of Knowledge (SEBOK) topics.
Finally, teaching elements are suggested that can be included even included in established curriculums to introduce systems engineers to the skills they need to be successful in a global world.

Paper#97

A generic Systems Engineering process tailoring methodology, based on lessons from MeerKAT

Thomas Kusel (SARAO) - tkusel@ska.ac.za

Presented on: Monday, 13:15-13:55

Keywords. Systems engineering;Systems engineering process tailoring;tailoring methodology;Radio Astronomy

Topics. 2. Aerospace; 3.7. Project Planning, Project Assessment, and/or Project Control; 5.2. Lean Systems Engineering; 5.5. Processes;

Abstract. Each system is unique and requires tailoring of the systems engineering process to ensure that it is applied effectively and efficiently. The concept of tailoring is well recognized, but there is limited literature on generic tailoring methodologies. In this paper, a simple yet effective generic tailoring methodology is proposed. The paper identifies the system characteristics that should be considered during the tailoring process and key performance indicators. The MeerKAT project is used as a case study to derive the methodology and is used to illustrate its application.

Paper#161

A Review of Hurdles to Adopting Industry 4.0 in Developing Countries

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Paper not presented

Keywords. Industry 4.0;developing countries;sustainability

Topics. 1.2. Cybernetics (artificial intelligence, machine learning, etc.); 11. Information Technology/Telecommunication; 4.1. Human-Systems Integration; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. The world is experiencing the fourth industrial revolution, and developing countries are experiencing it differently than developed countries. Developed countries have an advantage over developing countries in that they adopted industrialisation early, and this created a large gap between the two. Developed countries are not necessarily sustainable. Sustainable development is equally important in both developed and developing countries, but in different ways. Developed and developing countries will try to achieve sustainability development goals in different ways. Developed countries will most likely use the fourth industrial revolution to integrate technology into achieving their goals, while some developing countries might first need to catch up on industrial revolutions that they have skipped. Industrialisation, specifically that of the current revolution, will occur differently in developing countries. This paper describes this and discusses some of the hurdles that might hinder developing countries from adopting Industry 4.0, and develops an initial framework for readiness assessment.

Paper#17

A Study of System Development in a Research and Development Environment with a focus on Radar Systems

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Paper not presented

Keywords. Radar systems;systems engineering;research and development

Topics. 3.5. Technical Leadership; 5.5. Processes; 6. Defense;

Abstract. The objective of this study was to analyse the development of radar systems in a research and devel-opment environment from a systems engineering perspective and identify which, if any, systems en-gineering tools and methods are used. The practical portion of the research took a mixed methods ap-proach where both qualitative and quantitative data collection techniques were used. The quantitative portion of the research assessed aspects of systems engineering in the context of the research envi-ronment the participant is working in using categories of the Systems Engineering Capability (SECM) EIA/IS 731 model. Analysis of the data indicated that, in principle, systems engineering methods and tools are supposed to be applied in this research area, however this was not done con-sistently across projects. Some of the challenges in this research area included eliciting clear customer requirements, resource constraints and budget and schedule overruns. Recommendations were made based on the findings from a systems engineering perspective.

Paper#70

A sustainable software testing process for the Square Kilometre Array project

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Presented on: Monday, 12:30-13:10

Keywords. complex system and project;software testing process;agile development;radioastronomy;square kilometer array

Topics. 11. Information Technology/Telecommunication; 14. Autonomous Systems; 2.6. Verification/Validation; 5.1. Agile Systems Engineering; 5.7. Software-Intensive Systems;

Abstract. In this paper we show how to achieve a sustainable software testing process in a very complex scientific project, the SKA radio observatory. The project currently involves 13 countries, 16 agile development teams of about 150 individuals, governed through the SAFe framework; the software that is being built ranges from user interfaces to control systems, from transactional applications to high performance parallel scientific processing code.
The paper illustrates the testing challenges we have to tackle; it also defines what a "sustainable testing process" is and how that constitutes the foundation of an incremental adoption plan rooted on systems thinking. The plan is then described, highlighting the principles we adhered to for synthesising a sequence of 9 basic testing goals that are currently being rolled out.
We are confident that similar decisions can be made on many large scientific projects that are developed with agile methods.

Paper#141

A Trade Study of Requirements Software Tool Selection for a Small Aerospace Firm

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Paper not presented

Keywords. Trade Study;Requirements;Software;Aerospace

Topics. 1.6. Systems Thinking; 2. Aerospace; 2.3. Needs and Requirements Definition; 2.5. System Integration; 2.6. Verification/Validation; 3.3. Decision Analysis and/or Decision Management; 3.6. Measurement and Metrics; 4.1. Human-Systems Integration; 4.2. Life-Cycle Costing and/or Economic Evaluation; 5.5. Processes; 5.7. Software-Intensive Systems; 5.9. Teaching and Training; 6. Defense;

Abstract. An aerospace division studied works with many sophisticated and complex aerospace projects where requirements management is a necessity. This paper represents the results of a trade study into possible software tools for requirements management across the various division pro-grams. The study began with a survey to program leadership and systems engineers about their handlings of requirements and their use of specific requirements tools. This survey allowed for the formulation of criteria within an analytical hierarchy process (AHP) of various commercial re-quirements software platforms. Through the pairwise comparisons of AHP, five software tools were selected and evaluated for feasible implementation across the various division program sizes. With data from the survey and results from the AHP, this trade study suggests that Jama will most appropriately fulfill the specific needs of the division. This is based on Jama’s strong performance in aspects such as security, Excel integration, and file linking.

Paper#96

A Transdisciplinary Design and Implementation of Sustainable Agricultural Principles in the Waikato Region of New Zealand

Hendrik van Zyl (University of Otago) - henkvanzyl69@gmail.com
Jan Hendrik Roodt (Stone To Stars Limited) - henkroodt@icloud.com

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

Keywords. Sustainable agriculture;Transdisciplinary;Systems design;Business resilience;Land custodianship

Topics. 1.3. Natural Systems; 10. Environmental Systems; 3.9. Risk and Opportunity Management; 4.4. Resilience;

Abstract. The Ministry of Primary Industries in New Zealand, per the 17 United Nations Sustainable Development Goals, prioritised “increased sustainable resource use” as a critical success factor to ensure the wellbeing of New Zealanders. The challenge for a commercial vegetable farming operation is how to embed sustainable agricultural principles in operations to ensure a thriving, financially sustainable business. Of the 17 Sustainability Development Goals, 13 involve soil one way or another and Target 15 (Life on Land) relates to soil health as an integral part of sustainability.

A transdisciplinary systems approach was followed in a running agricultural operation to explore links between societal wellbeing, plant health and soil health while maintaining profitability and business resilience. The business used the client and policy-centred outcomes for the design and implementation of a thriving enterprise. It showed that increased profit is achievable utilising a combination of fertigation techniques and compost applications for onion production.

Paper#42

Achieving System-of-Systems Interoperability Levels Using Linked Data and Ontologies

Jakob Axelsson (Mälardalen University) - jakob.axelsson@mdh.se

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

Keywords. Systems-of-systems;Interoperability;Linked data;Ontology

Topics. 2.5. System Integration; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.);

Abstract. Interoperability is a key concern in systems-of-systems (SoS). Numerous frameworks have been proposed to deal with this, but they are generally on a high level and do not provide specific guidance for technical implementation. However, in the context of simulation, the Levels of Conceptual In-teroperability Model (LCIM) has been proposed. Also, the semantic web initiative has been intro-duced to provide description logic information to web pages. This paper investigates how these two concepts can be combined into a general approach for SoS interoperability. It also expands on the LCIM model by providing more details about the world models of a system and its content on the higher levels of interoperability. The combination is illustrated using an example of autonomous vehicles, and experiences from other applications are also discussed.

Paper#130

Addressing Challenges of the Circular Economy using Model-Based Co-Creation and Systems Design

Jan Hendrik Roodt (Stone To Stars Ltd) - henkroodt@icloud.com
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Presented on: Monday, 14:00-14:40

Keywords. Circular economy;Model-based co-creation;Reference model;Challenges of circular economy

Topics. 1.6. Systems Thinking; 10. Environmental Systems; 5. City Planning (smart cities, urban planning, etc.); 5.3. MBSE;

Abstract. The circular economy (CE) is increasingly discussed as a way to address climate change and sustainability. The idea is deceptively simple to explain. It is claimed that development is lead primarily by practitioners, while the rigorous scientific system design effort is mostly ignored as the pressure mounts to act in the face of climate change urgency.

In 2018 Swedish and Finnish authors distilled six limits and challenges of CE. These elements were used as a boundary object to define and co-create a simulation model environment. Reference models were introduced to develop an initial conceptual model for discussion. An international team of geographically separated researchers and practitioners used this simulation model to develop an understanding of initial requirements. The first outcomes of the approach are promising and accentuate the importance of starting early with the co-creation effort to develop a common language and simulation models for understanding.

Paper#116

Addressing Cognitive Bias in Systems Engineering Teams

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

Keywords. Cognitive Bias;Systems Engineering;Decison Making;Systems Thinking

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

Abstract. Cognitive bias is a general issue in human decision making. It is easy to assume there is less bias in engineering, systems engineering, and program management, as these are generally consid-ered rational processes. However, human decision making is almost always affected by bias. In the systems engineering practice as well as training systems engineers, we find directly ad-dressing principles of human cognition, decision-making, and bias to be an important part of individual and team learning. This paper discusses the characteristics of thinking, cognition, and decision-making; conceptual approaches in psychology that frame these characteristics in the context of human decisions; common biases that affect decisions in the domain of systems en-gineering; and application of systems thinking tools to help overcome these issues.

Paper#81

Addressing the Sustainable Development Goals with a System-of-Systems for Monitoring Arctic Coastal Regions

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

Keywords. system-of-systems;arctic;autonomous systems;satellite;stakeholder analysis;use-cases;sustainability;decision-making

Topics. 13. Maritime (surface and sub-surface); 14. Autonomous Systems; 2. Aerospace; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.);

Abstract. Norway has a large coastal industry, and a strong motivation for developing systems to enable sustainable management of the ocean resources. Recent advances in collaborating autonomous systems, Internet-of-Things, microsatellites, data fusion, and sensor development have led to initiatives for a more concerted and coordinated effort through the establishment of an ocean studies research project. Applying a System-of-Systems perspective on the project highlights the challenges in terms of interoperability and communication interfaces, as well as revealing the use-cases stake-holders rely on to enable informed decision-making.

Paper#19

An Approach to Architect using Spaces and Flows

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Paper not presented

Keywords. Architecture;Architecting;Architecture Frameworks;Architectural Intervention;Spaces and Flows;Architecting Approach

Topics. 11. Information Technology/Telecommunication; 18. Service Systems; 2.4. System Architecture/Design Definition; 5.5. Processes; 5.7. Software-Intensive Systems; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Today, architecture as a discipline is gaining prominence for addressing the increasing complexity associated with enterprises, systems, software, software intensive systems and other entities.
This is evident by the increasing architecture related activities that are performed as part of many of these endeavors.
Many architecture frameworks, that have been found useful by communities of practice, are increasingly found applicable in different situations requiring architectural interventions.
However, it is often the case that there is no foundational basis for many of these practices other than the fact that they are found to be useful.
In this paper, spaces and flows are introduced as the foundational concepts for architecting any entity.
An approach that utilizes these concepts is proposed.
The underlying rationale for the approach and the foundational concepts is also discussed.
Further, the usefulness of these concepts and approach is illustrated by means of an exemplar.

Paper#33

An Energy Poverty Case Study: A Whole Systems Perspective Applied to an Informal Settlement

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Keywords. systems thinking;systems reinforcing model;energy access sustainability;energy-poor community;informal settlements

Topics. 1.1. Complexity; 1.6. Systems Thinking; 5. City Planning (smart cities, urban planning, etc.); 5.5. Processes; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 8. Energy (renewable, nuclear, etc.);

Abstract. This paper describes the novel application of a systems approach within the context of energy poverty mitigation. This is enriched by using an informal human settlement situated in the Western Cape near Cape Town as case study. A systems approach is used to design and integrate system interfaces within an “energy poverty system” leading to a proposed new System Reinforcing Model (SRM) for Energy Access Sustainability (EAS) in energy-poor communities. The proposed model identifies interrelated systems and elements, developed as design decisions and system designs grounded in energy-use patterns and behavior, energy access options, sustainabil-ity, socio-economic, cultural, technical, and environmental issues. The proposed new SRM is then applied to a typical energy-poor community where the model’s significance is effectively demonstrated. Based on its participatory sensitivity, the model reveals system parts instigating energy poverty and limiting energy access.

Paper#107

An Interactive Tool for Collaboration and Knowledge Sharing of Customer Needs in the Conceptual Phase

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Paper not presented

Keywords. customer needs;customer requirements;conseptual phase;knowledge sharing;interactive tool

Topics. 1. Academia (curricula, course life cycle, etc.); 1.1. Complexity; 13. Maritime (surface and sub-surface); 2.3. Needs and Requirements Definition; 3.7. Project Planning, Project Assessment, and/or Project Control;

Abstract. This paper aims to research how the use of an interactive tool can facilitate collaboration, knowledge sharing and enhance the understanding of customer needs in conceptual phase at a global ship-building company. An effective conceptual phase depends on collaboration and mutual under-standing of customer needs to capture customer requirements and transform them into a base of design-document. Lack of early common understanding can result in increased project cost or in worst-case loss of contract. We used action research as an approach for our study and developed and implemented an interactive tool in a case at the company. In-depth interviews and root-cause analysis were used to determine the pain-points of the as-is situation. A feedback survey was used to evaluate the performance and result of the interactive tool. The results indicate that the interactive tool con-tributes to a better overview of ongoing projects, increased knowledge sharing, and enhanced common understanding.

Paper#128

Analysing the South African Junior Primary Education System with Agent-based Simulation Modelling

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Paper not presented

Keywords. Education system;Simulation modelling;South Africa

Topics. 1. Academia (curricula, course life cycle, etc.); 3.3. Decision Analysis and/or Decision Management; 4. Biomed/Healthcare/Social Services; 4.1. Human-Systems Integration; 5.4. Modeling/Simulation/Analysis;

Abstract. The state and quality of the South African education system is an increasing concern. Even more than two decades after the Apartheid era, the consequence of the segregation and discrimination is evident in the country's education system. In order to address this matter, an agent-based simulation model with the ability to model the academic progression of grade one to four learners from various socio-economic backgrounds, based on existing data, is proposed. The model aims to effectively simulate the academic progression of learners over a four-year period, as well as assisting intervention planning in identifying the effect that certain social or socio-economic intervention strategies may have on the academic progression of learners in the South African education system. The agent-based model allows for a graphical output visualizing the academic progression of agents and the effects that the activation of certain intervention strategies have on this progression.

Paper#4

Analyzing the effects of connecting Norway´s remote communities to large cities using the Systems Thinking approach

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Keywords. Systems Thinking;Urbanization;Systemigram;Context diagram;Infrastructure projects;Leverage points;Stakeholder analysis

Topics. 1.6. Systems Thinking; 12. Infrastructure (construction, maintenance, etc.); 3.7. Project Planning, Project Assessment, and/or Project Control; 5. City Planning (smart cities, urban planning, etc.);

Abstract. This paper explores how the Systems Thinking philosophy can be applied to determine the feasibility of significant infrastructure projects. Much too often, decisions are made without a thorough understanding of all the factors involved and their interrelations, as has been the case for many governmentally funded construction projects in Norway. The paper investigates the repercussions of connecting remote island villages to larger cities, by examining the short- and long-term effects for two real-life case studies Andørja and Linesøya in Norway. The analysis is supported by a number of systems thinking tools, including a context diagram, stakeholder analysis, systemigram to map user needs, and finally, leverage points to improve the decision-making process are presented.

Paper#39

Answering the Call for Technical Leaders: A Challenge for Systems Engineers

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Paper not presented

Keywords. technical leadership;complexity;Vision 2025;UN Sustainable Development Goals

Topics. 1.1. Complexity; 3.5. Technical Leadership;

Abstract. Systems engineers are called to lead! Addressing today's increasingly complex challenges demands the skills we systems engineers have demonstrated in the past and of which we are most proud. Our experience has taught us the importance of understanding: not only a problem, but also its context; not only the individual elements of a system, but also the relationships between the elements; not only immediate outcomes, but also long term impacts. But what we already know will not be enough. We must also develop new skills and be willing to set aside some of the approaches and much of the language that have served us well in addressing the complicated problems of the past. We need to continue to learn and to grow if we are to provide the leadership a complex world so desperately needs from us. This paper is a challenge from one systems engineer to all systems engineers to elevate our game in order to play a leadership role in taking on the complex challenges of the twenty-first century.

Paper#2

Applying Systems Thinking to Frame and Explore a Test System for Product Verification; a Case Study in Large Defence Projects

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

Keywords. Automation; Machine Learning; Systems Thinking; Verification

Topics. 1.6. Systems Thinking; 14. Autonomous Systems; 2. Aerospace; 2.6. Verification/Validation; 5.4. Modeling/Simulation/Analysis; 6. Defense;

Abstract. The test system is a vital part of delivering a verified product to the end customer. The test system used in Kongsberg Defence and Aerospace (KDA) to test missile products today needs to change to be able to cope with future requirements for faster project execution and running more projects simultaneously. This article uses a Systems Thinking approach to see the bigger picture and to ensure understanding of the entire problem domain. The system consists of the following structural elements: Data Preparation System, Mission Planning System, Simulators, Data Analysis System and Storage System. The stakeholders of the test system are testers, system owners, project managers, company, customers, government and suppliers. Several possible value added processes are foreseen to make this necessary transition; automation of test execution and test analysis to avoid bottlenecks, verification on both core product and adaption product level for modularity, combining test arena input over different systems/sub-systems/components for re-use of data, and Machine Learning only to trigger necessary manual analysis. These changes will influence the sys-tem in several ways and levels, which a possible implementation need to consider. Regarding aspects like facilities, environment, security and safety not to cause issues for the changes in question is important. The main steps in the current test process is that the test system will provide scenario data to the tester to run test scenario to generate test results to the analyzer to perform test results analysis to achieve a verified product. The test structure is a limiting factor in the process of ensuring test maturity. The analysis structure is a limiting factor in reaching the desired verification level. The test structure and analysis structure are leverage points of the test system, which can significantly change the test system. The test system should have an automated test execution and test results analysis process, not requiring tedious manual operations. The automated test process should further introduce Machine Learning to change the focus of everything to managing the exceptions. KDA will increase its probability of success in future projects by applying the proposed changes to its test system.

Paper#77

Bridging the Gap Between Architects, Engineers and Other Stakeholders in Complex and Multidisciplinary Systems – A Holistic, Inclusive and Interactive Design Approach

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Presented on: Monday, 12:30-13:10

Keywords. Model-based Systems Engineering;Complex Systems;Multidisciplinary Design Optimisation;Collaborative Design;Collaborative Engineering;Object Process Methodology;Conceptual Design;Interactive Visualisations;Chord Diagram

Topics. 2. Aerospace; 2.4. System Architecture/Design Definition; 3. Automotive; 5.3. MBSE; 5.5. Processes; 6. Defense;

Abstract. Systems Engineering and in the recent decade Model-based Systems Engineering have been widely adopted in the realisation of numerous complex products. Because of a complex system's intrinsic multi-level and multidisciplinary nature, a major challenge presents during the design of the complex product in facilitating the communication between stakeholders of the system who often speak different languages and assume different perspectives, for instance, program owners, architects, engineers and domain experts. An integral collaboration environment between domains and across levels is thus key to achieving efficient and high quality designs.

In this paper, a holistic, inclusive, and interactive design approach is presented. Holistic thinking is a fundamental practice in Systems Engineering that ensures the alignment of domain objectives with overall system objectives as the product matures, however, it is often hindered by the communication gap between system stakeholders. Consequently, we propose a simplified Systems Engineering framework as the basis to model the system using Object Process Methodology (Dori, 2002). Combined with the use of various interactivity and data visualisation techniques, an efficient collaborative design that promotes holistic thinking can be facilitated. Targeting the conceptual design phase, valuable design insights are obtained in our proposed approach that are usually only revealed in the later stages as the system is relatively more mature. As a result, the iteration cycle times during the conceptual design phase can be significantly shortened, well-informed design decisions can be made thereby allowing more accurate direction of resources to perform detailed engineering analyses and subsequent design optimisations.

Paper#123

Case Study: Achieving System Integration through Interoperability in a large System of Systems (SoS)

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Presented on: Wednesday, 17:50-18:30

Keywords. System of Systems;SoS;Constituent Systems;CS;Interoperability;Interoperable;Interface;Systems Integration;System Integration;Emergence;Transportation;Infrastructure

Topics. 12. Infrastructure (construction, maintenance, etc.); 16. Rail; 2.4. System Architecture/Design Definition; 2.5. System Integration; 3.5. Technical Leadership; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.);

Abstract. This paper provides a case study on system of systems engineering (SoSE) being performed in a multi-billion-dollar program, viewed from the systems integration perspective. The paper discusses why the subject program of projects (PoP) can be viewed as a system of systems (SoS), identifies the SoSE challenges faced, describes the SoSE activities performed, and summarizes the achieved outcomes and conclusions as of today.
Specific SoSE challenges discussed include SoS authority, leadership, architecting, collaboration, integration, and emergence. The paper reviews how decision-making in independently operated and managed constituent systems (projects) resulted in unanticipated SoS emergent behavior, which is one of the key challenges in the engineering of SoS.
The paper further discusses the performed SoSE activities, including an international best practice review, the tailoring of SoSE to the specific SoSE challenges, and provides examples where SoSE principles are being applied to perform successful SoS integration.

Paper#58

Comparing INCOSE and PMI Portfolio Management Practices

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Presented on: Tuesday, 17:05-17:45

Keywords. Portfolio management;Best practices;Systems engineering;Project management

Topics. 3.3. Decision Analysis and/or Decision Management; 3.7. Project Planning, Project Assessment, and/or Project Control; 5.5. Processes; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Many organizations use systems engineering and project management practices. In 2011, the International Council on Systems Engineering (INCOSE) and the Project Management Institute (PMI) announced a partnership to better integrate their practices and identified several common practices. This paper focuses on portfolio management by reviewing ISO/IEC/IEEE 15288 and key documentation from INCOSE and PMI. This paper 1) provides an overview of portfolio management; 2) provides insight into portfolio management practices published by each organization; and 3) provides systems engineering organizations areas to enhance their portfolio management practices. We found that out of the total 2,484 reviewed pages, 6.2% contained information on portfolio management. Additionally, PMI's The Standard for Portfolio Management contains the most portfolio management information, while INCOSE's Systems Engineering Body of Knowledge contained the least. We conclude that INCOSE should adapt more of PMI's practices on portfolio management to help systems engineers improve their portfolio management practices.

Paper#114

Complexity, Systems Thinking and an Integrated Systems Engineering and Project Management Model

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Presented on: Tuesday, 16:20-17:00

Keywords. systems thinking;complexity;decision support system;multi-disciplinary;integration;system dynamics;agile;management

Topics. 1.1. Complexity; 1.4. Systems Dynamics; 1.6. Systems Thinking; 13. Maritime (surface and sub-surface); 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Although theory and guiding principles exist for the integration of systems engineering and project management, there does not appear to be a practical approach offered. With unproduc-tive tension, discipline-specific disparate processes and models, and persistent project failures, there is a need for a paradigm shift in the approach to this integration. This shift may be achieved through systems thinking and the use of an integrated management model that includes key link-ages, a decision support system and system dynamics. The model presented in the current study provides a structured approach for multiple disciplines to address and manage product and project complexity through cross-functional processes within an interactive dynamic model environment consisting of system, process and policy levers. The model is validated through application of a case study, literature review, surveys and interviews with industry experts. Use of the model pro-vides for critical thinking and a multi-disciplinary agile approach to help navigate complexity.

Paper#24

Creating a Roadmap to Capture a Vision for a Sustainable Community in Transition; a Case Study in a Dutch town Best

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Presented on: Wednesday, 12:30-13:10

Keywords. roadmap;sustainability;enregy;transition

Topics. 1. Academia (curricula, course life cycle, etc.); 1.6. Systems Thinking; 10. Environmental Systems; 5. City Planning (smart cities, urban planning, etc.); 5.10. Diversity (cultural boundaries, diverse engineering teams, training underserved groups, etc.); 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.);

Abstract. Best Duurzaam is a cooperation that aims to facilitate a transition to a sustainable living at a local level. However, it is missing an overall vision. Additionally, Best Duurzaam would like to have a closer collaboration with the local municipality.
Roadmapping is a planning tool used for framing a vision shared by project participants. It aids in communicating the dynamic relations between group's ideas and accessible resources. A roadmap makes a project approach more specific in both contents and time.
The goal of this study was to investigate how roadmapping could help in solving communication issues. Researchers used roadmapping to understand the issues, to explore solutions and to improve communication. The research was done at municipality level to study the tool's effectiveness in the context of local sustainability transition. The research result suggests that the roadmap is a valuable tool for communication and sharing ideas among stakeholders.

Paper#11

Creating and Applying Total Cost Model: A Case Study at Maritime Company for Last Time Buy Estimation

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Presented on: Monday, 17:50-18:30

Keywords. Obsolescence management;Last time buy;Total cost;Product portfolio;Model

Topics. 13. Maritime (surface and sub-surface); 15. Oil and Gas; 3.9. Risk and Opportunity Management; 4.2. Life-Cycle Costing and/or Economic Evaluation;

Abstract. Kongsberg Maritime (KM) experiences growth in the number of reactive obsolescence events. Time constraints in the decision-making process limit options on how to resolve obsolescence. The total cost trajectory of labor and money consumed to resolve obsolescence is not sustainable for KM going forward.
Last time buy (LTB) is one of many tools in obsolescence management. LTB is attractive because it does not require reengineering, requalification, or redesign. Despite its benefits, LTB should only be used if the total cost of LTB outweighs other alternatives.
In this study a model was created to predict component obsolescence and quantifying the total cost of LTB. The research assumes obsolescence management less effective when dominated by LTBs. By proactively using this model, decision-makers can evaluate alternatives compared to LTB selecting the most cost-effective solution. Feedback from decision-makers confirms a need to have, and willingness to use, the model.

Paper#91

Design Thinking and Systems Engineering to Map Human Needs and Improve Digitization at an Emergency Health Care – a Case Study

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Paper not presented

Keywords. Emergency Care;Health technology;digitization;Design Thinking;Systems Engineering;Pareto Diagram;Empathy

Topics. 2.3. Needs and Requirements Definition; 2.6. Verification/Validation; 4. Biomed/Healthcare/Social Services; 4.1. Human-Systems Integration; 5.7. Software-Intensive Systems; 7. Emergency Management Systems;

Abstract. This study from out-of-hours emergency primary health care investigates methods to improve the digital solutions to become both effective and empathetic. A relatively small inter-municipal emergency care in Norway struggles with high costs and low efficiency. Employees spend a lot of time performing various manual work that is of little benefit to patients. We used the steps from Design Thinking and tools from Systems Engineering to come up with an improved solution. Furthermore, we tested this solution on staff at the emergency room.
The study shows that the current computer tools clearly lack functionality when it comes to meeting the needs of employees such as efficient operation and facilitation for good patient flow. Employees felt that complicated digital tasks steal time that could be better spent on health care. Furthermore, the employees lack a comprehensive overview of systems functionality.
We have proposed several innovative functional improvements, including interaction technology in the form of a wall-mounted work board, which according to the employees will enable streamlining of tasks at the emergency room. These solutions have emerged by using a step by step, iterative and structured system technique inspired by Design Thinking. Extensive interaction with the systems users throughout the project phase has enabled us to clearly understand the challenges of the emergency room and associated solutions. We believe that empathy with the users is essential in innovative digital solution.

Paper#48

Digital Product-Service Systems meet Product Line Systems Engineering – The Cart before the Horse?

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Presented on: Tuesday, 14:00-14:40

Keywords. Product-Services;Product Line Engineering;Feature-based PLE;Digitization

Topics. 18. Service Systems; 2.1. Business or Mission Analysis; 5.6. Product Line Engineering; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. The use of digital technologies opens the door to new business opportunities for traditional product manufacturing companies thanks to the numerous services that these technologies make possible. This trend, referred to as digital transformation, has taken over the business world in recent years. In this new technology-enabled opportunity space, the appropriateness of traditional Product Line Systems Engineering (PLSE) practices can be questioned. This paper addresses the different challenges facing the application of PLSE to product-service systems, including those supported by digital technologies. To meet these challenges, a conceptual framework is proposed to define a structured PLSE approach for Product-Service Product Lines (PSPL). The fundamental concepts behind the framework include a typology of PSPL and specific methods for architecting and engineering the PSPL (more precisely, for managing the variability of the PSPL), and for aligning the business strategies of classical product lines (i.e. tangible, physical product lines) with those of their corresponding, and less classical, service product lines. The authors believe that the proposed framework can help evolve the practice of PLSE and enhance the foundations of Systems Engineering with useful concepts.

Paper#118

Distributed Architecture for Monitoring Urban Air Quality: A Systems Engineering Approach

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

Keywords. air quality;systems engineering;ogc;communication fabric;climatechange;data standardization;data;satellite;monitoring;disaster

Topics. 1.5. Systems Science; 1.6. Systems Thinking; 10. Environmental Systems; 11. Information Technology/Telecommunication; 2.4. System Architecture/Design Definition; 2.5. System Integration; 4.1. Human-Systems Integration; 5.10. Diversity (cultural boundaries, diverse engineering teams, training underserved groups, etc.); 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 7. Emergency Management Systems;

Abstract. The United Nations' environment program has selected the fight against air pollution as the topic for 2019's World Environment Day to raise the awareness of world's population for the fact that 7 million people worldwide die each year due to diseases associated to low air quality (UN Environment 2019) This paper summarizes the result of a project to support the development of a new architecture of global sensing devices for air quality and other earth science challenges. the project goal is to build a multi-resolution unified picture of air quality using existing and potentially new technologies, allowing not only governments, but also scientists and regular citizens to contrib-ute and have access to the information generated. This approach will potentially enhance real-time monitoring and rapid reaction to degraded air quality events, or even better forecast events to take more efficient preventive actions. The project brought together NASA scientists and systems engi-neering students to conduct an initial system engineering analysis to build a high-level system archi-tecture. The effort helped to pave the way for further detailed engineering design and support the development of a testbed for early system verification and validation.

Paper#31

Do Product Lines Have Sweet Spots?

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Presented on: Tuesday, 12:30-13:10

Keywords. Product Line;Control System;Electronic Engine Control;Benefits

Topics. 5.5. Processes; 5.6. Product Line Engineering; 5.7. Software-Intensive Systems;

Abstract. Creating a Product Line should not be undertaken lightly. There are many complexities to consider relative to development of individual products or cloning of existing designs. How-ever, in today's business environment, development of multiple, similar products as individual or clone projects is unsustainable, both from the viewpoint of cost and of availability of suitably skilled engineers.
This paper considers approaches to development of Product Lines in the context of gas turbine engine full authority digital electronic control systems. The Product Line in this paper was created for an existing engine, with new Applications and a new control system for multiple helicopters.
The paper explores the challenges with developing the Product Line and the benefits relative to development of individual products. The benefits are illustrated by an investigation of software cost and schedule metrics for Product Line builds, Application Builds and non-Product Line builds.

Paper#21

Dream the future: Systems engineering in 2030

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Presented on: Wednesday, 14:00-14:40

Keywords. Future;Trends;Process;Method;Tool;Vision;Prospective;Collaboration;Co-engineering;Agile;DevOps

Topics. 2.4. System Architecture/Design Definition; 3.3. Decision Analysis and/or Decision Management; 5.1. Agile Systems Engineering;

Abstract. Based on observations on the evolving context of systems engineering in general, and the perceived consequences for the sector, this document proposes an example of a scenario of evolution and adaptation of engineering to new issues, already emerging or conceivable in the future. It then puts forward a number of capacities to be acquired in order to favor efficient adaptation of engineering to these issues, and outlines some guidelines for changing engineering practices and tools in the face of the coming challenges.

Paper#78

Early Validation of Stakeholder Needs by Applying Co-creation Sessions

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Keywords. Early Validation;Co-creation;Early Phase Systems Engineering;Stakeholder Needs

Topics. 2.1. Business or Mission Analysis; 2.3. Needs and Requirements Definition; 5.1. Agile Systems Engineering; 5.5. Processes; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. This paper investigates the application of co-creation sessions as a method in the early phases of development projects. The target is to do an early validation of stakeholder needs prior to project start. Co-creation sessions engage key stakeholders to share knowledge in collaborative exercises to gain a common understanding of the problem and building a solution landscape. We study three co-creation sessions in early phase development projects by using an industry-as-laboratory approach, interviews and feedback surveys. The co-creation method is based on design thinking techniques, system oriented design and other visual tools. The sessions are facilitated to provide active participation of key stakeholders, achieved by using hands-on activities. The results imply that co-creation sessions contribute to anchor, align and validate stakeholder needs, but do not necessarily elicit stakeholder needs. The study indicates that co-creation sessions increase customer engagement and can potentially lead to new development projects.

Paper#46

Electing User Needs Related to Human Values through Illustrative ConOps - a New-Energy Case Study

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Paper not presented

Keywords. illustrative conops;New energy;human values;hydrogen;offshore wind;design thinking;systems engineering

Topics. 2.3. Needs and Requirements Definition; 4.1. Human-Systems Integration; 8. Energy (renewable, nuclear, etc.);

Abstract. This paper investigates how to better understand end users' human values at an early phase of system design in an innovative new-energy project. By early involvement of end-user, companies can avoid making costly design mistakes that reduce the usability of the system. For the innovative system there were no end-users from where to directly obtain the operational knowledge. The paper has adopted research methods from the Design Thinking process, and uses industry-as-laboratory, conducting in-depth interviews with end-users from related applications. The research focuses on needs that originate from "human values" defined as an expressed emotional feeling addressing how the users perceive the system. The interviews resulted in 105 user needs translated into 17 relevant stakeholder requirements. The results showed that conducting inter-views showing an illustrative ConOps gave 17% more chance of finding needs originating from human values compared to not using this attribute. This research proposes a process for integrating the human values into the early phase of systems engineering.

Paper#25

Emergent Systemic Hierarchies and their Relevance to Project Governance

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Paper not presented

Keywords. Emergence;systemic hierarchies;project governance

Topics. 1.6. Systems Thinking; 2. Aerospace; 3.1. Acquisition and/or Supply; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. The objective of this study is to create an awareness of the emergent systemic hierarchies in the project environment, as well as their relevance to the design of project governance systems. A method is developed to identify the systemic hierarchy associated with the system of interest. The associated hierarchies of enabling systems and the user system are extracted.
The method used to extract the systemic hierarchy stems from systemic characteristics described in the Soft Systems Methodology. A simple metaphor is used to guide the thinking in the extension of these systemic hierarchies.
These resultant hierarchies provide a structured perspective of the levels in each hierarchy, the links between hierarchies as well as the emergent properties at each level in the hierarchy. Utilising the metaphor, specific work associated with each level in a hierarchy may be identified, quantified, and allocated during the initial design phase of a project organisation itself.

Paper#38

Employing Model Based Conceptual Design to Identify Test Range Resources Required to Validate the Delivered Solution

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

Keywords. Modeling and Simulation;Model Based Conceptual Design;Systems Analysis

Topics. 10. Environmental Systems; 2.3. Needs and Requirements Definition; 3.3. Decision Analysis and/or Decision Management; 5.4. Modeling/Simulation/Analysis; 7. Emergency Management Systems;

Abstract. During an initial system concept development, systems engineers will look at different areas of the problem space in order to develop a solution that will satisfy the overall capabilities defined by the stakeholders.
During this phase, the problem space is intentionally left large in order to consider a larger scope of system, targets, and operational environment.
Thus, the SE would like to consider as much of the space as possible to determine what is feasible and infeasible when progressing on to the next phase of system development.
This paper offers an extension of Model Based Conceptual Design (MBCD) to visualize the potential feasible solution space in order to inform decision makers of feasible solutions and test range resources required to validate the delivered solution.
An approach is offered to extend previous research on test and evaluation with MBCD as applied to an illustrative use case.

Paper#102

Engaging Mechanical Engineers in System Modeling

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

Keywords. System modeling;Mechanical engineering;Information exchange

Topics. 2.4. System Architecture/Design Definition; 3.4. Information Management Process; 5.3. MBSE;

Abstract. In Model Based Systems Engineering (MBSE) the system model is used to capture and share Systems Engineering (SE) data and artifacts. Using the model to communicate with the project engineers is found to be more successful with software (SW) engineers than with other domains. As a result, the system model is developed unevenly. This article reports on how a company, whose system model is decisively more detailed in its description of SW sub-systems, might better involve mechanical (and other) engineers in system modeling. Case-based research is applied to understand the company’s challenges. The conclusion is that the challenges originate from failing to consider the differences in how these domains view and relate to a system under development. The research determined that the models developed in the company-specific tool implementation were incapable of producing useful deliverables for non-software engineers. In the absence of a plan for how a mechanical engineer could access information from the model, the authors recommend defining a modeling environment to ensure the necessary contributions from both systems engineers and mechanical engineers.

Paper#113

Establishing a Reference Model for Requirements Elicitation Behavior

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

Keywords. Requirements Engineering;Requirements Elicitation;System Dynamics Modeling

Topics. 1. Academia (curricula, course life cycle, etc.); 1.1. Complexity; 1.4. Systems Dynamics; 1.6. Systems Thinking; 11. Information Technology/Telecommunication; 2.3. Needs and Requirements Definition; 6. Defense;

Abstract. Eliciting the correct requirements for a given product, project or service is crucial for the success of the endeavour. The requirements engineering process in general and the requirements elicitation process, in particular, is fraught with pitfalls. This paper proposes a mechanism that can be used to model the requirements elicitation behaviour that can provide a reference model against which to compare the actual requirements elicitation process and so potentially observe elicitation challenges earlier in the requirements engineering process.

Paper#59

Evaluation of Lean Business Process Improvement Methodology

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Presented on: Tuesday, 17:50-18:30

Keywords. lean business process improvement method;workshop facilitation;systems engineering

Topics. 2. Aerospace; 2.2. Manufacturing Systems and Operational Aspects; 3.5. Technical Leadership; 3.7. Project Planning, Project Assessment, and/or Project Control;

Abstract. Industry trends such as lean manufacturing have proven to work effectively in removing waste and improving the efficiency and effectiveness of production processes in manufacturing companies. The business processes within some manufacturing companies tend to lack the same attention as the production processes, however. This research explored the value of using the in company lean business process improvement (BPI) methodology for improving business processes an aerospace manufacturing company. The method aims to identify and reduce waste by mapping the current state of a selected process, suggest a future state with less waste, generate an action list for changes, and a plan for implementation of the proposals made. During this study, the method showed to be successful at improving the efficiency in 7 out of 8 of the processes adopted. The researcher also found that company employees respond favorably to BPI initiatives but that better preparation prior to each BPI workshop could further improve the effectiveness of the method.

Paper#80

Experiments in Leading through Influence: Reflections from a Group of Emerging Technical Leaders

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Presented on: Tuesday, 17:50-18:30

Keywords. technical leadership;diversity;leadership;Cynefin framework;defense;aerospace;transportation;tech;building;learning;learning together;international;feedback;growth;experiments;complex

Topics. 2. Aerospace; 3. Automotive; 3.5. Technical Leadership; 5.10. Diversity (cultural boundaries, diverse engineering teams, training underserved groups, etc.); 5.9. Teaching and Training; 6. Defense;

Abstract. Technical leadership is a skill defined in the INCOSE professional competencies. This paper presents reflections on a shared learning journey about technical leadership from the perspective of a group of emerging technical leaders. These reflections provide insights around building awareness, navigating power and influence, benchmarking personal performance, developing capacity for change and establishing critical friends. The final section provides lessons for working as a global team in technical leadership. This paper is of relevance to any technical leader looking to develop this capacity across technical sectors.

Paper#53

Framework for Deploying IDS Predictive Models

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Paper not presented

Keywords. cybersecurity;machine learning;intrusion detection

Topics. 1.2. Cybernetics (artificial intelligence, machine learning, etc.); 11. Information Technology/Telecommunication; 2. Aerospace; 2.4. System Architecture/Design Definition; 4.7. System Security (cyber-attack, anti-tamper, etc.); 5.4. Modeling/Simulation/Analysis; 6. Defense;

Abstract. The focus of this paper is the specification of a particular nascent framework for de-ploying a system of nonparametric, feed-forward polynomial neural network (PNN) models that can be used to address intrusion detection system (IDS) deficiencies. The framework is charac-terized by the formal specification in Z notation of black box operations upon which to base the implementation of an event-driven Intrusion Detection Support Software System. The deployment of PNN models to realize the operations within IDS3 shows complementary potential with other techniques in improving the ability and cost-effectiveness of an IDS. The key Intrusion Detection Support Software System operations were derived from a system-level diagnostic concept called abductive diagnostics that is applicable to IDSs (as well as equipment and medical diagnostics). Several experiments were conducted, which are not detailed in this paper, to train and evaluate PNNs using a commercial machine learning algorithm.

Paper#149

General Modeling Language to Support Model-based System Engineering Formalisms (Part 1)

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

Keywords. MBSE;Karma language;formalize;modeling approach

Topics. 1.5. Systems Science; 2.5. System Integration; 3.5. Technical Leadership; 4.1. Human-Systems Integration; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 5.5. Processes; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Model-based systems engineering (MBSE) has been proposed for systems engineering (SE) whereby modeling approaches have been developed to support formalisms of system artifacts. By using traditional MBSE approaches, these formalisms are described by different languages; however, the use of different tools for such languages leads to gaps which result in integration difficulties for various system engineering product views, such as the requirements, architecture, and others. In this study, a textual modeling language is developed based on a graph, object, point, property, role, and relationship approach, known as “Karma,” to formalize models and meta-models. Its main goal is to construct different MBSE languages and their models, and to for-malize the model-transformation and code-generation processes during the entire lifecycle. Based on the Karma language, an MBSE tool is developed to formalize the entire SE approach of products with the use of models, and to support automated model transformation for architecture-driven and code-generation schemes (introduced in Part 2 of this paper series). Finally, we evaluate the fea-sibility of the Karma language with our developed tool MetaGraph with an example which is based on the use of an auto-braking case in an autonomously driven system.

Paper#75

Hatley-Pirbhai Control Flow Diagram with SysML for Early Validation

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

Keywords. Simulation;Execution;Validation;Hatley-Pirbhai;SysML;Control Flow Diagram;Control Specification

Topics. 2.6. Verification/Validation; 3. Automotive; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis;

Abstract. Although CFD/DFD is one of the most used diagrams in the Hatley-Pirbhai (H/P) model-ing method, H/P does not offer the semantics to support the execution capability of behavioral mod-eling. In the cyber-physical systems that operate in an open environment, an executable model is necessary to perform simulation for early phase validation. This study proposes a method for provid-ing the execution capability by improving H/P using SysML with the MBSE Object-Oriented con-text. SysML is supported by the fUML execution engine that has been standardized by the Object Management Group (OMG). With this standardized platform, the simulation results are more precise, consistent, and less ambiguous, which are necessary to perform better validation. The results showed that SysML diagrams maintained model readability and could easily implement the H/P method com-pared to the H/P diagrams. With the SysML model simulation, systems engineers could perform a functional analysis on the feature control logic in the early stages of the system development.

Paper#14

How Systems Engineering and Systems Thinking Enable Innovation

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Paper not presented

Keywords. Systems Thinking;Systems Engineering;Innovation;Incremental innovation;Radical innovation

Topics. 1.6. Systems Thinking; 2.1. Business or Mission Analysis; 2.3. Needs and Requirements Definition; 2.4. System Architecture/Design Definition;

Abstract. There are many significant challenges facing the world, necessitating innovative and effective systems and products to enable a prosperous and sustainable future. However, successful delivery of innovative systems is very difficult. We argue that appropriate application of Systems Engineering and Systems Thinking plays a critical role in ensuring innovations have the best chance of success. Although many innovation methodologies exist, few incorporate the concepts or vocabulary of Systems Thinking in a structured way. This paper attempts to rectify this, by taking some basic innovation concepts and a simple structured approach to thinking about the system and its wider environment, and showing how they can be integrated in order to augment innovation processes with Systems Thinking concepts. Through applying Systems Engineering principles to the innovation context we identify innovation traps that may arise when failing to think about a system in its wider context, and we provide detailed case studies to illustrate our points.

Paper#69

Implementing a Model-Based, Digital Engineering Enterprise for a Defense Systems Integrator - an Ongoing Journey

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Presented on: Wednesday, 12:30-13:10

Keywords. Model-Based Systems Engineering;MBSE;Model-Based Engineering;MBE;Digital Engineering;DE;Systems Engineering;SE;Systems Engineering & Integration;SE&I

Topics. 2. Aerospace; 2.4. System Architecture/Design Definition; 2.5. System Integration; 3.5. Technical Leadership; 5.3. MBSE; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. As the aerospace and defense industry strives to embrace digital engineering transfor-mation, organizations quickly realize that this transformation is much more than just tools or infra-structure. It requires comprehensive change that involves people, process, and technology, and that calls for organizational strategy and stakeholder commitment. This paper provides an overview of an on-going corporate initiative to develop an enterprise-wide, model-based systems engineering (MBSE) and model-based engineering (MBE) capabilities and to instantiate a transformation of legacy workforce and culture. Our vision is to apply digital engineering (DE) as an enabler to transform legacy, document-based development stovepipes into a product-centric, integrated, digital engineering enterprise. At the implementation level, however, it involves a multipronged investment strategy in technology, infrastructure, process, and people, as well as an incremental process of learning and experiments. This paper lays out the architectural vision, implementation approach, and the business rationales. It also attempts to reflect on the journey to date, discussing some of the early successes, hurdles and challenges in implementing the digital engineering initiative for a diverse defense services business.

Paper#10

Implementing Model-Based Systems Engineering for the Development and Support of an Additive-Layer Manufacturing Plant in the Aerospace Context

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Paper not presented

Keywords. MBSE;Additive Layer Manufacturing;SysML;OntoREM

Topics. 2. Aerospace; 2.2. Manufacturing Systems and Operational Aspects; 2.3. Needs and Requirements Definition; 2.4. System Architecture/Design Definition; 5.3. MBSE;

Abstract. One of the revolutionary changes of the 21st century in the aerospace industry is the emergence of Additive Layer Manufacturing or 3D printing technology. This is so for a number of reasons. There is virtually no material waste in the production process. Existing aircraft parts of current designs can be produced in less time and for a fraction of the cost, whilst still meeting the 'form, fit and function' requirements of those existing parts. Modified parts that are stronger and lighter, but which could not previously be produced with traditional manufacturing methods and tools, can be designed. Going even beyond parts, new designs will increasingly be enabled with larger ALM machines that are capable of printing much larger components, which have most of the traditional parts already integrated. This dramatically reduces manufacturing and assembly times and costs, as well as weight, while increasing the level of functional integration inside such components.
This paper reports on the application of MBSE for the development and support of a new ALM Plant in the UK. The establishment of this 'ALM System' followed years of cutting-edge research activities on laser and electron beam powder bed technologies. The requirements for and the solution architecture of the ALM System were developed using various methods and supporting tools, until the final requirements cascade and part of the corresponding system design, down to the level of certain detailed production processes, was modeled in SysML using MagicDraw.

Paper#41

Implementing Systems Engineering in Early Stage Research and Development (ESR&D) Engineering Projects

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Presented on: Tuesday, 14:00-14:40

Keywords. Early stage research and development;Tailoring;Tradeoffs

Topics. 1.6. Systems Thinking; 2. Aerospace; 3.9. Risk and Opportunity Management; 5.2. Lean Systems Engineering; 6. Defense; 8. Energy (renewable, nuclear, etc.);

Abstract. Early Stage Research and Development (ESR&D) is one of the most crucial phases in the design process. It is of interest to Federally Funded Research and Development Centers (FFRDCs), university affiliated Research and Development (R&D) centers, government entities, and public and private commercial enterprises.
This paper explores the topics of whether and when to apply systems engineering (SE) in ESR&D projects, how much SE to apply and how to make that determination, and barriers to implementation with advice on how to overcome them. The authors conclude that applying SE in the early stages of R&D projects is a necessary element of the overall risk management strategy, but that the SE effort must be appropriately tailored to balance investment with value while supporting scalability for future growth.

Paper#103

Integrating Process Standards for System Safety Analysis to Enhance Efficiency in Initial Airworthiness Certification of Military Aircraft: A Systems Engineering Perspective

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

Keywords. Airworthiness certification;System Safety;Aircraft System Safety;System Safety Analysis;System Safety Standards;ISO/IEC/IEEE 15288:2015;EMAR 21;MIL-STD-882;SAE ARP4761;SAE ARP4754

Topics. 2. Aerospace; 2.5. System Integration; 3.3. Decision Analysis and/or Decision Management; 4.6. System Safety; 6. Defense;

Abstract. When designing an aircraft, a System Safety Analysis (SSA) is an important part of the initial air-worthiness certification. For military aircraft, this this requires not only a process to determine whether the analyzed system is safe enough, but also a process to identify an acceptable balance between safety, cost and military capability. In this paper, standards for performing the SSA, mainly for civilian aircraft, have been analyzed for their relevance to certifying military aircraft. Also, the systems engineering standard ISOI/IEC/IEEE 15288:2015 have been analyzed for its applicability to integrate SSA with other activities in a military aircraft project. The purpose of the presented work is to analyze how these processes relate and how they can be combined to create an effective and efficient process for developing and certifying aircraft in accordance with the EMAR 21 requirements for military design organizations.

Paper#61

Interface Management – the Neglected Orphan of Systems Engineering

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Presented on: Wednesday, 12:30-13:10

Keywords. Interfaces;Architecting;Management;Lifecycle;Stakeholders

Topics. 16. Rail; 2. Aerospace; 2.4. System Architecture/Design Definition; 2.5. System Integration; 3.3. Decision Analysis and/or Decision Management; 6. Defense;

Abstract. Every Interface is an opportunity to lose information, time, control and / or money through contention between stakeholders at either end. There are many issues surrounding Interface management, which are relatively unexplored in the engineering literature. Interface management is perceived as a critical skill in the engineering of successful systems, but finding useful material on the subject proves elusive. It is not that there is a gap in the collective Body of Knowledge (BoK) – but there is definitely a gap in the documented BoK. This paper explores some of the characteristics of this gap, and strings together some of the key concepts in best practice. Along the way, the differences between best practice for interfaces and best perceived practice for architecting systems are noted, and recommendations for changes in approach are given.

Paper#133

Investigating Organization Attributes that Support Systems Engineering Workforce Effectiveness

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Keywords. Helix;Organization;Culture;Governance;Systems Engineering workforce;Effectiveness

Topics. 3.5. Technical Leadership; 4.5. Competency/Resource Management; 5.10. Diversity (cultural boundaries, diverse engineering teams, training underserved groups, etc.); 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. This paper describes a multi-year effort to understand the attributes of organizations that support systems engineering workforce effectiveness. Using a combination of surveys, interviews, and commercially available culture assessment tools, the research identifies key components of organization culture, structure, governance, process, and tools that enable systems engineers to deliver value in industry and government contexts in the United States and Europe. The results can be used by people to improve effectiveness in their own organizations and to stimulate discussion and action to support effectiveness across the profession.

Paper#6

Investigation of Humanmade Climate Change; A Study Utilizing The Systems Thinking Approach

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Paper not presented

Keywords. Global warming;Manmade emissions;Causal loops;Systems thinking

Topics. 1. Academia (curricula, course life cycle, etc.); 1.6. Systems Thinking; 10. Environmental Systems; 8. Energy (renewable, nuclear, etc.);

Abstract. The emission due to the way human lifestyle have evolved over the centuries have led to one of the most complex and difficult issue the human species have ever met: Manmade climate change. The issue of global warming can ultimately lead to consequences which will significantly damage the world as we know it. The goal of this paper is to study the problem of global warming by utilizing tools from systems thinking, by applying analysis on the stakeholders connection to the issue and the relations existing inside the complex system, to enable the development of solutions which are applicable to negate the problem at hand.

Paper#54

Is petroleum activity in the marine areas of Lofoten, Vesterålen and Senja desirable for Norway? – a case study in the oil and gas industry

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Paper not presented

Keywords. Systems Thinking;LoVeSe;Lofoten;Vesterålen;Senja;Stakeholder Analysis;Oil and Gas;Perspective;Systemigram.

Topics. 1.1. Complexity; 1.3. Natural Systems; 1.6. Systems Thinking; 13. Maritime (surface and sub-surface); 15. Oil and Gas; 8. Energy (renewable, nuclear, etc.);

Abstract. The discussion concerning petroleum activity in the marine areas of Lofoten, Vesterålen and Senja (LoVeSe) has characterized the Norwegian oil debate for many years. On one side you have the ones supporting Environmental Impact Assesment (EIA) (an assessment which by law has to be conducted prior to opening an area for petroleum activities) and subsequent opening for petroleum activity in the area. On the other hand, you have the ones supporting the current state in LoVeSe – to keep the untouched, spectacular nature closed for petroleum activities. This paper seeks to give insight into the discussion by describing both parties perspectives by the means of system thinking and system thinking tools. A stakeholder overview showing the main stakeholders key interests in the discussion, in addition to systemigrams illustrating their perspectives has been made.

Paper#148

Linking Behaviour Data to Knowledge: Contextualization and De-Contextualization

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

Keywords. Contextualization and de-contextualization;Linking behaviour data to knowledge;Modelling black-box observable behaviour;Occurrence Type DAG;Knowledge frames;Systems science view of system modelling;Knowledge management

Topics. 1.5. Systems Science; 5.3. MBSE;

Abstract. Sensor informatics provides extensive data about system behaviour, which we would ideally like to link to system models and the underlying knowledge. The nature of systems knowledge formation is that we observe the behaviour of particular systems in their context, and incrementally de-contextualize it to arrive at formal knowledge. Conversely, the nature of engi-neering synthesis is that we develop and reason about the behaviour of system configurations by identifying and combining all the knowledge applicable to that particular configuration and context i.e. by successive levels of contextualization.
This systems science paper proposes a conceptual framework for linking knowledge, system models and behaviour data. It inquires into the levels of system description involved, and the relationships between the levels that drive contextualization and de-contextualization. We propose organizing knowledge about individual entities and interactions into type knowledge frames, complemented by patterns and other knowledge related to configurations. We use assume-guarantee concepts to for-mulate self-contained type knowledge frames with internal consistency relationships between structures, interactions and behaviours. We suggest how observations data can be abstracted into observable behaviour models. Together, these insights point towards the possibility of tooling sup-port for populating knowledge frames, and creating bi-directional relationships between behaviour data, system models and domain knowledge, based on contextualization and de-contextualization.

Paper#87

Managing Integration and Verification Risks of the SKA Radio Telescope

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Presented on: Monday, 16:20-17:00

Keywords. Integration;Verification;Validation;Risk;SKA;Radio Telescope;MeerKAT

Topics. 11. Information Technology/Telecommunication; 2.5. System Integration; 2.6. Verification/Validation; 3.9. Risk and Opportunity Management; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. The Square Kilometre Array (SKA) project is an international effort to build the world's largest radio telescope (SKAO 2020). A brief overview of the SKA project is provided, outlining some of the major challenges that such a project needs to manage. These challenges give rise to risk, which could lead to schedule delays, cost overruns and degraded performance of the final system. This paper describes how the integration and verification (I&V) of this radio telescope has been planned, and how the objective of mitigating risk has been an underlying motivation throughout this planning effort.

Paper#157

Mechanisms for a Systems-Oriented Mindset - Towards Organizational Systems Thinking

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

Keywords. Systems thinking;Organizational transformation;Communication mechanisms;Systems-oriented mindset

Topics. 1.6. Systems Thinking; 3.5. Technical Leadership; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. The paper examines a set of related questions regarding the capability of organizations with decentralized, project-focused life cycle processes and fragmented system perspectives to manage complex systems: how can communication-focused mechanisms for envisaging, visualizing, and analyzing the system support a shift towards a systems-oriented mindset in the organization, and; to what extent does a shift in mindset improve organizational capabilities when hierarchy, process framework, and governance model of the organization remain fixed and suboptimal? The central hypothesis explored is that a shift in mindset within the organization, by focusing on the means and ways of communication about the system, can bridge gaps and fragmentations of system perspectives and improve organizational systems thinking capabilities without a need for urgent and drastic or-ganizational actions. A toolkit of 18 mechanisms was developed to support the transformation pro-cess from six identified and analyzed problem domains to corresponding solution domains. Results were promising, with several signs of a shift in mindset; however, the long-term effects on the overall organizational capability remain uncertain.

Paper#142

Model Integrated Decomposition and Assisted Specification (MIDAS)

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Presented on: Wednesday, 16:20-17:00

Keywords. requirements;ears;clear;opm;intent;abstraction;model-based

Topics. 1.6. Systems Thinking; 2. Aerospace; 2.3. Needs and Requirements Definition; 5.3. MBSE;

Abstract. MIDAS (Model Integrated Decomposition and Assisted Specification) is an innovative new approach to requirement specification. By integrating textual and intent-based model-assisted requirement flows, MIDAS presents a paradigm shift from prior model-based and traditional textual requirement processes. Such a shift is necessary to address the full intent of design assurance. MIDAS has been conceived to address many of the challenges that we have observed in the application of the current model-based certification guidance. The principal issue with the interpretation of the guidance is a misplaced focus on the separation of graphical vs. textual specification rather than clean and clear separation of design from intent. Hence, this aspect forms the core of our proposed MIDAS approach. Our intent-based focus also mitigates the often implementation-centric perspective of model-based requirement flows. Our hybrid model-based constrained language flow also addresses the weakness of informal natural language-based specification. Finally, MIDAS facilitates the integration of knowledge management with requirement engineering, allowing for the full context of the requirement to be easily and formally captured. By writing this paper, we share our observations and ideas openly to encourage feedback and collaboration with potential development partners.

Paper#101

Model-Based System Engineering for Life Cycle Development of Digital Twins of Real Estate

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Presented on: Wednesday, 13:15-13:55

Keywords. Cyber Physical Systems;Asset;Internet of things;Digital Twins;Building Information Modelling;Digital Twins of Real Estate;Systems Architecture;Systems Engineering;Model-Based System Engineering;Digital Engineering

Topics. 12. Infrastructure (construction, maintenance, etc.); 5. City Planning (smart cities, urban planning, etc.); 5.3. MBSE; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.);

Abstract. The evolving complexity of today's Smart City challenges requires agile systems that can deliver quick, real-time insight into as-built assets to all stakeholders. Cyber-Physical Systems (CPS) or digital twins hold promise to enable interconnected, data analysis of as-built assets throughout the lifecycle of the asset. In the real estate industry, a vision is emerging to develop Digital Twins of Real Estate (DTREs) – being dynamic, virtual data models of real-world assets that aggregate all infor-mation on the asset and provide continuous feedback via a single, 3D dashboard. Key technologies in use include Internet of Things (IOT) technology, Artificial Intelligence (AI) processes and Machine Learning (ML). A DTRE enables stakeholders to better understand, predict and optimize perfor-mance of the real-world asset throughout its lifecycle.

In practice, most as-built assets are not in digital, data model format and owners and managers are faced with distributed information sets and analytical tools. ISO 19650 (Part 1 and 2) guides the Architectural, Engineering and Construction (AEC) industry in Building Information Modelling (BIM) and management processes to deliver data models during the design and build phase. There is no formal process to guide DTRE development and limited, published case studies to demonstrate the business case.

This paper presents a first Model-Based System Engineering (MBSE) framework for the AEC in-dustry to guide development of DTREs. The framework was compiled by synthesizing the author's experience, the traditional System Engineering (SE) vee diagram, ISO 19650 and reverse engineer-ing available case studies. The paper concludes with a recommendation to develop case studies of different nature to validate the proposed MBSE framework.

Paper#126

Models as enablers of agility in complex systems engineering

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

Keywords. mbse;agile;incremental;case study;models

Topics. 2.4. System Architecture/Design Definition; 5.1. Agile Systems Engineering; 5.3. MBSE;

Abstract. Complex systems engineering programs not only deal with the inherent complexity of the systems they develop, they also face shorter time-to-market, increasing changes in environments and us-ages, and more sophisticated industrial schemes. The ability to adapt to new circumstances, or agility, becomes mandatory. In this paper we present how Model-Based Systems Engineering (MBSE) approaches can be enablers of the implementation of agility in complex systems engi-neering programs. Known to provide additional engineering rigor and quality, MBSE also brings key concepts favoring agility and co-engineering.

Paper#127

Modernization Challenges of Command and Control Systems

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Presented on: Tuesday, 13:15-13:55

Keywords. System Modernization;Command and Control Systems;Legacy Systems

Topics. 1.5. Systems Science; 2.5. System Integration; 4.5. Competency/Resource Management; 6. Defense;

Abstract. Today's missions are more complex and more dynamic, requiring significantly increased capabilities and efforts. Governments aim to modernize command and control systems to address these operational needs. Also, maintaining of these huge systems are challenging, obsolescence problem makes modernization inevitable. On the other hand, the managing legacy systems and their upgrades are difficult. This paper investigates the difficulties of the legacy system modernization on command and control domain. We performed Systematic Literature Review (SLR) to extract system modernization challenges from the literature.

Paper#49

Patterns for Success in the Adoption and Execution of Feature-based Product Line Engineering: A Report from Practitioners

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Presented on: Tuesday, 13:15-13:55

Keywords. Feature-based product line engineering;Organizational change;Patterns for adoption

Topics. 3.5. Technical Leadership; 5.6. Product Line Engineering; 6. Defense;

Abstract. Systems and Software Product Line Engineering (PLE) is a general approach to engineer a portfolio of related products in an efficient manner, taking advantage of the products' similarities while respecting and managing their differences.
The approach manages a product portfolio as a single entity, as opposed to a multitude of separate products. Numerous resources describe the or-ganizational benefits associated with incorporating PLE techniques and tools. Feature-based System and Software Product Line Engineering is a specific form of PLE that is powered by commercial off-the-shelf automation, fully defined processes, and a formal language of variation based on fea-tures.
Many case studies show the efficacy of Feature-based PLE and the improvements in cost, schedule, and quality that can come with it.
In this paper, practitioners from four of world's six largest defense companies highlight their experience with the practices that enable and inhibit success with this powerful engineering discipline.

Paper#104

Pervasive Simulation in a PLM Platform – The key to effective management of ever-increasing product complexity

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Presented on: Tuesday, 17:05-17:45

Keywords. Simulation;Systems Thinking;PLM;SPDM;Digital Thread;Systems Model

Topics. 1.6. Systems Thinking; 14. Autonomous Systems; 2. Aerospace; 3. Automotive; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 5.5. Processes; 6. Defense;

Abstract. Companies invest in new approaches to manage the ever-increasing complexities of products and systems being designed today, and more importantly, those that will be designed to-morrow. These involve methodologies, tools, and the underlying platforms that support enter-prise-wide integration of these methodologies, tools, data models, and design flows.
Simulation is a critical part of this investment. Unfortunately, simulation remains stubbornly stand-alone and isolated. For the most part, simulation solution users and tool vendors have focused on automating the simulation process for the individual design phases but not for the entirety of the product's lifecycle that starts with gathering of requirements and ends with deployment of the assets in the field.
This paper demonstrates how an appropriate vision for providing simulation as a pervasive tool, available on-demand within a comprehensive PLM platform (Product Lifecycle Management), al-lows users to resolve these limitations. This is particularly critical today as PLM platforms are be-ginning to shift to the cloud.
The goal of this paper is not to lay out a scientific theory, but to provide a practical example of a challenge solved through a best practice. The authors have worked and communicated with many OEMs that are all facing a similar set of challenges. These challenges are quite well-known and
hence the authors do not think it is necessary to take up room documenting them in this paper – we think it is more important to document/present a vision for a real-world, working solution.

Paper#121

Preparing the Acquisition Workforce: A Digital Engineering Competency Framework

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Paper not presented

Keywords. Digital Engineering;Competency model;Model Based Systems Engineering (MBSE);Acquisition workforce

Topics. 3.1. Acquisition and/or Supply; 4.5. Competency/Resource Management; 5.3. MBSE; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. This paper describes the goals, methods, approaches, and preliminary results of research to develop a Digital Engineering Competency Framework (DECF) for the acquisition workforce. Evidence across the Services and industry has affirmed digital engineering is a critical practice necessary to support acquisition in an environment of increasing global challenges, dynamic threats, rapidly evolving technologies, and increasing life expectancy of our systems currently in operation. The purpose of the DECF is to provide clear guidance for the DoD acquisition workforce, in particular the engineering (ENG) acquisition workforce, through clearly defined competencies that illuminate the knowledge, skills, abilities, and behaviors required for digital engineering professionals.

Paper#43

Putting the “Systemic” (back) into the “Engineering of Systems”

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Presented on: Tuesday, 12:30-13:10

Keywords. Systems Thinking;Modelling;Simulation;Efficiency and Effectiveness;Systems Engineering;Conceptual Design;Functional Architecture;Physical Architecture;SE Life-Cycle

Topics. 1. Academia (curricula, course life cycle, etc.); 1.6. Systems Thinking; 10. Environmental Systems; 2. Aerospace; 2.3. Needs and Requirements Definition; 2.4. System Architecture/Design Definition; 3.1. Acquisition and/or Supply; 3.5. Technical Leadership; 4. Biomed/Healthcare/Social Services; 5.5. Processes; 6. Defense; 8. Energy (renewable, nuclear, etc.);

Abstract. The motivation for this paper is to rejuvenate and elevate Systems Engineering from a systematic process to a methodology for systemically engineering systems. It is broadly structured into four parts. The first introduces three key systemic concepts - Systems Thinking. Modelling and Simu-lation - as foundational pillars of Systems Engineering. The second describes a model of how we as humans perceive and create our reality, defining two orthogonal and complementary concepts - Efficiency and Effectives. The third describes a “typical” Systems Engineering life-cycle as a systematic process as a contextual reference frame for the subsequent, and central, fourth part of this paper. The fourth part then integrates the systemic concepts described in the first part, inter-weaving this into the two-dimensional framework of efficiency and effectives described in the second part, back into the Systems Engineering life-cycle outlined in the third part, highlighting the systemic aspects of the process and the central role of systems engineers in the creation of critical capability. This is followed by a conclusion and recommendations for future consideration.

Paper#35

Reverse architecting conventional footwear. Towards an A3 Architecture Overview that supports development of alternative footwear architectures.

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Presented on: Monday, 13:15-13:55

Keywords. Reverse Architecting;A3 Architecture Overview;Footwear;Development;Health

Topics. 1.3. Natural Systems; 1.6. Systems Thinking; 2.4. System Architecture/Design Definition; 4. Biomed/Healthcare/Social Services;

Abstract. The architecture of contemporary footwear is the result of a long history of footwear development. In this history, part of the argumentation behind the architecture has been lost, causing footwear developers to make decisions based on habits and badly underpinned assumptions. New insights on the negative influence of most conventional footwear on human (foot) health and the design freedom that arises from modern manufacturing techniques, create the urge to reconsider the common way of developing. By reverse architecting conventional footwear, this paper derives an A3 Architecture Overview of conventional footwear. In the future this overview should provide a tool for enabling product evolution towards healthy footwear, by allowing developers to consciously and purposefully deviate from 'the standard architecture' while taking into account the consequences of design decisions they make. The approach that is described in this paper is also applicable to the development of architecture overviews for other product families.

Paper#115

Risk and Opportunity Management for Project Selection in the Road Construction Industry

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Presented on: Monday, 17:05-17:45

Keywords. Risk management;Construction project;Project selection;systems engineering

Topics. 12. Infrastructure (construction, maintenance, etc.); 2.1. Business or Mission Analysis; 3.9. Risk and Opportunity Management; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Road Construction projects failing to meet deadlines or budget costs puts burden on the construction company. The consequence may be economically unprofitable projects that significantly weaken the company's financial performance. To avoid unnecessary use of resources, the companies must identify and filter out unprofitable projects as early as possible. This paper lays out a process for use with road construction companies to improve their ability to choose profitable projects. The focus is on active management of risk and opportunity in the pre-selection phase.
The research is based on a case study at a road construction company. We interviewed key personnel to understand their main needs. We validated the proposed solution through a survey of nine employees at the same company.
Our research resulted in a new method targeted to guide construction companies through the project selection process. The developed process flow illustrates the sequence and interaction of the different process stages. The risk and opportunity process is complemented with a check list, a risk and opportunity register, and the associated risk and opportunity matrix.

Paper#122

SKA Maintenance and Support Modeling

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Paper not presented

Keywords. Reliability;Availability;Maintenance;Health & Condition Monitoring;digital twins;Modelling;Simulation

Topics. 1.6. Systems Thinking; 2.3. Needs and Requirements Definition; 2.4. System Architecture/Design Definition; 3.4. Information Management Process; 4.2. Life-Cycle Costing and/or Economic Evaluation; 4.3. Reliability, Availability, and/or Maintainability; 5.4. Modeling/Simulation/Analysis; 7. Emergency Management Systems;

Abstract. The availability requirement for the SKA telescopes will have a major impact on the design, capital and operating costs. The design-for-reliability, maintainability, maintenance planning and performance expectations should be well balanced.
Engineering analysis indicates that the SKA telescopes should have an inherent availability of 99% and both telescopes are required to have an operational availability of at least 95%.
This paper discusse the availability and support challenges of building and operating two telescopes in Australia and South Africa. It describes the approach to the critical design review of the system, with a special focus on simulation modeling and sensitivity analysis.
It also discusses the use of failure data from the precursor telescopes and gives technical insight into the development of a digital twin for decision making.

Paper#32

Synergetics as a Systems Theoretical and Methodological Lens in Structuring Energy Poverty

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Keywords. energy poverty;synergetics;complexity;emergence;wicked problems

Topics. 1.1. Complexity; 1.5. Systems Science; 1.6. Systems Thinking; 8. Energy (renewable, nuclear, etc.);

Abstract. Energy poverty, as part of the energy trilemma, remains a global challenge in the 21st century. More than 1.7 billion people remain without access to modern energy sources while more than 3 billion people rely only on fossil fuel resulting in negative health and environmental impacts. While admittedly modern biomass fueled energy systems benefit from newer technologies their use is still blamed for detrimental effects on social, economic and environmental aspects of human existence. No wonder then that in many parts of the world distributed renewable energy systems show promise in addressing some of the more important issues of energy access challenges, particularly energy poverty and fuel poverty; this is specifically evident in the global south through improved efficiency, effectiveness, access and quality of energy services. Nevertheless, understanding the complexities and subsequent structuring of energy poverty becomes a complex systems issue since energy technology plays a dual role in enhancing and inhibiting energy access. This paper, borrowing from systems thinking theory, applies a synergetic elements framework where the authors attempt to enhance the comprehension and structure of the wicked problem of energy poverty; this is done by developing a conceptual model. The paper continues by showing the critical role played by interactions between socio-technical system elements, notably those between soft and hard systems. This includes energy poverty depicted in multiple and complex synergetic subsystems, micro and macro elements, exogenous and internal barriers, control parameters and the environment.

Paper#55

Systems and Software Interface Survey

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Paper not presented

Keywords. Systems-software;Interfaces;Best practices;Challenges

Topics. 1. Academia (curricula, course life cycle, etc.); 5.7. Software-Intensive Systems; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. INCOSE formed the Systems and Software Interface Working Group (SaSIWG) in 2017, in response to Corporate Advisory Board interest in software, and problems identified in the systems and software interface (physical, logical, data and human). This third SaSIWG paper presents the results of a survey of systems engineers, software engineers, and project managers as to what are best practices and what are the priority challenges related to the interface between systems and software. The best practices mentioned by the 31 interviewees are grouped and summarized, followed by information on priority challenges and problems. Systems engineering must be done well, and that includes an ever-increasing amount of Model-Based Systems Engineering. It also includes developing and holding to a vision, addressing data, ensuring inter-disciplinary work, planning systematic verification, and ensuring modularity. Systems Engineering must evolve to meet new challenges and most important, the expertise of systems engineers must include software engineering.

Paper#162

Systems Engineering as a Data-Driven and Evidence-Based Discipline

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Presented on: Wednesday, 13:15-13:55

Keywords. Data Driven; Evidence Based; Data analytics; Modeling and simulation; Model based system engineering

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

Abstract. Data and information are considered today as the “new oil” or the “new gold” in almost all aspects of life and economic domains, such as industry, healthcare, education, entertainment and more. The so-called 4th Industrial Revolution is based on the digital transformation derived from the Big Data revolution, through the capability of storing huge amounts of data and performing very sophisticated analytics.
In this paper, we present opportunities for Systems Engineering (SE) to evolve towards a da-ta driven and evidence-based discipline, thereby making better systems and engineering decisions. We discuss how systems engineers can apply data-driven characteristics through systems engineering processes and programs. The classical Model Based Systems Engineering (MBSE) approaches are presented here as powerful tools to collect, generate, and analyze data on systems under development. In addition, the “Digital Twin” concept is presented here in the context of system design. We highlight the challenges for systems engineering to become an evidence-based discipline. Moreover, we emphasize research and development in systems engineering processes using statistical techniques in the design and analysis of systems testing, and Model Based Systems Engineering (SE) as a source for evidence-based engineering decisions. The success of data driven SE in organizations depends on the information and data analytics infrastructure in these organizations. An information quality framework is proposed for evaluating organizational information infrastructure. In addition, it is proposed to assess the data analytics maturity level in organizations. The level of data analytics is the basis for planning implementation programs of data-driven and evidence-based systems engineering. The paper concludes with a case study based on a real-life complex project, and lessons learned for effective data analytics implementation.

Paper#63

Systems Engineering Evidence in Commercial Kitchens

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Paper not presented

Keywords. Non-typical applications;systems thinking;architecture

Topics. 1.6. Systems Thinking; 19. Very Small Enterprises; 2.3. Needs and Requirements Definition; 2.4. System Architecture/Design Definition; 5.9. Teaching and Training;

Abstract. INCOSE has expressed interest in the application of systems engineering principles and practices in industries outside of the classic aerospace, communications, and other large system developments commonly related to the discipline. In this case, a visit to the kitchen at the Inn at Little Washington triggered thinking about how and why it was so different from other commercial kitchens. The resulting analysis of how systems engineering has significant relationship to the design of a wide variety of commercial kitchens is provided in this paper. The objective is to learn how we can see systems engineering in places it isn't normally found to both find other ways it can be applied and to help others improve their results by using systems engineering discipline.

Paper#68

Systems Engineering Issues in Microgrids for Military Installations

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Presented on: Wednesday, 14:00-14:40

Keywords. Microgrid;Department of Defense;Military;Critical Infrastructure

Topics. 12. Infrastructure (construction, maintenance, etc.); 4.3. Reliability, Availability, and/or Maintainability; 4.4. Resilience; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 6. Defense; 8. Energy (renewable, nuclear, etc.);

Abstract. This article investigates the systems engineering issues involved in the design of microgrid systems for military installations.
A review of how microgrids function including major system elements is provided from a systems engineering perspective for non-microgrid experts.
Specific issues that systems engineers are beginning to address and that remain to be addressed are high-lighted. The activities of the INCOSE Critical Infrastructure Protection and Recovery (CIPR) Working Group demonstrate the growing importance of systems engineers to addressing microgrid issues. The increasing interest within the US Department of Defense in improving microgrids on installations shows the need to address issues that are specific to military microgrids.

Paper#13

Systems Engineering the Conditions of the Possibility (Towards Systems Engineering v2.0)

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Paper not presented

Keywords. systems engineering version 2.0;adaptable systems;agile-systems

Topics. 1.5. Systems Science; 2.4. System Architecture/Design Definition; 5.1. Agile Systems Engineering;

Abstract. Traditional systems engineering focus is on cause and effect. When we turn a wheel, pull a lever, or flip a switch we expect a certain outcome. This is a rules-based approach where stimulus-response is deterministic in a well-defined, well-bounded, finite, and predominantly static system. If there is any deviation from expected, there are simple systemic structures (logic gates) or simple rules (if-then-else) to provide optional courses of preplanned action. Human intervention provides the in-telligence and action necessary for dynamic adjustment to a negative event (adversity, avoid loss); or, to detect and dynamically adjust to a positive event (opportunity, seek gain). The now and future discipline of systems engineering (SE v2.0) has the tools to transcend cause-effect and effectively embrace the nondeterministic, flexibly defined, blurred-boundaries, highly combinatorial if not infi-nite, and adaptability. Systems engineers can design solutions to adapt to predictable and unpredict-able change in order for the system to remain viable in the face of adversity (loss-driven) and relevant in the face of obsolescence (opportunity-driven). In addition to cause and effect, SE v2.0 is systems engineering the conditions of the possibility.
The intent of this paper is not provide answers, but to provide a framework from which to discern better questions and elicit research in the many technical areas that provide for continual dynamic adaptation of complex socio-technical systems of systems. Realizing SE v2.0 will come from the hard work of many over years. We are already on the way with this being one more step toward formalizing a new discipline.

Paper#72

Systems of systems ontology in practice

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Paper not presented

Keywords. System of Systems; Collaboration;Ontology; Architecture Framework;Systems Engineering Standards;System Safety

Topics. 14. Autonomous Systems; 2.4. System Architecture/Design Definition; 3. Automotive; 3.7. Project Planning, Project Assessment, and/or Project Control; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. This paper explores possibilities for collaboration between two companies that share interest in a System of Systems (SoS). Although traditional architectural frameworks and standards are applicable, there has been little work presented of how they can be used for collaboration by a practician. As a response to this an anonymous working group established a proposal for an ontology that could support collaboration in the context of directed SoS and acknowledged SoS. This ontology is evaluated in the paper, first by a mapping of terms used in product development to test the ontology terms. Then the ontology is further explored with an example of how it could be used in architecture work in relation to directed SoS, specifically from a system safety aspect.

Paper#138

Systems Theory: Bridging the Gab Between Science and Practice for Systems Engineering

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Paper not presented

Keywords. Systems Theory;Systems Science;Systems Engineering

Topics. 1. Academia (curricula, course life cycle, etc.); 1.1. Complexity; 1.5. Systems Science; 1.6. Systems Thinking; 17. Sustainment (legacy systems, re-engineering, etc.);

Abstract. This paper explores Systems Theory (ST) contributions to improve the Systems Engineering (SE) discipline and practice. Recently, INCOSE has recognized that ST can provide a valuable theo-retical and conceptual foundation to better ground the evolving SE discipline. At a fundamental level ST can be described as a set of axioms (taken for granted truths about systems) and propo-sitions (principles, concepts, and laws that explain system behavior, structure, and performance) with a basis in the underlying science of systems. Our purpose is to bridge the gap between Systems Science and SE by exploring the practical implications for ST to improve both the SE discipline and practice. Following a short introduction to ST in the context of the SE discipline challenges, two primary objectives are pursued: (1) overview and positioning of ST for contribution to SE devel-opment, and (2) examination of articulation of ST axioms and associated propositions and their implications for enhancing SE practice. The paper closes with suggestion of the reciprocal con-tributions for SE and ST as well as the enhancement of SE to deal more effectively with increas-ingly complex systems and their problems.

Paper#29

The Capability to Engineer Systems is a System Itself!

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Paper not presented

Keywords. Capability;Architect;Complex;Organization

Topics. 1.1. Complexity; 1.6. Systems Thinking; 2.4. System Architecture/Design Definition;

Abstract. Systems Thinking can be applied to anything.
This paper explores an important application of Systems Thinking - to identify the capability needed by an organization to engineer products and services and so produce value for its customers and for the enterprise.
The work draws upon work in the authors' company to develop and deliver the engineering capability necessary for the business context.
It draws upon the ideas of capability, but adapts them to the idea of the effect of the capability being used to produce systems.
The issue is the understanding of the capability needed to engineer capability as a system, and how that understanding can be used to both ensure capability is complete and can be prioritized. Recent experience in identification and prioritization of capability needs in the authors' organization is explored in this paper.

Paper#76

The Greatest Young System Engineers of the Year Challenge

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

Keywords. Youth outreach;Professional development of young graduate system engineers;Training system engineers

Topics. 5.10. Diversity (cultural boundaries, diverse engineering teams, training underserved groups, etc.); 5.9. Teaching and Training;

Abstract. In 2015 the Greatest Young Systems Engineers of the Year Challenge was launched as part of the INCOSE SA annual conference. This annual challenge has now occurred five times from 2015 through 2019/20 with a total of 84 contestants from nine employer companies. This paper summa-rizes the results and explains the lessons learnt.

Paper#129

Top-down functional composition

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Presented on: Wednesday, 17:50-18:30

Keywords. Functional composition;Design integration;MBSE

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

Abstract. The functional decomposition methodology forms the basis for how to design system behavior in the systems engineering literature. Unfortunately, this design approach has inherent weaknesses that does not allow for requirement sets to be both complete and design agnostic, both of which are considered necessary characteristics for good requirement sets. In practice, it is also difficult to design the behavior of complicated systems using functional decomposition since a large portion of the design challenge must be handled up-front.
This paper introduces a top-down functional composition methodology approach to behavioral design. The paper argues that the presented methodology does not have the shortcomings associated with functional decomposition and that it also enables early and continuous integration of design, test of design and validation of design. Therefore, this approach is more beneficial for engineering design of complicated systems, especially when model based systems engineering (MBSE) is applied.

Paper#154

Toward a Probabilistic Risk Assessment (PRA) Method for Assessing Mishaps in Legacy Systems Using Mishap Reports

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Keywords. systems safety - mishap reports - mishap modeling

Topics. 3. Automotive; 3.9. Risk and Opportunity Management; 4.1. Human-Systems Integration; 4.6. System Safety; 6. Defense;

Abstract. There is a significant delta between the acknowledged probability of potential mishaps un-der the current safety assessment approach derived from Military Standard 882E (MIL-STD-882E), Department of Defense Standard Practice of System Safety, and what is observed from actualized mishaps being reported. When assessing systems safety during the design process, the approach used in MIL-STD-882E simplifies the mishap scenario by assuming a single initiating mechanism. By decomposing mishap reports from legacy sys-tem, common failure modes have been identified that were not adequately assessed under the current process. Each of the mishap reports assessed identified more than one initiating mechanism. As such, this work suggests a greater mishap probability than was originally acknowledged. To address the current limitation, this work develops (1) an approach for decomposing mishap scenaios, (2) a method for systematically implementing the mishap decomposition on a system, and (3) characteristics for an improved systems safety method.

Paper#12

Toward Architecting the Future of System Security

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Presented on: Monday, 17:50-18:30

Keywords. system security engineering;security architecture;cybersecurity;system security

Topics. 1.5. Systems Science; 2.4. System Architecture/Design Definition; 4.7. System Security (cyber-attack, anti-tamper, etc.);

Abstract. Cybersecurity is not just a technical decision regarding cost, benefit, and performance. Cybersecurity interweaves with civil liberties (opting out of the digital world), privacy (the right to be unobserved and the right to be forgotten), automated resolution of moral dilemmas (autonomous vehicle choosing who to hit), financial security (wealth representation being bits on a hard drive), socio-political deception (detecting fake news on which we base life decisions), and physical safety (loss of life and property from adverse cyber-physical events). As we look to the future of system security and system security engineering, we have hard choices to make that effect the way we live. This paper examines many of those choices and establishes architectural premises toward architecting the future of system security.

Paper#106

Towards a Common Systems Engineering Methodology to Cover a Complete System Development Process

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Presented on: Monday, 14:00-14:40

Keywords. MBSE;SysML;Modeling Methodology;Systems Engineering

Topics. 2. Aerospace; 2.4. System Architecture/Design Definition; 3. Automotive; 5.3. MBSE; 5.5. Processes; 6. Defense;

Abstract. Model-Based System Engineering (MBSE) provides the ability to experience systems early from conceptual phases, and is one of the masterpieces of the Industry renaissance. We see now in many Industries that we are leaving the world of experimentation to an effective and growing deployment of MBSE. One of the common challenges in industry is to bridge the gap between systems engineering studies and product development in a digital continuity and providing a seamless system experience. This paper presents an end-to-end systems engineering methodology, MagicGrid, extending the MBSE Grid methodology, to consider all the viewpoints of engineering of a cyber-physical system.

Paper#88

Towards a semantic approach of MBSE frameworks specification.

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Keywords. MBSE;Semantic consistency;ISO-42010;Ontology;OPM

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

Abstract. For decades, the use of models has been progressively extended to nearly all Systems Engineering activities and for a large variety of concerns and disciplines. It has resulted in the de-velopment of large modeling frameworks that involve many different tools and types of models. The goal of this paper is to propose an approach to specify such modeling frameworks in a way to ensure and manage the overall semantic consistency of modeled Systems Engineering assets. The proposed approach relies on the ISO/IEC/IEEE-42010 principles, on the elicitation of an ontology of the sys-tem architecture, and on the definition of how the architecture description elements represent the elements of the ontology. By identifying resulting semantic correspondences and correspondence rules, it allows eliciting consistency rules and then, to define and specify advanced modeling services ensuring the semantic consistency of models.

Paper#57

Towards an Automated UAF-based Trade Study Process for System of Systems Architecture

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Presented on: Tuesday, 14:00-14:40

Keywords. Trade Study Process;Trade-Off;UAF;SoS

Topics. 5.3. MBSE; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. The major driver for the Model-based systems engineering adoption in industry is the ability for an engineer to develop systems with traceability to requirements, using one integrated architecture model that enables all types of automated analysis, e.g. impact analysis, gap analysis, trade studies, and simulations. Today, complex real-life problems require the application of MBSE practices, where evolving systems communicate independently, both operationally and managerially, to achieve a common goal.
This is the level of system of systems. At this level the major concern is an architecture assessment and trade study analysis, which can lead to different criteria and techniques for identification and comparison of alternatives to keep architecture in line with budgets and timelines. Although there are multiple process that provide step-by-step descriptions of trade study analyses, there are none that detail how trade study analyses could be automated in the model-based environment in combination with existing architecture frameworks, languages, and tools.
The goal of this paper is to propose an automated trade study analysis process for the System of systems architecture developed in the Unified Architecture Framework models. It is a part of the larger research of trade study analysis automation, including modeling guidance, model quality checks, and automation scripts.

Paper#52

Towards an Ontology for Collaboration in System of Systems Context

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

Keywords. System of Systems (SoS);Object Process Methodology;Collaboration;Ontology;ISO 19450;Architectural Framework;Systems Engineering Standards

Topics. 14. Autonomous Systems; 2.4. System Architecture/Design Definition; 3. Automotive; 3.7. Project Planning, Project Assessment, and/or Project Control; 5. City Planning (smart cities, urban planning, etc.); 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.);

Abstract. There is considerable number of architectural frameworks and standards with many pertinent definitions of concepts that are often not compatible with each other, hindering collaboration, especially in the context of System of Systems (SoS). To address this issue, we propose an ontology for SoS that uses Object Process Methodology (OPM) ISO 19450 to facilitate collaboration among organizations with focus on safety aspects. The current effort focuses on the foundational extended taxonomy that uses a minimal set of terms to model system- and SoS-related concepts and relations among them to streamline collaboration among involved SoS stakeholders, with focus on safety. The ontology is illustrated through an example of a self-parking facility.

Paper#143

Towards Defining the Systems Habits of an 'Aware' Student Engineer

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

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

Keywords. systems thinking;competencies;education

Topics. 1. Academia (curricula, course life cycle, etc.); 1.5. Systems Science; 1.6. Systems Thinking;

Abstract. In this paper, the philosophical underpinnings of a systems approach to engineering are described. These "habits of thought" capture fundamental ways of thinking that—when used together—distinguish systems engineers from traditional, discipline-based engineers, with particular attention to a 'pre-awareness' level of the Systems Thinking competency within the INCOSE competency framework. By discussing the philosophy for a systems-level approach to engineering, the foundational aspects from systems engineering and the broader systems sciences important in an undergraduate program can be discussed. Through this paper, systems principles—or habits—are proposed, essential for creating modern engineers who can shape the engineering profession into the future.

Paper#40

Towards Systemic Handling of Requirements in the Oil and Gas Industry – a Case Study

Siv Engen (University of South-eastern Norway) - siv.engen@technipfmc.com
Kristin Falk (University of South-eastern Norway) - Kristin.Falk@usn.no
Kirsten Helle (TechnipFMC) - kirsten.helle@technipfmc.com

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

Keywords. Requirement Management;Oil & Gas;Case Study;Digitization;Requirement Engineering;Systems engineering;Supplier

Topics. 15. Oil and Gas; 2.3. Needs and Requirements Definition; 5.5. Processes;

Abstract. This paper presents valuable insights on implementation of requirement management system in the oil and gas industry. The focus on cost reduction in this industry has led to an urgent need for a more systematic requirement handling.
The paper presents a survey asking international oil and gas actors for status and needs with respect to requirement management. Furthermore, the paper presents experiences from implementing a Re-quirement Management System at a major supplier in the industry.
The international survey confirms that the oil and gas industry is lagging behind other industries when it comes to implementation of systematic requirement handling. A second result is that the paper shows a clear positive effect when implementing a requirement management system at a single supplier. In conclusion, by implementing such a system, the industry will limit the number of re-quirement, save cost, and reduce the need for testing and validation. To achieve this, companies will need management support and collaboration across the supply chain. A cross-industry implementa-tion would result in a significant effect, both in terms of reduced cost and increased flexibility.

Paper#56

Transferring Needs and Operational Experience from Life-of-Field to Engineering functions - a case study from the Subsea Industry

Siv Engen (University of South-Eastern Norway) - siv.engen@gmail.com
Kristin Falk (University of South-Eastern Norway) - kristin.falk@hbv.no
Severin Myhre (University of South-Eastern Norway) - severinmyhre@outlook.com

Paper not presented

Keywords. Need transfer;Operational experience;Oil and Gas;Subsea Industry;Case Study

Topics. 15. Oil and Gas; 2.3. Needs and Requirements Definition;

Abstract. This paper investigates how a company in the subsea industry are transferring needs and operational experience from Life-of-Fields functions to Engineering functions, to allow for more holistic life cycle design and to improve engineering solutions. The subsea industry is changing, putting more emphasis on total life-cycle cost. In order to improve their offerings, suppliers within this industry see the need for more effective utilization of Life-of-Field's needs and operational experience. Challenging communication between Life-of-field and Engineering affect transference of needs and operational experience, hindering engineering for life cycle. To research this problem, we investigated the operational process and made in-depth interviews of relevant personnel at both the Engineering and Life-of-field functions of a global subsea supplier. We discovered that sub optimal transference of needs and operational experience between the Life-of-Field and Engineering functions results in added work, repetitive design issues and operational inefficiencies from project to project. We found an insufficient organisational process, low prioritization of cross-functional feedback together with formal tools not fit for purpose to be the predominant causes for ineffective transferring of needs and operational experience between Life-of-Field and the other functions. Suggestions for improving the transference of needs and operational experience are presented based on the findings and analysis.

Paper#131

Understanding Evolutionary Societal Decision-making for Sustainable Social Systems Engineering Purposes

Dana Polojarvi (Maine Maritime Academy) - dana.polojarvi@mma.edu
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Pascal Gambardella (Emerging Perspectives LLC) - pascalgambardella@gmail.com

Paper not presented

Keywords. social systems engineering;modeling;evolution;overshoot;collapse;Easter Island;Tikopia;simulation modeling;systems thinking;operational thinking;gamification

Topics. 1.1. Complexity; 1.3. Natural Systems; 1.4. Systems Dynamics; 1.6. Systems Thinking; 10. Environmental Systems; 17. Sustainment (legacy systems, re-engineering, etc.); 4.1. Human-Systems Integration; 4.4. Resilience; 5.4. Modeling/Simulation/Analysis;

Abstract. To engineer sustainable social systems for Earth's future, we need to understand how they change over time based on human decision-making. The problem of the rise and fall (or overshoot and collapse) of cultures has been studied in the social sciences for centuries, so it is a useful pattern for this purpose. To understand this behavior pattern from an operational, social systems engineering perspective, this paper reviews two of the main simulation modeling approaches to this problem and finds them to be limited (from an operational perspective) by a basis in non-human population dynamics that leads to a problematic dependence on initial conditions. We build upon this previous work, adapting it to include decision-making and show how these decision-making processes change the behavior over time. To demonstrate our process, we start with a recent model of Easter Island's collapse and add operational structures that allow human decision-making to enter the modeling structure. We show how the addition of operational decision-making structures provides a better fit to the anthropological data and how these structures were used to generate policy on the island of Tikopia. Finally, we argue that these decision-making structures are, themselves, engineered objects that can be improved through better understanding of their evolutionary nature.

Paper#23

Using System Dynamics to Determine the Impact of Electric Vehicles on Employment in the Component Manufacture Industry

Nalini Sooknanan Pillay (ESKOM SOC) - PILLAYNA@ESKOM.CO.ZA
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Paper not presented

Keywords. system dynamics;employment;automotive

Topics. 1.4. Systems Dynamics; 3. Automotive;

Abstract. The automotive industry is thought to have direct and indirect impacts on national job creation for both the formal and informal sectors. There have been debates around employment impacts and socio-economics in South Africa with the introduction of EVs, however, a definite consensus of whether the impact is positive or negative has not been established. Unless all the driving factors affecting automotive employment have been modelled, no resolution can be reached through the various engagements. This study used a system dynamics modelling approach to determine the employment impact of substituting the internal combustion vehicles (ICEVs) with hybrids and pure electric cars, specifically in the component manufacture segment of the automotive value chain. Scenarios were also run to determine the impact of localized electric battery manufacture on employment. Results indicate that a 22% substitution of ICEVs with electric cars results in a 2.65% decrease in employment, while a 34% increase in hybrids in the electric car mix results in an in-crease of 1.73% of employment in the component manufacture segment. The simulator also shows that from 2020 until 2027, employment due to localized manufacture of electric car batteries, in-creases, however, there is a steady decrease from 2028 to 2050, likely due to the reduction in demand for electric batteries because of technology improvements in first life applications, resulting in better durability and shelf life.

Paper#28

Using your BRAIN to get beyond “It Depends…”

Ian Gibson (Atkins) - ianthesonofgib@yahoo.co.uk

Presented on: Tuesday, 12:30-13:10

Keywords. Mission Analysis;Mission Engineering;Scenario Definition;Concept Generation;BRAIN Analysis

Topics. 2.1. Business or Mission Analysis; 6. Defense;

Abstract. This paper describes an approach for framing a problem where the potential operational scope is large and diverse, and for quickly evaluating potential points in the solution-space in a manner which is easy for non-technical stakeholders to digest and interact with.
The two aspects of scenario framing and concept assessment work well together but can easily be decoupled depending on the needs of the task at hand.
It has been used so far on series of tasks exploring concept and pre-concept phase op-tions in the UK Defence environment, but has wider applicability to any situation that shares similar characteristics.

The scenario framing approach addresses the familiar problem of getting past stakeholder responses of “it depends” when they are asked to validate processes or behavioural models.
The concept assessment approach, based upon the acronym BRAIN, is intended to be quick and easy to apply, supporting rapid iteration.
Two case studies are used to illustrate the combined approach.

Paper#30

What's the Problem? Issue Investigation and Engineering Change on Legacy Products

Andrew Pickard (Rolls-Royce Corporation) - Andrew.C.Pickard@rolls-royce.com
Charlotte Dunford (Rolls-Royce plc) - Charlotte.Dunford@rolls-royce.com

Presented on: Tuesday, 16:20-17:00

Keywords. Legacy;Requirements;Modification;Change

Topics. 2.3. Needs and Requirements Definition; 2.4. System Architecture/Design Definition; 2.6. Verification/Validation;

Abstract. Systems Engineering best practice has changed greatly over the past 10 to 20 years.
Aero-engines are normally in service for over 30 years (an example is included in this paper of a recent modification to a WWII engine) and so many still in service were not designed using current systems engineering best practice.
When changes need to be introduced into these products the pre-work required to get the product information dataset to the point that current best practice can be employed is often not worth the benefit.
The challenge is to decide what level of systems engineering rigor is of value to apply when making changes to these legacy products.
This paper describes the authors' work tackling this issue focusing on understanding the change needed. It proposes a generic approach for tailoring systems engineering to understand the change needed on a legacy product.

Paper#15

When to Constrain the Design? Application of Design Standards on a New Development Program

Tami Katz (Ball Aerospace) - familykatz@earthlink.net

Presented on: Wednesday, 17:05-17:45

Keywords. Standards;Requirements;Optimization

Topics. 2.3. Needs and Requirements Definition; 3.8. Quality Management Process; 5.2. Lean Systems Engineering;

Abstract. Use of design and construction standards have many benefits when trying to meet ex-pectations on product safety and quality - they help ensure commonality and consistency of ap-proaches to design, manufacturing, test and verification. However, the use of standards can drive cost and inhibit innovation for certain applications. This leads to the question of when is it ap-propriate to constrain the design and apply standards on a program? This paper looks at the typical usage of design and construction standards across three different industries to evaluate when their usage enables projects, and when they drive cost. This paper provides the conclusion that opti-mization of a project for cost, technical and schedule is best served when standards are limited to industries with common products in a highly regulated domain. Usage of standards is not a "one size fits all" approach, and alternate strategies exist for industries in cases where limiting the de-sign solution could impact ability to realize cost effective, innovative designs.

Panel

Panel#2

Everything you Wanted to Know about Technical Leadership but were Afraid to Ask

Heather Feli - heatherjfeli@gmail.com
Kerry Lunney (Thales Australia) - kerry.lunney@thalesgroup.com.au
Stueti Gupta (BlueKei Solutions) - stueti.gupta@gmail.com
Courtney Wright (V1 Decisions, LLC) - Courtney.Wright@v1decisions.com

Presented on: Monday, 10:00-11:25

Keywords. technical leadership;journey;vision;strategic thinking;diversity;institute for technical leadership;TLI

Topics. 3.5. Technical Leadership;

Abstract. Let's be honest.
If the "How to Become a Technical Leader" guide existed, we would all already own copies and be following it.
But it doesn't.
We do, however, have each other and our shared experiences.

What technical leadership questions are keeping you up at night?
• How do I create and hold a leadership vision?
• Where does strategic thinking come into play as a technical leader?
• How do I balance diversity and inclusion?
• How do I develop capacity for change?
• What challenges are ahead what which approaches to try?
Come to this panel, ask those questions, hear the valuable insights that only come with experience and having been through the struggle, and learn some ways to navigate and influence the way forward from others who have found the way!
(What works and what fails epically – there are bound to be good stories).
And who knows, maybe you'll meet a fellow INCOSE member who shares in your struggle that can help you or better yet you can embark on the journey together.
(A little networking never hurt anyone.)

A panel covering three continents, four industries, and decades of technical leadership at your disposal for a candid dialog. All phases of leadership journeys are welcome!
INCOSE's Institute for Technical Leadership will provide questions to get the discussion going.

Biography

Kerry Lunney (Thales Australia) - kerry.lunney@thalesgroup.com.au
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. Recent roles include Chief Systems Engineer, Solutions Architect and Design Authority. 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 Expert Systems Engineering Professional

(ESEP) qualification from the International Council on Systems Engineering (INCOSE). In addition to her "day job", Kerry is the INCOSE President-Elect. She has also been a past-INCOSE Sector Director for Asia-Oceania, a past-National President of the Systems Engineering Society of Australia (SESA), the Australian Chapter of INCOSE, and has held various roles on conference and events committees and University program advisory boards throughout her career.

Position Paper

Making the jump from engineer to expert to executive

As an engineer, you've had to develop highly specialised technical skills and make critical decisions within a niche area of knowledge. However, as a leader, your scope of strategic input will widen, becoming responsible for a wide range of people and projects. So how do you transition from an engineer to technical expert into a strategic leader? Questions such as –

• How do you create shared values
• How to manage your time effectively
• How do you create trust and delegate responsibility

are typically not taught in engineering programs and may be invested in during your working career.

The journey you may undertake in your career will take detours and you will travel along new paths not envisaged from the onset. I will endeavour to walk you through some of the highs and lows of my career path to date outlining what worked, what I experienced and the "gotchas" to be aware of. My journey has included working on very diverse programs, living in Australia, India, Sri Lanka, Thailand, New Zealand and USA, not to mention many other locations where I had short postings across the world.

I can honestly say the jumps from engineer to expert to executive did at times feel like I was traversing hurdles in a maze, but my compass still remained true! However I recognise that change we are experiencing as part of the 4th industrial revolution will require change in leadership to be truly effective. As such my compass will still remain true but my journey will continue. As part of this panel I will discuss possible impacts and variations in leadership styles, techniques and priorities to lead going forward.

Stueti Gupta (BlueKei Solutions) - stueti.gupta@gmail.com

Stueti is an experienced Systems and Architecture lead as well as has been manager for off-highway equipment automation teams. She has led systems engineering research projects and co-led Systems Engineering competency development at the technology center during her tenure at John Deere India, largely around Model Based Systems Engineering. She has some publications in this area, one of which received the best paper award at an international conference. Stueti studied at BITS Pilani, and completed her second masters from Cornell University, USA. She also received formal certification in Systems Design and Management from Massachusetts Institute of Technology, USA. She is actively involved in the International Council on Systems Engineering and is also the President of India Chapter. Stueti has held various leadership roles in Society of Women Engineers locally in India as well as in global initiatives.

Position Paper

It is often said that being a frontline manager is like walking on fire. Well it is. Let's say you might be visualizing a successful career as an individual contributor and probably a technical one. And then suddenly you are asked to lead teams. Several aspects come in light the moment you step into manager shoes. One end of the spectrum is meeting team or function KPIs, managing stakeholder requirements, continue to be technically involved and other end of spectrum is making people / team successful or resolving conflicts and others such become prime important. It gets overwhelming but transition to a leader role can be managed and enabled if we engage and expose ourselves to community leadership roles such as those in INCOSE, SWE or other professional organizations. The leadership roles teach you to achieve goals that you have set, manage teams while no one is reporting to you, keep people motivated and engaged and connect with the higher purpose. Many of these aspects are transferable skills you can bring to your day job.

For me leadership is all about

- Creating a career capital which provides you the direction to grow
- Building and leveraging your network to continuously learn through conversations or mentoring
- Develop and support others on the way

Building and investing in the support system around you, whether within family or extended family, at work or among friends, to make it all work for you

Courtney Wright (V1 Decisions, LLC) - Courtney.Wright@v1decisions.com

Courtney Wright is an INCOSE Certified Systems Engineering Professional with twenty years of systems engineering experience. She has a bachelor's degree in Mechanical Engineering from the University of Virginia and a master's degree in Operations Research from Georgia Institute of Technology. After working as a contractor for the US Air Force, NASA, and the Federal Aviation Administration, she joined INCOSE as the Program Manager for the Certification Program.

Position Paper

I've always been a good manager. Since childhood, teachers have recognized my skills at alphabetizing, following rules, and speaking politely. This set the groundwork for being a leader. I prefer to lead by steering, rather than dictating, even when I have the authority that I'm allowed to dictate. I think this comes in part from being a woman in engineering – I was always noticed and almost always given a chance to speak, leaving it up to me to make the most of that attention. The other big part of my leadership development is that I've rarely been in situations where I'm significantly smarter than those around me. I heard a study described on public radio, so it may have been a joke, but the summary was that those people who are most attractive in high school are less successful in life, because they did not have to develop a personality or academic skills in order to have positive experiences. Similarly, I think it's a disadvantage to developing soft skills for someone to be the smartest or most powerful person in their environment. I've walked away from situations where I was easily at the top in those ways, preferring challenges.

Panel#8

How Cyber and Systems Security Engineering is Fighting for a Safe and Reliable Future

Alice Squires (Washington State University) - alice.squires@wsu.edu
Keith Willett (Department of Defense) - kwillett@ctntechnologies.com
Peggy Brouse (George Mason University) - pbrouse@gmu.edu
Peter Beling (University of Virginia) - pb3a@virginia.edu

Presented on: Wednesday, 10:00-11:25

Keywords. cyber security;systems security;information technology;safety;reliability

Topics. 1. Academia (curricula, course life cycle, etc.); 11. Information Technology/Telecommunication; 4.7. System Security (cyber-attack, anti-tamper, etc.); 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 5.9. Teaching and Training;

Abstract. The growth of cyber and systems security engineering is a result of the driving need to ensure the security and safety of our global citizens in a world that is increasingly being driven and controlled by computer systems and networks that are open to ever changing forms of threats and attacks.
This panel explores the role of cyber and systems security engineering in preserving our way of life as a necessary consequence of our increasing use and dependency on technology that is open to forces that are attempting to use that technology for personal gains, to manipulate others, or to cause harm and destruction. Panelists will summarize their experience with emergent training and education, technology development, and industry practices while giving their varying perspectives on current and future challenges, best practices, the trends they are seeing within the field, and the future of cyber and systems security engineering.

Biography

Alice Squires (Washington State University) - alice.squires@wsu.edu
Dr. Alice F. Squires has served in professional roles for over 35 years including nearly 25 years in industry. Alice currently serves as an Associate Professor in Engineering and Technology Management at Washington State University. Alice founded the INCOSE Empowering Women Leaders in Systems Engineering (EWLSE) group and serves INCOSE Academic Matters and the Americas and as co-editor of the SEBoK wiki. She also serves on the boards of the ASEE Systems Engineering Division, Corporate Member Council, and Committee on Diversity, Equity, and Inclusion. She recently wrote an IEEE-USA women in engineering ebook on women overcoming various challenges to complete a STEM education and succeed as a STEM professional, titled: "Dandelion Wishes: A World Where We Collaborate as Equals" (see: https://ieeeusa.org/shop/careers/wie-book-21/), co-authored Chapter 5: Merging Literature and Voices from the Field: Women in Industrial and Systems Engineering Reflect on Choice, Persistence and Outlook in Engineering published by CRC Press as part of Emerging Frontiers in Industrial and Systems Engineering: Success Through Collaboration, and served as theme co-editor for the Fall 2019 'Diversity in Systems Engineering' INCOSE Insight edition.

Position Paper

Cyber and systems security is a growing field to combat those that would usurp today's systems in negative and unethical ways for their own gain or amusement. I will challenge the panellists to look beyond their current involvement and relate their initiatives to the larger theme of how their efforts can and should support global sustainability over the long term.

Keith Willett (Department of Defense) - kwillett@ctntechnologies.com
Dr. Keith D. Willett has degrees in computer science/math, business/information systems, information assurance, and systems engineering; plus, 35+ years' experience in technology and security as an educator and practitioner across commercial industry, government, and academia. Dr. Willett's professional position is an Enterprise Security Architect with the United States Department of Defense. He is the co-chair of the INCOSE Systems Security Engineering Working Group and an active member in the Agile Systems Engineering WG and the Resilient Systems WG. Dr. Willett is also active in two INCOSE Future of Systems Engineering (FuSE) projects in Adaptable Systems and Systems Security Engineering. He is the co-author of three books: How to Achieve 27001 Certification, Official (ISC)2 Guide to the ISSMP CBK, and Multisystemic Resilience: Adaptation Across Systems and Scales; and sole author of Information Assurance Architecture. He has actively published and presented at conferences since 1996 on the topics of telecommunications, security architecture, systems engineering, and the role of cognitive assistants in cybersecurity operations. Dr. Willett was also an active participant in defining the ABET accreditation criteria for cybersecurity undergraduate programs.
Position Paper
Cybersecurity is not just a technical decision regarding cost, benefit, and performance. Cybersecurity interweaves with civil liberties (opting out of the digital world), privacy (the right to be unobserved and the right to be forgotten), automated resolution of moral dilemmas (autonomous vehicle choosing who to hit), financial security (wealth representation being bits on a hard drive), socio-political deception (detecting fake news on which we base life decisions), and physical safety (loss of life and property from adverse cyber-physical events). As we look to the future of system security and system security engineering, we have hard choices to make that effect the way we live." --- Abstract from the paper Toward Architecting the Future of Systems Engineering by Dr. Keith D. Willett.
The primary of goal of any engineered system is value-delivery with value being in the eye of the stakeholder. Systems must provide value-delivery under nominal conditions (function-oriented) and adverse conditions (loss-oriented). Therefore, a close secondary goal is to sustain value-delivery. Functional objectives include the system being effective (produce desired results), efficient (produce desired results within specified performance parameters), and elegant (produce desired results with minimal resource expenditure). Loss-driven objectives include reliability (dependable, consistent), sustainability (renewable), and survivability (compatible with the current order).
Sustainability includes minimizing the use of depletable resources and maximizing the use of renewable resources for inputs to the system (raw material) as well as that which is used to power the system (fuel, energy). If sustainability is not directly part of security, it is closely related under the umbrella of loss-driven systems engineering.

Peggy Brouse (George Mason University) - pbrouse@gmu.edu
Dr. Peggy Brouse is a Professor in both the Cyber Security Engineering (CYSE) department and the Systems Engineering and Operations Research (SEOR) department at George Mason University (GMU). She is the Director and curriculum creator of the first Bachelor of Science in Cyber Security Engineering (BS CYSE) program. The BS CYSE is also the first to be ABET accredited. Dr. Brouse was a member of the INCOSE team that participated in developing the ABET program criteria for accrediting cybersecurity engineering degree programs. She is a member of the INCOSE Academic Affairs Committee. Dr. Brouse worked for MITRE Corporation before joining GMU.
Position Paper
Cyber Security Engineering is concerned with the development of cyber resilient systems which include the protection of the physical as well as computer and network systems. It requires a proactive approach in engineering design of physical systems with cyber security incorporated from the beginning of system development. Cyber security engineering is an important quantitative methodology to be used in all industries to include, but not limited to, transportation, energy, healthcare, infrastructure, finance, government (federal, state, and local), and defense. This necessitates a systems engineering approach to cyber security engineering which is a critical competency for the workforce of today that will only increase in demand with the growth of Industry 4.0, smart cities, artificial intelligence, etc.
Educators of the future workforce must continue to foresee the trends in demand and the changes in the requirements for cyber and systems security engineering across all domains, as the systems continue to evolve. In support of these needs, I will present the approach used to develop what is currently the only ABET approved undergraduate degree program in cyber security engineering and the systems engineering foundation for the degree. I will share relevant experiences from the students in the program, what has worked, what areas will be evolving, and how the various challenges are being addressed. Finally, I will cover how the degree, through senior design supported by industry and constantly changing technical courses, is supporting industry's need for cyber security professionals, and the changes that are anticipated moving forward.

Peter Beling (University of Virginia) - pb3a@virginia.edu
Dr. Peter A. Beling is a Professor of Systems Engineering at the University of Virginia (UVA). His research interests are in the area of decision-making in complex systems, with emphasis on AI assurance and cyber resilience for cyber-physical systems. His research has found application in a variety of domains, including mission-focused cybersecurity, reconnaissance and surveillance, prognostic and diagnostic systems, and financial decision making. He directs the UVA

site of the Center for Visual and Decision Informatics, a National Science Foundation Industry/University Cooperative Research Center, and the Adaptive Decision Systems Laboratory, which focuses on data analytics and decision support in cyber-physical systems. Additionally, he serves on the Research Council of the Systems Engineering Research Center (SERC), a University Affiliated Research Center for the Department of Defense.

Position Paper

Generally, security for cyber-physical systems (CPS) refers to the application of defensive and resilience measures implemented to help sustain acceptable levels of operation in the face of adversarial actions. More specifically, defensive measures are the steps taken to prevent an adversary from disrupting, terminating, or taking over control of the operation of a system. Resilience, on the other hand, refers to the actions taken to ensure the continuity of the system's expected service in spite of adversarial actions. Methodologies and techniques for achieving enhanced system security in the cyber domain are prevalent and well-researched, and have been applied to CPS as well. However, the methods and techniques used for enhancing the security of strictly cyber systems are not sufficient for CPS due to their lack of focus and inability to account for the physical interactions inherent to CPS and the system's usage in a broader mission.

Security needs and solutions are developed based on the perceived threats to the system and potential vulnerabilities identified in the system's design. Often, this means that vulnerabilities are only discovered after a security breach or after detrimental effects have already occurred (e.g., Stuxnet). Of course, it is impossible to discover all potential vulnerabilities, and systems must be routinely updated and adapted as new threats emerge; however, new trends call for integrating security into all parts of the system's lifecycle, including the pre-design and design phases. There are several challenges that we perceive in the preliminary design phase with respect to security of CPS. There are potentially many important stakeholders with many different (valid) perspectives and knowledge bases. How does one use these stakeholders, and how are they organized? What should be done in terms of methodology, technology, and/or tools that can be used to make the process more scaleable, traceable, and potentially repeatable? One thing that is clear is that there is not a single disciplinary collection that is capable of doing everything in terms of knowing how the system should behave, assessing the vulnerabilities or possible attacks to the system, or bringing to bear the operational characteristics in its intended environment(s).

Panel#6

Humans with AI: It's not like it is in the movies!

Christopher Eck (Raytheon Technologies) - christopher_eck@raytheon.com
Barclay Brown (Raytheon Technologies) - barclay@barclaybrown.com
Moha Chami (Chami Consulting) - mohachami@gmail.com

Presented on: Monday, 12:30-13:55

Keywords. Intelligent Systems;AI4SE;Artificial Intelligence;Machine Learning

Topics. 1.2. Cybernetics (artificial intelligence, machine learning, etc.); 4.6. System Safety; 4.7. System Security (cyber-attack, anti-tamper, etc.);

Abstract. The dramatically increasing success of artificial intelligence, especially machine learning and deep neural networks has occasioned the increase of concern among both the public and technical professionals about the long-term safety of intelligent systems. As systems become more intelligent, people reason, there is more to fear from them, since they may one day rival human intelligence. When and if they do, the concern becomes the moral and ethical behavior (or the lack of it) that they will exhibit when making decisions and working with human beings.

Since the 1950s and even before, depictions of intelligent machines in movies, fictional literature and television have almost universally portrayed intelligent machines as evil-minded, contentious and dangers to human beings.

This panel will examine, from a number of relevant angles, the appropriateness and potential realism of such depictions, based on current and projected artificial intelligence capabilities. Panelists will introduce viewpoints and

illustrate them with examples from the fictional world of cinema and television, and facilitate discussion on the potential of intelligent machines to acts as depicted.

Biography

Christopher Eck (Raytheon Technologies) - christopher_eck@raytheon.com
Chris Eck is the Corporate Technology Area Director for Systems Engineering & Architecture at Raytheon Technologies. His work includes extensive experience developing architecture and technologies for tracking, correlation and information fusion operating on various real-, near-real-, and non-real-time data sources and their interaction with Command & Control (C2) functions such as fire control, intelligence, and situation awareness. He has also built and architected systems in domains such as renewable energy, social networking (using artificial intelligence techniques), cyber, and communications to enhance mission performance for U.S. Navy, Air Force, Army and Marines C2 systems. He has worked all phases of the system life cycle from initial concept and proposal development through sustainment. Chris enjoys innovating capabilities and fostering the same skills in others. He has been awarded multiple U.S. patents including cooperative unmanned aerial vehicle tracking and control, the use of radio frequencies with nanoparticles for renewable energy, the aggregation of data from multiple sensor sources on a single display, and several patents for estimating the evolution of network graphs, including predicting cyber threats. Chris earned his Ph.D. in astrophysics from the University of Oklahoma and enjoys teaching physics at the University of South Florida.

Barclay Brown (Raytheon Technologies) - barclay@barclaybrown.com
Barclay R. Brown is an Engineering Fellow for Raytheon Company and the business unit lead for model based systems engineering and facilitator for the Artificial Intelligence / Machine Learning Center of Excellence. Before joining Raytheon, he was the Global Solution Executive for the Aerospace and Defense Industry at IBM Watson IoT, and was the lead systems engineer for some of IBM's largest development projects. Dr. Brown holds a bachelor's degree in Electrical Engineering, master's degrees in Psychology and Business and a PhD in Industrial and Systems Engineering. He teaches systems engineering and systems thinking at several universities, and is a certified Expert Systems Engineering Professional (ESEP), certified Systems Engineering Quality Manager, and the former INCOSE Director for the Americas.

Moha Chami (Chami Consulting) - mohachami@gmail.com
Mohammad Chami is the founder of Chami Consulting | MBSE Services, and a full-time, tool-independent, Model-Based Systems Engineering (MBSE) consultant. Mohammad is an MBSE expert with a solid academic and industrial experience in modeling languages, processes, developing and deploying methods for system modeling and customizing its tools. In recent years, his focus has shifted towards the application of artificial intelligence, i.e., natural language processing and machine learning, in MBSE. With over 10 years of experience in MBSE, Mohammad has gathered valuable experience in different MBSE applications, including systems modeling, requirements engineering, functional architecture, variant management, testing, safety analysis, and verification and validation. Mohammad has authored or co-authored numerous publications in the fields of MBSE, variant management, artificial intelligence, and mechatronics systems design. He is an active member of INCOSE and actively participating in both its German and Swiss chapters. As a passionate lecturer whose goal is to motivate others, he enjoys attending and speaking at MBSE-related conferences.

Panel#1

Issues, impediments, and Inspiration for Continuous Integration in Mixed Discipline Development Projects

Rick Dove (Paradigm Shift International) - dove@parshift.com
Barry Papke (Catia | No Magic) - Barry.PAPKE@3ds.com
Kerry Lunney (Thales Australia) - kerry.lunney@thalesgroup.com.au
Robin Yeman (Lockheed Martin Corporation) - robin.yeman@lmco.com
Tom McDermott (Systems Engineering Research Center, Stevens Institute of Technology) - tmcdermo@stevens.edu
Duncan Kemp (Ministry of Defence) - Duncan.kemp735@mod.gov.uk

Presented on: Wednesday, 16:20-17:45

Keywords. Systems engineering;mixed discipline;continuous integration;rework;DevOps;stakeholder feedback

Topics. 2. Aerospace; 2.5. System Integration; 5.1. Agile Systems Engineering; 6. Defense;

Abstract. Mixed discipline systems engineering projects typically await completion of major project increments before an integrated system test and demonstration can be accomplished. Major project increments in mixed discipline projects are often 6-9 months or more in duration. In contrast, continuous integration and DevOps in software development projects are mainstream methods for incremental collaborative interaction with various stakeholders on work in process. Frequent feedback on work in process can reduce rework, a major cause of cost and schedule overruns. Some organizations have found ways to provide more frequent integration and demonstration feedback on mixed discipline projects, and some are actively investigating impediments and possible mitigation methods. This panel will discuss and debate the issues, impediments, and inspirations for continuous integration in mixed discipline projects with panel members expressing views from government acquisition, subcontractors, software and hardware engineering, systems engineering, and security engineering. Attendees will be invited to air their views as well.

Biography

Rick Dove (Paradigm Shift International) - dove@parshift.com
Rick Dove is a researcher, practitioner, and educator of fundamental principles for agile systems and agile systems engineering. In 1991 he initiated the global interest in agility as co-PI on the seminal 21st Century Manufacturing Enterprise Strategy project at Lehigh University. Subsequently he organized and led collaborative research at the DARPA-funded Agility Forum, involving 250 organizations and 1000 participants in workshop discovery of fundamental enabling principles for agile systems and processes. He is CEO/CTO of Paradigm Shift International, specializing in agile systems research, engineering, and education; is an adjunct professor at Stevens Institute of Technology and an Instructor at Caltech. He chairs the INCOSE working groups for Agile Systems and Systems Engineering, and for Systems Security Engineering, and is the leader of the INCOSE Agile Systems Engineering Life Cycle Model Discovery Project. He is an INCOSE Fellow, and the author of Response Ability – the Language, Structure, and Culture of the Agile Enterprise. His publication list numbers in excess of 200 papers, he has conducted in excess of 100 workshops.
Position Paper
Cyber physical mixed discipline agile systems engineering needs a continuous integration platform stood up early in the project to enable and facilitate frequent integration test, demonstration, and stakeholder collaborative feedback on work in process. Initial platform can employ hardware and software simulations, proforma stubs, COTS proxy components, reusable previously developed components, and re-employable SIL equipment. All platform elements can be incrementally and asynchronously evolved as work progresses. The platform should be instrumented to monitor and detect a variety of likely integration issues.

Barry Papke (Catia | No Magic) - Barry.PAPKE@3ds.com
Barry Papke has 34 years of systems engineering and project engineering experience across multiple US DoD and

NASA programs. Project experience includes the full engineering lifecycle from concept development through requirements definition, design, integration, test, sustainment and system upgrades. Through his project history in airborne systems, Barry has extensive experience with development and use of systems integration labs (SILs) and development test beds to support early integration, development test and integration, training and system sustainment. Throughout his career, Barry has been an advocate for Model Base Systems Engineering and currently teaches and consults on modern MBSE practices. Barry has earned a Bachelor of Science in Mechanical Engineering from Texas A&M University and a Masters of Engineering in Systems Engineering from Steven's Institute of Technology.

Position Paper

Early and continuous integration is a critical capability for any program developing complex systems with complex internal and external interfaces. It is even more critical for programs with multiple, distributed subcontractors and suppliers, each responsible for large subsystems that interact with each other.

Contractor teams within the US DoD, particularly those in the airborne command and control and surveillance domain, have developed many advanced practices to support early integration of mission systems prior to flight test. This includes both integration of systems within and external to the platform.

The primary approach involves the development and operation of a Systems Integration Lab (SIL.) Typically, multiple SILs are created, located at the prime contract facility, each of the major supplies and at a government/customer operated site interconnected by networks. The earliest integration testing of mission system software is often performed on commercial hardware on commercial racks. As the program proceeds, commercial hardware is replaced by fully qualified mission hardware. Simulators are developed for some systems and may be replaced by real systems as their development progresses. Eventually selected external interface simulators and surrogates are replaced by live data links and communications networks and SIL systems begin integration with real world external systems. Where RF performance though cabling is critical, commercial racks are replaced by production racks and SIL lab cables are replaced by production aircraft harnesses of the correct length, materials and RF characteristics.

When combined with a physical mockup of consoles, rack installations, access panels and cable runs, the SILs use can be extended to support early integration efforts for human factors and maintenance.

Next generation concepts include complete virtual integration and test environments that include libraries of virtual hardware, sensors and constructive/virtual simulation to support real-time and faster than real-time automated integration testing of highly complex autonomous systems. The two biggest impediments to implementing a continuous integration capability are (1) failure to correctly quantify the integration risk and therefore fail to provide the required early integration resources and (2) failure to quantify the required fidelity for simulators and surrogates sufficient to stress and detect integration/interface issues.

Kerry Lunney (Thales Australia) - kerry.lunney@thalesgroup.com.au

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. Recent roles include Chief Systems Engineer, Solutions Architect and Design Authority. 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. In addition to her "day job", Kerry is the INCOSE President-Elect. She has also been a past-INCOSE Sector Director for Asia-Oceania, a past-National President SESA, the Australian Chapter of INCOSE, and has held various roles on conference and events committees and University program advisory boards throughout her career.

Position Paper

The theory of the continuous integration, DevOps and other similar approaches in supporting collaborative interaction is not new. History does show for complex, large systems of System of Systems (SoSs) acquisitions, projects with the higher success rates (ie delivering with acceptable compliance, on schedule and within budget) were executed under very collaborative and continuous integration environments, generally through incremental or evolutionary structures, taking into consideration the whole life-cycle needs. So why now has the importance of continuous integration, DevOps, agile practices and other lean approaches taken on significance?

Working under the age of the 4th Industrial Revolution, with greater velocity in technology changes and disruptors, the introduction of new technologies such as AI and autonomy and the increasing prevalence of inter-connectedness whether through IoT devices or otherwise, our solutions are more complex. In parallel, the expectations of our stakeholders are higher, primarily through greater maturity and exposure to technology. This 2 edged sword makes mixed discipline projects even tougher to delivery.

However, is this purely an Engineering problem? We do have enablers such as digital engineering, advances in computational power and storage, greater sensors and easier interfaces. But is this enough? I will argue no for mixed discipline projects

Consider different disciplines involved – technical and non-technical. The assumption all challenges for each discipline can be met with the same mindset, similar tools and equivalent risks is dangerous. Add to this mix the contractual constraints imposed by both the acquirer and the supplier and the ability of either of these organisations to change their approach and indeed culture is often "the black elephant" in the room.

As a panelist I will discuss from the perspective of a practitioner across the various domains I have worked around the

world, the hurdles that must be met, and the recommendations I have found to be of worth. These same recommendations have become my personal set of heuristics which I will share.
In the discussion I will present various view points from an acquirer and supplier perspective, and from a supply chain perspective. For example the challenge on what is possible on a SoS project where the contract is based on milestone deliveries with penalties (not rewards), a large volume of documentation to deliver and the supply chain is global, with both a mix of commercial-off-the-shelf items (COTS), non-development items and developed items, will be presented and dissected. I will identify what leverages may be possible and the pitfalls to avoid.

Robin Yeman (Lockheed Martin Corporation) - robin.yeman@lmco.com
Robin Yemen is a Lockheed Martin Fellow with over 25 years of experience in software engineering across multiple domains building everything from submarines to satellites. She has been leading Agile projects at scale since 2002 both domestically and internationally. In 2014 she began to move the DevOps practices and has seen even greater success with the increased levels of automation. Robin Received her bachelor's degree in computer science at Syracuse University, Master's Degree in Software Engineering at Rensselaer Polytechnic Institute, and is currently working on her PHD in Systems Engineering at Colorado State University.
Position Paper
Mixed discipline projects, where we build products such as Radar, Planes, and Satellites can and do benefit from continues integration and DevOps practices. Practices such as multiple horizons of planning, timeboxing, cross functional teams, test first, short feedback loops, and continuous (continuish) integration enable us to deliver high quality products in the shortest sustainable lead-time. As technology has improved leveraging tools such as modelling, emulation, simulation, and digital twins provide mechanisms to get faster feedback on Cyber Physical systems where we have long lead times on bespoke hardware. In many cases the tools will reduce risk exposure much earlier in the project. So while we may not deploy a radar every two weeks, obtaining feedback from stakeholders as we are building capabilities reduces the amount of rework and fixes problems much earlier therefore reducing the total cost of ownership.

Tom McDermott (Systems Engineering Research Center, Stevens Institute of Technology) - tmcdermo@stevens.edu
Tom McDermott serves as the Deputy Director of the Systems Engineering Research Center (SERC) at Stevens Institute of Technology in Hoboken, NJ. The SERC is a University Affiliated Research Center sponsored by the Office of the Secretary of Defense for Research and Engineering. With the SERC he develops new research strategies and is leading research on Digital Engineering transformation, education, security, and artificial intelligence applications. Mr. McDermott also teaches system architecture concepts, systems thinking and decision making, and engineering leadership. He is a lecturer in Georgia Tech's Professional Education college. Mr. McDermott has over 33 years of experience in technical and management disciplines, including 15 years at the Georgia Institute of Technology and 18 years with Lockheed Martin. He served as Director of Research and Deputy Director of the Georgia Tech Research Institute. He held a director level position with Lockheed Martin, serving as Product Team Lead and Division Manager for Lockheed Martin's F-22 Raptor Avionics Team.
Position Paper
Continuous integration in software is a practice where code is integrated back into a product repository as it is finished, often several times a day. These practices rely on tools that automatically rebuild and test the software as it is reintegrated. Continuous integration is built on the practices of test-driven development, where product and test are developed simultaneously, ideally creating an emergent mindset across the development team of continuous quality. Automated build processes minimize the time between a software team's submittal of new or modified code and the subsequent build and/or test processes. This implies that automation of product build/assembly, test, and more recently deployment. These concepts have been applied by the DevOps community to integrate multiple disciplines such as software, IT, security, product support, marketing, etc. It must be noted that most of these disciplines produce "intangible" work (software, information, documents, training, etc.) dependent on relatively stable "tangible" items (computing hardware, networks, physical devices, people, etc.). Even when employing agile or DevOps processes in traditionally hardware dominated disciplines such as aircraft or automotive domains, the assumption of a stable set of "tangible" platforms is critical.
The organizations and disciplines that focus on developing new tangible components of a system tend to be assumed out of a continuous integration process. There are a number of technologies that may shift this, including additive manufacturing, low-cost IoT sensors, digital twin simulations, and digital engineering. Although the continuous integration cycle time will generally be longer for tangible items, the philosophy of continuous integration should be expanded to all disciplines.
The concept of a live-virtual-constructive simulation may be useful for continuous integration in an automated build and test infrastructure. Digital engineering, digital thread, digital twin, and similar concepts push the idea of co-developing systems (tangible) and models/simulations (intangible) as common linked products. We can envision a systems engineering process where system level integration occurs in hardware-in-the-loop simulation environments that have automated system build and test capability.
There are challenges the systems engineering community needs to address. The first is our own disciplinary stovepipes. Modeling & simulation, particularly at the systems level, tends to be its own disciplinary stovepipe. It is defined as a supporting process in systems engineering. Another is instrumentation and visualization, as each discipline needs to get data from the continuous integration environment in a form that supports their disciplinary

evaluation and learning process. A final is lifecycle related – what do you build, simulate and test? Operational, manufacturing, build, or external environments? And to what level and test-driven purpose?
These questions are and will be affected by the evolution to digital engineering processes and tools, and to systemic co-development of live-virtual twins. We do not yet know what is possible. However, the concept of a system level continuous build and integration environment is one that needs to come about and be a key component of digital product development and systems engineering strategies.

Duncan Kemp (Ministry of Defence) - Duncan.kemp735@mod.gov.uk
Duncan Kemp is the Senior Fellow for Systems Engineering at Defence Equipment and Support in the UK MOD. Duncan is currently the team leader of DE&S internal SE team which he has grown from scratch to over 40 people overt the last four years. Duncan's team supports a range of programmes from Command and Control systems through to major maritime, land and air platforms. Previously roles include: • Chief systems engineer for rail in the Department for Transport, where he initiated the work on the Rail Value for Money study and led the study's work on asset management, supply chain management and whole system asset management. • The MODs C4 architect, responsible for integrating over 1000 applications, systems and services on to the MOD's core network. Duncan oversaw the development of the deployed technical architecture for operations in Afghanistan and the introduction of the MODs network joining rules. • Warship Support Enterprise Integration programme manager. Duncan oversaw the implementation of a range of e-business applications to better integrate warship supply chains. Duncan has authored over 20 peer reviewed papers, and is one of the authors of the INCOSE SE Vision 2025, the INCOSE UK Capability SE Guide and the INCOSE UK Agile SE guide. Duncan is a Chartered Engineer and Fellow of the Institution of Engineering and Technology. He was elected a fellow of INCOSE in February 2020.
Position Paper
Until the mid to late 1990s, there were significant synergies between System and Software Engineering practice. By the early 2000's, however, the practices had started to diverge.
This divergence was driven by the explosive growth of the World Wide Web and later e-commerce. This was, in turn, driven by a small number of technological innovations. The use of thin clients on the front of heavy-duty databases enabled significant reductions in cycle times. Previously deployment of thick client solutions required tight control of client configurations and would typically take weeks to deploy (or even months for deployed hardware).
In parallel, time to market became critical. A good solution delivered late was a failure. A barely acceptable solutions delivered early would become a market leader. Flaws on the delivery of the working solution could be fixed in a later update. This environment led to a massive increase in the use of Agile approaches such as DSDM or SCRUM.
Despite some attempts to speed up Systems Engineering, Systems are different to software. Specifically:
• Few systems are open and modular, making it hard to modify the solution once it has been developed. The upgrade costs are significant, and physically upgrading products that have already been deployed can be prohibitively expensive
• The physical manufacturing phase can significantly increase the time to deploy.
• Most systems have significant safety and regulatory challenges. In a large number of cases the minimal viable product is the end product.
Attempts to bridge the gap have either been:
• To embrace the Agile software development approach and apply it to systems. This has worked well in high margin consumer goods (although, for example, Smartphone development times are still 3-5 years). It has also led to significant failures.
• To apply lean approaches to reduce the time to market. Modular build and architecting the system for rapid development have generally reduced development time (normally at increased cost)
• To partition development in to high-integrity and high-tempo developments with a clearly defined interface between the two.
The challenge of cyber-physical systems is that they often have significant safety or security risks. The expectation from investors and consumers is that they will be delivered at the tempo of low-integrity software. The expectation of regulators and consumers is that they will meet industry standard safety and security requirements. Duncan will discuss the challenges of meeting both sets of needs.

Panel#3

Meet your Match: A Mentoring Roundtable

Erika Palmer (Ruralis) - erika.palmer@ruralis.no
Stueti Gupta (Self-employed) - stueti.gupta@gmail.com
Lisa Hoverman (HSMC) - lisa@hsmcgroup.biz
Lauren Stolzar (EWLSE) - lstolzar@gmail.com
Alice Squires (Washington State University) - Alice.squires@wsu.edu

Paper not presented

Keywords. EWLSE;Empowering Women Leaders in Systems Engineering;mentor;mentee;mentoring;mentorship;diversity;career development

Topics. 2. Aerospace; 4. Biomed/Healthcare/Social Services; 5.10. Diversity (cultural boundaries, diverse engineering teams, training underserved groups, etc.); 5.9. Teaching and Training; 6. Defense;

Abstract. Have you ever wondered what it means to be a mentor? Or what makes for a successful mentoring relationship? Are you currently looking to mentor someone, or find a mentor for yourself?

Join EWLSE (Empowering Women Leaders in Systems Engineering) for a discussion on what it takes to form a strong and lasting mentor / mentee relationship. We will explore topics such as:
• What makes a successful mentor / mentee relationship?
• What are the benefits and challenges of cross-cultural mentorship?
• How do you define a mentor / mentee relationship?
• How does a mentoring relationship change throughout your career?

During the discussion, there will be opportunities to meet potential mentors and mentees, as well as time dedicated to networking and finding your match.

All are encouraged to join for what promises to be a great opportunity to dig deeper and work towards building stronger mentorship opportunities.

Biography

Stueti Gupta (Self-employed) - stueti.gupta@gmail.com
Stueti Gupta is formerly a Systems and Architecture Lead at John Deere India. She has led systems engineering research projects such as system dynamics modeling and simulation and system architecture analysis. She co-led Systems Engineering competency development at the technology centre of John Deere India largely around Model Based Systems Engineering using SysML. Stueti received formal certification in Systems Design and Management from Massachusetts Institute of Technology, USA. She has trained over 200 engineers on TRIZ and other innovation methods and has a Journal publication, 9 conference presentations (1 best paper award), 8 Deere Tech Letters on her work. She is currently the President of International Council on Systems Engineering India Chapter, re-elected for second term. Stueti has held various leadership roles in SWE locally in India as well as in global initiatives. Stueti received Society of Women Engineers' Distinguished New Engineer Award in 2016. This award category honors women engineers who have been actively engaged in engineering in the first 10 years of their careers. SWE and INCOSE leadership roles have had a significant impact in her personal and professional development.

Lauren Stolzar (EWLSE) - lstolzar@gmail.com
Lauren Stolzar is a systems engineering lead and member of Cohort 4 of INCOSE's Institute for Technical Leadership (TLI). She specializes in bringing systems engineering to complex, software-centric projects and organizations. With over 10 years of experience, Ms. Stolzar has led the charge bringing technology from early stage research to production, with a focus on organizational structures and technologies that enable the full lifecycle.

Alice Squires (Washington State University) - Alice.squires@wsu.edu
Alice F. Squires has served in professional roles for over 35 years including nearly 25 years in industry. Alice currently serves as an Associate Professor in Engineering and Technology Management at Washington State University. Alice founded the INCOSE Empowering Women Leaders in Systems Engineering (EWLSE) group and serves INCOSE Academic Matters and the Americas and as co-editor of the SEBoK wiki. She also serves on the boards of the ASEE Systems Engineering Division, Corporate Member Council, and Committee on Diversity, Equity, and Inclusion. She recently wrote an IEEE-USA women in engineering ebook on women overcoming various challenges to complete a STEM education and succeed as a STEM professional, titled: "Dandelion Wishes: A World Where We Collaborate as Equals" (see: https://ieeeusa.org/shop/careers/wie-book-21/), co-authored Chapter 5: Merging Literature and Voices from the Field: Women in Industrial and Systems Engineering Reflect on Choice, Persistence and Outlook in Engineering published by CRC Press as part of Emerging Frontiers in Industrial and Systems Engineering: Success Through Collaboration, and served as theme co-editor for the Fall 2019 'Diversity in Systems Engineering' INCOSE Insight edition.

Panel#5

Preventing Big System Failures: Quality Management for a new Era of Complex and Intelligent Systems

Barclay Brown (Raytheon Company) - barclay@barclaybrown.com
Jack Ring (Self) - jring7@gmail.com
Jorg Largent (Self) - LARGENT_ATPMD@msn.com
Larry Kennedy (Quality Management Institute) - larry@qmnation.com
Hazel Woodcock (IBM) - hazel.woodcock@uk.ibm.com

Paper not presented

Keywords. Quality Management;System Failures;Intelligent Systems;Complex Systems

Topics. 1.2. Cybernetics (artificial intelligence, machine learning, etc.); 1.6. Systems Thinking; 3.8. Quality Management Process; 4.4. Resilience;

Abstract. Complex, interconnected systems are now the norm in all aspects of human endeavor. Few, if any, systems are isolated and able to control their own destiny, including the complex biological systems known as human beings. When these complex systems fail in systemic ways, especially in ways that make headlines, the causes are systemic as well. Quality Management, in particular Systems Engineering Quality Management, is the field that aims to prevent systems-level failures. Of course, it is important to try to prevent system failures to prevent the loss of life, property, money and time, but it's also important to be able to assure the world that there is someone on the case and that they need not fear the unintentional emergence of SkyNet-enabled killer robots, uncontrolled autonomous weapons, risky self-driving cars or devastating cyber attacks on our unnecessarily vulnerable online systems.

Topics and Questions for Discussion:

Can systems and processes overcome the need for good people?
Are some catastrophic events inevitable?
Are intelligent systems MORE susceptible to failure, or less?
How can verification and debug procedures be made better and more efficient through artificial intelligence?
How can we ensure that a human+computer system is better than just a human or just a computer?

Biography

Barclay Brown (Raytheon Company) - barclay@barclaybrown.com
Barclay R. Brown is an Engineering Fellow for Raytheon Company and the business unit lead for model based systems engineering and co-lead for the AIML Center of Excellence. Before joining Raytheon, he was the Global Solution Executive for the Aerospace and Defense Industry at IBM, and was the lead systems engineer for some of IBM's largest development projects. Dr. Brown has been a practitioner, consultant and speaker on systems engineering, intelligent systems and software development methods for over 25 years and holds a bachelor's degree in Electrical Engineering, master's degrees in Psychology and Business and a PhD in Industrial and Systems Engineering. He teaches systems engineering and systems thinking at several universities, and is a certified Expert Systems Engineering Professional (ESEP), certified Systems Engineering Quality Manager, and the former INCOSE Director for the Americas.

Jack Ring (Self) - jring7@gmail.com
Jack Ring is a Fellow, 2002, of the International Council on Systems Engineering (INCOSE). He has more than sixty years of experience as executive, system thinker and management practitioner in aerospace, industrial, commercial and public sectors. His contributions spanned project management, systems engineering and product manager as well as market research and competitive intelligence director, and corporate strategy and development VP. As a systems practitioner in General Electric Aerospace (20 years), Honeywell Large Computer Systems (10 years), and IBM Object

Technology Consulting (5 years) he staffed and organized more than 40 SE projects that met stakeholder expectations and recommended corrective action on more than 20 others that were not. He has mentored more than a dozen high tech startups as sole proprietor of Innovation Management and is a founding partner of Kennen Technologies llc, OntoPilot llc, and Educe-U llc. He is currently leading a dialog on the implications of initializing autonomous systems that Do No Harm.

Position Paper

Ensuring Big Systems Do No Harm,

Our current decade of producing and controlling autonomous systems for military and industrial purposes has revealed that
A) SE practitioners do not yet know how to initialize autonomous systems that Do No Harm,
B) Prevailing SE practices presume deterministic situations whereas autonomy involves probabilities such as permissible levels of False Positives and False Negatives, and
C) INCOSE, NIST, SAE and others are focusing on deployed systems whereas the key challenge is the mostly human system we call Systems Engineering that initializes the deployed system.

We must focus on SE'ing SE to ensure that the mostly human system will First, Do No Harm. Our opportunity is to
A) Acknowledge that there is more to SE than Engineering, e.g., General Semantics, Social Group Dynamics, and a 15:1 span of competency levels among available practitioners that goes beyond systems Thinking to systems Feeling, to systems Making (laboratory), to systems Doing (with others) to systems Being (with autoimmunity of harm in their personal evolution and progeny).
B) Ensure our specification regarding system Purpose and Fit For Purpose clarifies what a system must Not Do as well as what it Must Do.
C) Adopt and leverage the already proven practices of Systems Engineering Quality Management, SEQM.

Jorg Largent (Self) - LARGENT_ATPMD@msn.com

Jorg Largent's career spans 55 years and ranges from the enlisted ranks of the United States military to Lead Systems Engineer on the B-2. In between he matriculated at the Georgia Institute of Technology. After completing his formal training, he worked in orbital mechanics on the Apollo Program. At the close of the Apollo program Jorg became a Flight Test Engineer, primarily on the CH-46E, the B-1A, and the B-2. After he left Flight Test he moved on to liaison engineering and then to system engineering on the B-2 program and special projects. Jorg has been active in INCOSE working groups, including Transportation, Very Small Entity, and Systems Engineering Quality Management. Jorg is a writer and the Editor of the INCOSE-LA Newsletter.

Larry Kennedy (Quality Management Institute) - larry@qmnation.com

Larry Kennedy Larry Kennedy is the Founder and CEO of the Quality Management Institute and has provided consulting 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 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.

Panel#4

Systems Approaches in Policy and Governance

Jargalsaikhan Dugar (TUSSolution)
Chuck Keating
Alan Harding (BAE Systems) - alan.d.harding@baesystems.com
Mo Mansouri (Stevens Institute of Technology) - mo.mansouri@stevens.edu

Paper not presented

Keywords. Governance;Policy;Socio-Technical Systems;Systems Thinking;Systems Dynamics

Topics. 1.4. Systems Dynamics; 1.6. Systems Thinking; 5. City Planning (smart cities, urban planning, etc.); 5.4. Modeling/Simulation/Analysis; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Human agents and societies they belong to are always a part of systems complexities. Societal aspects are always an inevitable part of any socio-technical system in which human beings interact within the context of a multi-layered infrastructural and technological complex. New approaches for designing policies and governing mechanisms are necessary in order to optimize collective gains through dynamics of such systems. Development of such approaches based on principles of systems thinking and systems design methodology will be also useful in problem solving processes in response to challenges in societies and in response to wicked problems we are all facing around to world.
This panel is dedicated to discuss and examine current research and practices, also explore future trends on methods and tools related to governance of societal systems and other complex environments through engagement and education of stakeholders, informing policymakers through data-driven approaches, implementation of incentive structures, and collaborative problem solving.

Biography

Jargalsaikhan Dugar (TUSSolution)
Jargalsaikhan Dugar is CEO of TUSSolution LLC Management Consultancy in Ulaanbatr, Mongolia. he has held senior roles in investment banking and finance, and the role of Head of Geology and Mining in the Ministry of Trade and Industry, Mongolia. BSc Mineral Economy, Moscow School of Mining. Diploma - Mining and Geology, Colorado School of Mines.
Position Paper
Jargalsaikhan Dugar case study examples of applying systems approaches to government policy and applying systems and logical thinking to governance challenges.

Chuck Keating
Chuck Keating is Professor of Engineering Management & Systems Engineering. He also serves as the Director, National Centers for System of Systems Engineering. He joined the faculty of Old Dominion University in 1993. Ph.D. in Engineering Management, Old Dominion University,(1993). M.A. in Management and Supervision, Central Michigan University,(1984). B.S. in General Engineering, United States Military Academy,(1979)

Alan Harding (BAE Systems) - alan.d.harding@baesystems.com
Alan Harding is the Head of Information Systems Engineering in the BAE Systems Air business in the UK, responsible for the provision of systems engineering capability across the Defence Information business. Alan is also a BAE Systems Global Engineering Fellow, appointed in 2012. Alan was INCOSE President for 2016-2017, he co-chairs INCOSE's Systems of Systems Engineering working group. Alan is a systems engineer with over 34 years' experience mainly in defence and aerospace. Alan has a Bachelor's Degree in Physics from the University of Durham, is a Chartered Engineer, and a Fellow of the IET.
Position Paper
Alan Harding All engineered systems (as per the INCOSE definition of systems engineering) exist in a wider context, framed by the sustainable development model (social, economic, environmental). Ultimately the UN sustainable development goals 2030 set the success criteria for success of each of our engineered systems … and for human civilisation and our planet. Policy and regulation (international, national, regional, local) is both part of this context and is an element of the wider system of systems that can be "engineered". What is the state of art and practice, where are today's challenges, and how well is our engineered policy contributing to global sustainability?

Mo Mansouri (Stevens Institute of Technology) - mo.mansouri@stevens.edu
Dr. Mo Mansouri joined the Stevens Institute School of Systems and Enterprises in July 2006. His research interests are resilience in Infrastructure Systems and Infrastructure Governance. Prior to joining Stevens he served as a consultant for the HAND Foundation, the World Bank, NIAC and other non-profit entities. Dr. Mansouri holds a PhD in Engineering Management from George Washington University.
Position Paper
Mo Mansouri will discuss research and experience of applying systems dynamics and other approaches to assessing and evolving governance.

Panel#7

The Role of Diversity, Equity, and Inclusion in Sustaining Earth's Future

Stueti Gupta (BlueKei Solutions) - stueti.gupta@gmail.com
Alice Squires (Washington State University) - alice.squires@wsu.edu
Suja Joseph-Malherbe (Letter27) - sjosephmalherbe@gmail.com
Alan Harding (BAE Systems – Air) - alandharding@gmail.com
Lamona Rajah (Cummins Africa Middle East) - Lamona.rajah@cummins.com

Presented on: Tuesday, 10:00-11:25

Keywords. diversity;equity;inclusion;sustainability

Topics. 1.6. Systems Thinking; 10. Environmental Systems; 17. Sustainment (legacy systems, re-engineering, etc.); 5.10. Diversity (cultural boundaries, diverse engineering teams, training underserved groups, etc.);

Abstract. As the trends of a more diverse world population and increasingly interdependent global community continues, the impact of imbalances in access, opportunity, and power for underrepresented communities could have far-reaching negative effects on the planet's future. This panel will investigate through a systems thinking lens how our ability to integrate diversity, equity, and inclusion in our approaches and practices will affect the long term sustainability of the planet, its resources, and the human race.

Biography

Stueti Gupta (BlueKei Solutions) - stueti.gupta@gmail.com
Stueti is an experienced Systems and Architecture lead as well as has been manager for off-highway equipment automation teams. She has led systems engineering research projects and co-led Systems Engineering competency development at the technology center during her tenure at John Deere India, largely around Model Based Systems Engineering. She has some publications in this area, one of which received the best paper award at an international conference. Stueti studied at BITS Pilani, and completed her second masters from Cornell University, USA. She also received formal certification in Systems Design and Management from Massachusetts Institute of Technology, USA. She is actively involved in the International Council on Systems Engineering and is also the President of India Chapter. Stueti has held various leadership roles in Society of Women Engineers locally in India as well as in global initiatives.

Position Paper

Scientists say it took universe 13.8 million years to create Earth and it will not take long for us to make it inhabitable. Natural disasters such as wildfires, earthquake, sudden cloudbursts eventually leading to floods, air quality decline and many other such events have caused major devastation not just loss of life but poor public health, cause diseases, destruction of private and public infrastructure. What happens to our planet's future as part of the universe can only be predicted and is not in our control, however in the context of our living environment, many things are in our control and every action of human race has an impact.

Consider the human race as a system. Humans have social & physical behaviour, define and imbibe policies, legalities, humans migrate and their interactions lead to a certain behavior of the system. Historically gender stereotyping, patriarchal society, cultural barriers, lack of governance have led to various industries, societies to be less inclusive to women.

As per UN, globally, over 2.7 billion women are legally restricted from having the same choice of jobs as men. 104 of 189 economies still have laws preventing women from working in specific jobs, 59 economies have no laws on sexual harassment in the workplace, and in 18 economies, husbands can legally prevent their wives from working. More than 50% of urban women and girls in developing countries live in conditions where they lack necessary resources and many more such insights.

All the surveys and news only indicate one thing that it is time to be more equitable, inclusive and have diverse perspectives in decision making. The only way to accomplish this would be the use of systems thinking. Systems thinking will empower decision makers to understand and analyze the context, system and stakeholder behaviour, help

with how different agencies across borders will need to work together and enable cooperation and thereby make more informed decisions.
The speaker has been personally involved since several years in the STEM education of school girls and career development of college and professionals to attract and retain women in the workforce. She has organized and led several events to show the importance of education and inspire participation of women in global workforce.

Alice Squires (Washington State University) - alice.squires@wsu.edu
Dr. Alice F. Squires has served in professional roles for over 35 years including nearly 25 years in industry. Alice currently serves as an Associate Professor in Engineering and Technology Management at Washington State University. Alice founded the INCOSE Empowering Women Leaders in Systems Engineering (EWLSE) group and serves INCOSE Academic Matters and the Americas and as co-editor of the SEBoK wiki. She also serves on the boards of the ASEE Systems Engineering Division, Corporate Member Council, and Committee on Diversity, Equity, and Inclusion. She recently wrote an IEEE-USA women in engineering ebook on women overcoming various challenges to complete a STEM education and succeed as a STEM professional, titled: "Dandelion Wishes: A World Where We Collaborate as Equals" (see: https://ieeeusa.org/shop/careers/wie-book-21/), co-authored Chapter 5: Merging Literature and Voices from the Field: Women in Industrial and Systems Engineering Reflect on Choice, Persistence and Outlook in Engineering published by CRC Press as part of Emerging Frontiers in Industrial and Systems Engineering: Success Through Collaboration, and served as theme co-editor for the Fall 2019 'Diversity in Systems Engineering' INCOSE Insight edition.
Position Paper
While there are many aspects of diversity that when understood and embraced lead to higher performing teams and superior product and service outcomes, there are global contexts and issues our planet faces that create divisiveness among our people that are not directly related to what we traditionally view as diversity related differences. These global contexts and challenges include differing views and positions related to various global challenges such as global warming, anti-resistant bacteria, sustainability of the earth's ecosystems, gasoline-powered versus electrical-powered systems, artificial intelligence, etc. That is, where raising awareness may be the first step towards embracing the diversity of all peoples, there are areas upon which groups of diverse individuals remain divisive and non-accepting of alternative views (views different from their own) – potentially resulting in exclusive behaviour and inequities that can inhibit the ability of the human race to solve the global challenges critical to the survival and prosperity of the planet and the human race. According to the Global Challenges Foundation "… the next 50 years will set the pace for humanity's survival in the next 10,000 years."
(https://www.businessinsider.com/biggest-risks-survival-of-humanity-in-50-years-2018-10) To address diversity, equity, and inclusion more broadly requires the development of cognitive and affective perspective-taking – precursors to cognitive and affective empathy. Perspective-taking allows us to recognize and appreciate another person's point of view, even or especially when it is different from our own. Cognitive perspective-taking supports the ability to infer another person's thought or beliefs, and affective perspective-taking supports our ability to infer another person's feelings or emotions. The empathic equivalents allow us to think (take on the mental perspective and infer mental or emotional states) and feel (share the emotional experience) what others are thinking and feeling. Through inclusivity, perspective-taking, and empathy, groups supporting different agendas can break down divisive barriers and find equitable solutions in support of a promising future for both the planet, and the human race.

Suja Joseph-Malherbe (Letter27) - sjosephmalherbe@gmail.com
Suja Joseph-Malherbe provides training and consultancy services in systems engineering and leadership development services through training and coaching to individuals and organizations. She is a Certified Systems Engineering Professional and a Solution-focused Brief Coach (ICF-ACSTHs training). Previously, she developed training material for Project Performance International, Australia, and created first-of-its-kind outdoor and fitness products for Garmin Stellenbosch. She led the management of software releases including the testing, deployment and support of new software, performed substantial modelling and simulation, image processing, and developed technology systems, such as battery packs for the dismounted soldier for the Council of Scientific and Industrial Research (CSIR) for the defence industry in South Africa. Suja received her B.Sc in Electrical Engineering from the University of Witwatersrand, South Africa and her M.Eng in Electrical and Electronic Engineering from the University of Johannesburg, South Africa. She has a passion for leadership and systems engineering and is active in INCOSE, serving as a member of the INCOSE International board of directors, as Chair of the Ways and Means Committee, from July 2014 to December 2016, as a member of the inaugural cohort of the INCOSE TLI, and as the Immediate Past President of INCOSE South Africa to 31 December 2020.
Position Paper
Addressing diversity, inclusion and equity is important to the potential growth and innovation in engineering. It is about creating opportunities to adapt and to find creative approaches to the engineering challenges we are facing.
Diversity is not limited to gender alone. It is about creating teams with diverse thinking achieved through tem members with diverse personalities, thinking styles, working styles, age, background, area of expertise, experience etc. As a result, team members will be exposed to multiple points of view, have their own views and contributions challenged and in the process, formulate approaches and solutions that achieves better results.
This will only work if the environment is also inclusive. Inclusion is about creating the space where team members have a sense of belonging. As such, they are their authentic selves in the workplace and feel valued. They are willing to put

themselves out there if you in sharing their thoughts and ideas. In both instances, research shows that diversity and inclusion encourages better creativity and innovation. Of course, this is something that ought to be ingrained in the organization and not dealt with as an after-thought.

Alan Harding (BAE Systems – Air) - alandharding@gmail.com
Alan Harding is the Head of Information Systems Engineering in the BAE Systems Air business in the UK, responsible for the provision of systems engineering capability across the Defence Information business. Alan is also a BAE Systems Global Engineering Fellow, appointed in 2012. Alan was INCOSE President for 2016-2017, he co-chairs INCOSE's Systems of Systems Engineering working group. Alan is a systems engineer with over 34 years' experience mainly in defence and aerospace. Alan has a Bachelor's Degree in Physics from the University of Durham, is a Chartered Engineer, and a Fellow of the IET.

Position Paper

• The UN sustainable development goals for 2030 highlight what we have to do together as a human race to survive and prosper. These 17 goals and 169 targets frame the toughest challenges, each of which is a systems challenge.
• All engineered systems (as per the INCOSE definition of systems engineering) exist in a wider global context, framed by the sustainable development model (social, economic, environmental)
• It is widely recognised that organisations with diverse leadership and teams achieve better results. Therefore it is clear that we should harness the maximum possible diversity to address the global goals.
• The aspect I will explore is what can INCOSE, the global systems engineering society, do to make the greatest possible contribution to achievement of the global goals.

Lamona Rajah (Cummins Africa Middle East) - Lamona.rajah@cummins.com
Lamona Rajah is the Diversity & Inclusion (D&I) Leader for Cummins Africa Middle East where she enables leaders and employees to value and leverage diversity and practice inclusive behaviours to fuel business success. She has developed and implemented a D&I Framework in Africa Middle East covering 17 countries in the region. Prior to this, Lamona spent 11 years in the Banking sector in various business roles before moving into HR and specializing in Transformation Focused Development Programs targeting previously disadvantaged groups in South Africa. During the next 4 years in the ICT sector (Accenture) she specialized in Talent Strategy and D&I managing global Women's Programs to increase the pipeline of women. Lamona has been at Cummins Africa Middle East for 3 years. She facilitates topics on unconscious bias, inclusive leadership, cultural diversity, race & ethnic diversity, disability awareness etc. and serves as a key note speaker on D&I topics. As a Gallup Strengths facilitator, she believes that leveraging people's strengths is key to engagement, job satisfaction, productivity and high performance. She holds an Honours degree in Psychology, and a Marketing Diploma. She is pursuing her second Honours degree in Industrial & Organisational Psychology.

Position Paper

• The business case for diversity and inclusion is solid and in 2020 is well socialized, yet as the world advances in knowledge and technological innovations, gaps still exist in how innovations and environmental sustainability efforts are received at community grass root level.
• I believe that this is due to cultural ignorance and the myth that great solutions that work in the Western world will work in the under developed and developing world. Yet it is the latter that require the solutions more than the former -especially as we progress toward a more sustainable future for the planet.
• As advancements are discovered, a diversity and inclusion mindset will leverage the knowledge and talents in local communities to develop relevant sustainable engineering solutions to human issues. Often, we rely on expertise outside of the region or country to develop solutions that are not consumable by local communities. Sometimes it is because of the misnomer of the "one-size-fits-all" and at other times it is due to resistance from local communities. Investing in local talent to refine existing knowledge and skills or developing new ones is key to creating sustainable efforts for the future.
• In Africa Middle East, a deep-seated belief and behavioural norm is that knowledge and wisdom lies in the elders and those bestowed with power, whether from ancestral lineage or earned positions in societal structures. It will benefit the engineering community and other technology gurus to understand these dynamics and learn the skills of advocacy and allyship to gain knowledge that is "protected" from outsiders and gain buy in for acceptance of new solutions.
• A collaborative problem-solving approach with a default mode of intentionally including diverse perspectives from locals at concept level is key before progressing onto the advanced solutioning phases.

Presentation

Presentation#27

A Lean Trade Analysis Methodology for Improved Alignment with Stakeholders

Mike Celentano (Eli Lilly and Company) - mike.celentano@lilly.com

Paper not presented

Keywords. Trade Studies - Trade Analysis - Stakeholder Management - Industry - Commercial - Lean - Decision Management - Celentano Matrix

Topics. 19. Very Small Enterprises; 3.3. Decision Analysis and/or Decision Management; 5.2. Lean Systems Engineering; 5.5. Processes;

Abstract. Since Stuart Pugh published his Concept Selection methodology in 1981 most engineers have been trained to use decision matrices for trade analysis. It is an undeniably
powerful tool to help reach objective and documented decisions for engineering teams.

However, this method is often driven by engineers to a level of detail that becomes problematic.
Sometimes specmanship and analysis paralysis prevails.
Other times those with agendas game the scoring or weighting until they get the answer they want. Often, the level of detail and resulting size of the table becomes disenfranchising to stakeholders, which can lead to distrust in the commercial industry where the stakeholders often do not have a technical background.

A novel decision matrix was developed over the years that is specifically tailored for system level decisions that must be ratified by stakeholders. While it can be supplemented by a full Pugh matrix, this one-page method has proven to be effective enough in most circumstances to gain stakeholder consensus on important trades without more analysis. This lean approach has resulted in a reduction in waste while gaining faster decisions without sacrificing good decision management.

Presentation#5

A survey of emerging standards for supporting Digital Engineering Information Exchange

Celia Tseng (Raytheon) - celiastseng@gmail.com

Presented on: Wednesday, 14:00-14:40

Keywords. Digital Engineering - MBSE - standards - digital artifact - Supply and Acquisition

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

Abstract. There are currently no industry-wide agreement on standards or conventions to enable a universal exchange of digital artifacts between buyers and suppliers in a global supply chain. Digital Engineering Information Exchange Working Group Standards Framework (DEIX WG -SF) conducted a survey of current and emerging standards for facilitating digital information exchange. This presentation contains the initial summary findings of reverent standards and gaps.

Presentation#60

An introduction to Systems Safety

Duncan Kemp (Ministry of Defence) - duncan@17media.co.uk
Meaghan Oneil (INCOSE) - meaghan.oneil@gmail.com

Presented on: Monday, 16:20-17:00

Keywords. Safety - Leadership - Safety Culture - STAMP - Functional safety - Safety management - Intrinsic safety - Machine learning

Topics. 4.6. System Safety; 4.7. System Security (cyber-attack, anti-tamper, etc.);

Abstract. This presentation will provide an introduction to System Safety.
The presenters will explore three basic safety management challenges faced by system developers:
• Intrinsic safety of individual components.
• Emergent safety of the system being developed.
• Safety of the wider system of interest including people and the wider services and enterprise the system is supporting.
• Establishing an effective safety culture to support the above
The presentation will focus on the last two classes of system safety and explain the challenges of ensuring safe system behavior. The presenters will explain the challenges of:
• Aligning the safety management practices in some highly regulated environments (such as rail, aerospace or medical devices) to the systems engineering practices whilst minimizing costs and time to market.
• Different safety management approaches in different sectors, geographies and positions in the supply chain
The presentation will cover some of the emerging challenges to ensuring system safety including:
• Increased use of software
• Systems-of-systems and internet of things
• Inexpert 'designers', operators and unlicensed maintainers
• Increased use of automation, machine learning and deep learning
Finally, the presenters will present their personal views as to the future of System Safety engineering.

Presentation#3

Design integration of a multi-national science infrastructure project

Gerhard Swart (SKA Organisation) - g.swart@skatelescope.org
Marco Caiazzo (SKA Organisation) - m.caiazzo@skatelescope.org

Paper not presented

Keywords. Science Infrastructure - Design Integration - Interface Management - System Budgets - System Model

Topics. 2. Aerospace; 2.4. System Architecture/Design Definition; 2.5. System Integration; 5.5. Processes;

Abstract. The Square Kilometre Array (SKA) Observatory will establish its headquarters at Jodrell Bank in the UK and construct two radio telescopes: SKA-Low in Australia and SKA-Mid in South Africa. The SKA will be the largest radio telescope on earth, with unprecedented sensitivity and scientific capability. The first phase of the SKA, called SKA1, will cost around 790m Euro and is due to start construction in early 2021.
SKA1-Mid will comprise 197 dish-antennas and is located in the remote, radio-quiet Karoo region, incorporating the recently completed MeerKAT antennas. The more than 18 Tb/s of digitised antenna data is initially processed in the Central Signal Processor near the array. This reduces the data rate to ~9 Tb/s before it is sent to the Science Data Processor in Cape Town, 500km away. This super-computer performs further user-configurable, real-time processing and stores the science data artefacts for use by the scientific community.
Since 2013 several international consortia, co-ordinated by the SKA Office in the UK, have been developing and prototyping the various telescope Elements in accordance with the top-level System Requirements and an initial architecture. However, due to the collaborative nature of the consortia limited top-down System Engineering was applied, so that the delivered designs were not fully aligned. This made it necessary to re-integrate these designs to establish a coherent System Design Baseline. This extensive process culminated in a recently completed SKA1 System Critical Design Review (CDR).
This paper describes the process and outcome of this design integration and summarises key outcomes and lessons learned.

Presentation#59

Digital Engineering in Practice

Eran Gery (IBM Isreal) - eran.gery@il.ibm.com
Graham Bleakley (IBM UK Ltd.) - graham.bleakley@uk.ibm.com

Presented on: Wednesday, 13:15-13:55

Keywords. Digital Engineering - Digital Threads - OSLC - SAfe

Topics. 14. Autonomous Systems; 16. Rail; 2. Aerospace; 2.4. System Architecture/Design Definition; 3. Automotive; 3.4. Information Management Process; 4. Biomed/Healthcare/Social Services; 5.4. Modeling/Simulation/Analysis; 5.5. Processes; 6. Defense;

Abstract. The presentation describes a practical approach and an architecture to implement digital systems engineering. Today's engineering environments consist of various domain specific tools, and there is no single monolithic solution. The presented architecture is a service oriented architecture based on Oasis/OSLC that provides an integration framework for such typical federated engineering environments. The framework facilitates key lifecycle concerns such as end to end traceability (digital threads), federated configuration management and PLE, central lifecycle graph that supports lifecycle analysis, and cross lifecycle change management. In addition we discuss how agile frameworks such as SAFe are integrated as part of the digital framework. A special focus is to integrate model based environments as part of a broader lifecycle framework. We will present and demonstrate how this architecture implements lifecycle processes such as INCOSE handbook and others like Automotive SPICE as digital processes. We also discuss how the framework is integrated with traditional PLM tools to streamline the systems engineering environment with downstream disciplines like mechanical engineering and manufacturing.

Presentation#55

How much Systems Engineering roles are needed in a project to create value?

Sven-Olaf Schulze (UNITY AG) - sven-olaf.schulze@gfse.de
Christoph Nüse (UNITY AG) - christoph.nuese@unity.de
Sven Hering (UNITY AG) - sven.hering@unity.de

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

Keywords. Project organization - Roles - Tailoring - SE Competency

Topics. 3.5. Technical Leadership; 4.5. Competency/Resource Management; 5.10. Diversity (cultural boundaries, diverse engineering teams, training underserved groups, etc.); 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Systems Engineering is everywhere. The automotive industry, plant engineering industry, consumer good industry, medical industry and others are integrating Systems Engineering thinking into their company based on different business constraints and needs. This impacts large groups and small and medium enterprises (SME) equally and all have the same question to answer: How many Systems Engineering related roles and resources do we need to run an effective and efficient project? Resources are limited and competency must be developed in parallel, too. Another constraint are the levels of hierarchy and architecture levels within the project and the number of teams who are responsible to develop a system. Based on these enterprise problems, the ISO15288 processes and Sarah Sheard's "The Value of Twelve Systems Engineering Roles" paper a methodology of modular roles has been developed with the aim to reduce the risk of missing competencies and limit the resources. Applying the concept helps to create job descriptions and can be mirrored against the project processes, especially when these processes are developed concurrent. Tailoring to the individual enterprise size and project needs the categories of managing, acting, monitoring, collecting and analyzing activities are the challenges. Using the processes of requirements, verification, validation, architecture, decision making, measurement, project planning, configuration management etc and the further need to control the development under the business cases of digitalization new roles are important and need Systems Engineering competency. Considering the projects supported by the authors so far, a concept of "basic roles" where identified to define job specifications in a project and can be applied in different industries and enterprise sizes. In large projects additional supporting roles must be initiated, and the responsibilities must be clarified and written down, while in small projects different roles are allocated to one person. In large projects, eg. a configuration manager needs support to manage all change requests and models and a Chief Engineer in a project may need some domain specific support on system level. How to generate these job specifications not impacting the responsibilities of each main role in a project team? Distinguishing between basic roles and defining the responsibilities ensure a traceable and consistent job map within a project. Furthermore, this must be continued on the sub-system down to the competent level as well and interfacing communication must be clearly defined. The presentation will provide the findings from projects and a modular approach to generate consistent job descriptions.

Presentation#21

Joint Force Integration & Interoperability (I2) Assessment Frameworks: a case study

Jaci Pratt (DST Group) - jaci.pratt@gmail.com
Adam Iannos (DST Group) - adam.iannos@dst.defence.gov.au

Paper not presented

Keywords. Integration - Interoperability - Measurement - case study - framework

Topics. 2.5. System Integration; 3.6. Measurement and Metrics; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 6. Defense; 7. Emergency Management Systems;

Abstract. Introduction
The Australian Department of Defence (ADoD) has been increasing the joint and integrated nature of the Australian Defence Force (ADF) since the Defence White Paper (DWP 2016) and preceding First Principles Review.
The creation of Force Design and Force Integration organisations with new responsibilities and processes has been key to its implementation.
Plan Aurora is the approved ADF plan to ensure delivery of integrated Defence capability throughout the capability life cycle and across time epochs.
The plan follows the principles of reuse, utilising existing governance regimes, leveraging extant activities, aligning with current practices and necessitating no additional resources.
It sets the purpose and goals for Integrated Capability Realisation, using four-year cycles for evaluation of Joint Force Integration and Interoperability (I2) that are linked to current joint training cycles.
Joint Operations and Analysis Division (JOAD) within the Defence Science & Technology (DST) Group has been supporting the ADoD on this journey over many years with an emphasis on the application of Systems, and System-of-Systems (SoS), Engineering and Integration in the development of concepts, methodologies and tools (i.e. Pratt & Cook 2018; Zadeh et al. 2018).
This presentation will discuss the development of SoS / I2 assessment frameworks and measures, and their application in a case study in support of Plan Aurora development and execution.

Assessing Joint Force I2
Joint Force I2 assessment combines two challenging tasks - I2 assessment and joint force evaluation.
I2 assessment has been studied in earnest since the 1990s.
A number of different methodologies, maturity models, standards and frameworks have been proposed, most specifically addressing the technical aspects of interoperability with some extension for organisational and process aspects (Lane et al. 2011).
It is recognised that interoperability is an important quality for an effective enterprise or SoS.
These I2 assessment processes have been applied with varying degree of success, but none have been adopted for full time use in the development and assessment of SoS.
Assessing Joint Forces is a difficult yet essential task (Ochmanek 2018), with doctrine existing to provide evaluation direction for plans, operations and effects (ADoD 2006; OJCS 2011).
However, the complexity, scale, scope, uncertainty and dynamic nature of warfare, military objectives, capabilities, threats and the environment (Ochmanek 2018; Zvijac 2012) create numerous challenges for joint force assessment.
An SoS is a "set of systems or system elements that interact to provide a unique capability that none of the constituent systems can accomplish on its own" (SEBoK, 2020).
Defence capabilities are inherently SoS, and the collation of these capabilities into single service and joint forces are SoS of large scale and scope.
SoS Engineering (SoSE) is a growing discipline within systems engineering that provides concepts and methodologies for design, development and management of SoS.
Understanding, developing and assessing joint force I2 for the ADoD should therefore be informed by SoSE, as well as the lessons from I2 and joint forces assessment.
SoSE also recommends that methodologies must be tailored to fit both the problem context and the SoS under investigation.

A Joint I2 Assessment Framework

The principles and methodologies of SoSE and Test & Evaluation (T&E) were applied to develop assessment methods and measures for the Joint Force I2 problem.
A series of relevant lessons and principles from SoSE were identified and a process designed for the development of an appropriate Whole-of-Force (WoF) scale assessment framework, tailored for the context of the SoS.
The process includes a comprehensive understanding of the SoS context and the identification of values, needs, and risk-opportunity areas.
With these at hand, a framework for analysis and assessment could then be derived and a hierarchy of measures created.

Case Study
The process was applied to develop assessment frameworks for specific cases relating to joint forces.
The Heimdall Experiment was an activity, initiated by DST and conducted by Surf Life Saving South Australia (SLS-SA), to investigate information interoperability across different organisations in a search & rescue scenario.
An I2 framework was developed and applied to understand the state of I2 across the five organisations involved, as an adjunct to detailed technical interoperability studies within SLS-SA.
The exercise was conducted at a local beach with data collected pre-, during and post-activity.
Analysis and comparison of the high level I2 assessment with the separate study data was performed to derive insights on I2, effectiveness, and efficiency; identify root causes & potential solutions; and evaluate the exemplar WoF assessment framework, measures & construction process.

Summary
This presentation will discuss context and issues surrounding Joint Force I2 assessment for the ADoD and the development of an I2 assessment framework utilising SoSE practices.
An account of the initial application of this framework as a case study will then be provided and the lessons identified for implementation within the ADoD.
While this presentation will focus on the Defence context, the implications for I2 assessment across many other domains for which SoSE is utilised will be raised.

Presentation#32

Model-based Cyber Threat Analysis Approach

Leqi Zhang (L3Harris) - nekworld@gmail.com

Paper not presented

Keywords. Model Based System Engineering - MBSE - Cyber Threat - Cybersecurity - Cyber Threat Modeling - Attack Vector - Vulnerability

Topics. 2. Aerospace; 4.7. System Security (cyber-attack, anti-tamper, etc.); 5.3. MBSE; 6. Defense;

Abstract. Model Based System Engineering (MBSE) principles have been widely adopted in modern system engineering processes across industries.
Cybersecurity design and analysis is the most effective when it is an integral part of the upfront system model development process.
Instead of performing an isolated cybersecurity analysis on a system, the behavior and architectural design details provided by a system model should be leveraged.
This enables a comprehensive cyber threat analysis on the target system.
A model-based cyber threat analysis approach is proposed to facilitate and standardize the process in incorporating cybersecurity analysis into system models.
The core of the proposed cyber threat modeling approach is the standardized construct of a cyber threat.
Based on this construct, a cyber threat consists of Threat Scenarios, Threat Events and Attack Vectors.
A Threat Scenario describes the high level CONOP of an attack, which is achievable by realization of one or more Threat Events.
The Threat Events are enabled by one or more Attack Vectors.
The cyber threat constructs can be developed as a standalone model based on published attack libraries such as ATT&CK and CAPEC.
Such model will correlate the Threat Scenarios, Threat Events and Attack Vectors together.
This allows the constructs to be re-usable across different systems.
The other aspect of the model-based cyber threat modeling approach is the tailoring of the cyber threat constructs to the model of the target system.
First, Threat Sources are identified based on the context of the target system.
Based on the list of Threat Sources, associated Attack Objectives are identified.
Then, the Attack Objectives are analyzed against the library of Threat Scenarios in the cyber threat model to arrive at a tailored set of Threat Scenarios that associate with the target system.
As a result, the correlations in the cyber threat model will automatically derive a tailored set of Attack Vectors that pertains to the target system.
The resulting Attack Vectors can then be traced to the design elements of the system model, such as interface specifications and function/operation definitions.
The traceability between the Attack Vectors and the design elements enable identification of vulnerabilities of the system.
The identified vulnerabilities can then be used to drive system model updates to incorporate necessary mitigation designs and controls, which are then traced back to the vulnerabilities in the model. The proposed model-based cyber threat modeling approach allows cybersecurity design to be fully integrated to the system model by leveraging a re-usable cyber threat model based on existing cyber-attack libraries.

Presentation#20

Practical experience of successful System of Systems delivery

Duncan Kemp (Ministry of Defence) - duncan@17media.co.uk

Presented on: Tuesday, 13:15-13:55

Keywords. System of Systems - SOSE - Asset Management - Supply Chain Management - Service Management - Partnering - Business Collaboration - Capability - Enterprise - Cynefin - Programme Management

Topics. 16. Rail; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. This presentation describes practical approaches that the presenter has used to deliver Systems of Systems.

The INCOSE Systems Engineering Vision has identified Systems of Systems Engineering (SoSE) as a key development goal for Systems Engineering. The vision that "Embracing and learning from the diversity of systems engineering approaches." is a "systems engineering imperative", identifying the need to encompass the diversity in systems approaches rather than a single narrow perspective. This paper explores a diverse set of practices to extend ISO 15288 to enable the delivery of effective SoS. The need for a better understanding of the diverse set of SE approaches was reflected in the 2019 INCOSE Fellows paper on SE.
There have, however, been a range of successful SoS implementations including, the evolution of the British rail system from 1950-1900, the North American power grid, European Air Traffic Control and more recent 'Internet of Things' implementations. In each case, the SoS was delivered, albeit inefficiently.

There is a relatively well documented understanding of the SoSE problem space:
• The development of a spectrum of SoS types, from Acknowledged to Virtual (or even Accidental), with Virtual SoS having the lowest level of central operational and managerial control.
• The INCOSE system of system pain points, that describe the challenges of implementing a SoS compared with conventional SE.
• The cultural challenges of working across different national and business cultures and coping with different decision-making styles (Cynefin)

There is less consensus on the SoSE solution space. The US DoD wave model, and the INCOSE UK Capability SE guide describe similar approaches to implementation. Recent work on standards has captured the current levels of understanding, however we still lack an overarching model of how to deliver SoS.

This presentation will describe common patterns of SoS delivery based on the presenter's real-world experience of SoS delivery in UK Defence, European Rail and Information Services. It explains how an integrated approach based upon:
1. Capability Planning (from ISO 55000) can be used to identify how the constituent systems in the proposed SoS need to work together and what changes (including new and changed systems) are required.
2. Project and Programme Delivery (using ISO 15288) to deliver the required changes.
3. Service Design and Management (based on ISO 20000) to manage the asynchronous arrival of changes whilst delivering seamless end to end services; and,
4. Business collaboration (using ISO 44000) to manage the conflicting needs and priorities of different organisations managing and delivering elements of the SoS.
... can deliver effective SoS.

The presentation will describe how these four parts have dealt with the SoS pain points and realised different types of SoS. This presentation will also propose three principles for effective SoS Engineering: Recognising the need for the four different approaches, implement the right approach in the right place, and integrating the approaches within, and between, organisations.

Presentation#10

Schema and Metamodels and Ontologies, Oh My!

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

Presented on: Monday, 17:05-17:45

Keywords. MBSE - Digital Engineering - metamodel - ontology - semantics - enterprise

Topics. 2. Aerospace; 3.4. Information Management Process; 5.3. MBSE; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Over the last five years, there has been a growing fascination with conceptual data models, metamodels, and ontologies in systems engineering. What began as a murmur – something living largely at the fringes of systems engineering and MBSE – has grown as many projects and practitioners delve into these topics.

So what are these concepts? What differentiates them, and more importantly, why should I care? How do I properly leverage these ideas to advance my projects and my enterprise?

As organizations apply model-based systems engineering, managing information in a computer model requires a defined data structure. Combined with the ease of modern ontology editors such as OWL or capabilities embedded in many tools, practitioners have begun to develop their own conceptual data models and ontologies. As systems engineers experiment and leverage these capabilities, they cross into the area of language design, often developing custom languages for their projects without the greater depth or consideration necessary to connect enterprise practices.

There is a fundamental information model that underpins systems engineering. This information model characterizes the knowledge we must elicit, develop, analyze, and manage in order to successfully engineer systems. It lives implicitly in the process standards that guide our practice, the data item descriptions that define our artifacts, and the representations we use.

The challenge is to move from implicit and explicit, not to advance MBSE but to advance the greater practice of systems engineering. To do so means that we must do more than develop independent data models for projects (the trap of “define and use”). We can leverage decades of practical experience to develop a shared systems metamodel that enables us to effectively communicate, analyze, and reason as we address today’s systems challenges. Rather than each project or each organization isolated on an island of their own language, we can and must achieve consistency of data and commonality of practice across the enterprise, across the supply chain, and across the profession.

Invited Content

InvitedContent#techops2

Being Social with Social Systems

Erika Palmer (Chairs of the Social Systems Working Group) - erika.palmer@ruralis.no
Randy Anway (Chairs of the Social Systems Working Group) - randy@new-tapestry.com

Presented on: Wednesday, 17:05-17:45

Keywords. TechOps;

Abstract. The Social Systems Working Group (SocWG) was formed after the INCOSE IS 2019 and was part of its first IW in 2020. The group was formed with support from the Complex Systems Working Group and has now grown to 98 members.
The purpose of the SocWG is to evaluate evolving changes to systems engineering processes and practices and develop measures to integrate social and socio-technical systems understanding at theoretical, applied and technical levels, in collaboration through outreach initiatives with the social sciences and interested stakeholder groups.
We have a variety of initiatives envisioned and in progress:
*The UN Sustainable Development Goals – Supporting a hub of activity on SE and SDGs
*Social Systems Ontology/Primer
*WG Outreach – Connecting a network of intersecting efforts across WGs
*Special focus activities on AI and Ethics

InvitedContent#techops4

Developing the INCOSE-PPI Systems Engineering Tools Database Using a Systems Engineering Approach

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Presented on: Wednesday, 17:50-18:30

Keywords. TechOps;

Abstract. The INCOSE membership and PPI client community have not had a single or comprehensive source of information for system engineering tool capabilities for many years. Many man-hours can be expended searching for tool information while trying to select the right tool for the task at hand, largely in ignorance of the broad spectrum of available tools. At IW 2018, INCOSE Technical Operations leadership tasked the Tool Integration and Lifecycle Management Working Group to work jointly with Project Performance International (PPI) to develop a new Systems Engineering Tools Database (SETDB) accessible to members via the INCOSE and PPI websites. Operating under a Memorandum of Understanding, the TIMLM WG and PPI have executed a system engineering approach to develop a web-based platform for the systems engineering community containing valuable information regarding the capability of software tools in a host of categories.

InvitedContent#PIC4

Exploring Real AI: A Systems Engineering Approach

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Ali Raz - akraz@purdue.edu
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Presented on: Monday, 16:20-18:30

Abstract. Artificial Intelligence is a hot topic today in both technical and popular arenas, but the waves of exciting progress on real applications are accompanied by an undercurrent of misinformation, misunderstanding and fear. This session offers an in-depth exploration of AI technology for the systems engineer. First, we explore deep neural networks—the fastest growing and most widely useful of all AI technologies—by building one in a workshop format. In Part II, we look at the real problems that concern systems AI specialists and systems engineers and how they affect the performance, safety and dependability of systems. In Part III, we look at the current and near-future research in systems AI, for a look into where it all may be going.

Part I: Workshop: Building a Deep Neural Network
Lead: Barclay Brown
Deep neural networks, more than any other technology are behind the AI revolution in the past decade. In this section, we'll walk through how a deep neural network works and remove all the mystery about how they accomplish such amazing and even counter-intuitive results. Participants will learn how deep neural networks are designed for specific applications and the uses for specialized networks such as convolutional, recurrent and auto-encoder networks. We'll build a simple neural network in class, and participants can follow along on their own laptops if they wish.

Part II: Systems Engineering of AI: Real Problems (and Solutions)
Panel Lead: Barclay Brown
Panel Members (to be confirmed): Tom McDermott, Ali Raz, Peter Santhanam
Like any new technology, AI is not without its problems and challenges. In this section, we'll discuss these problems, starting with the ones most often mentioned in the popular press including explainability, bias and unpredictability. We'll explain the issues and show why they aren't as simple as popular opinion makes them seem—some are worse and some may not be problems at all! Also included is a demonstration of how bias can be eliminated in natural language neural networks.

Part III: The Cutting Edge: Systems Research in AI
Lead: Tom McDermott
In the final section, we'll provide an overview of current and planned near-term research in systems AI. Most AI research focuses on the development of algorithms and single-point applications of the new technology. As systems engineers, we are more concerned with systems that include AI technology, and how to specify, architect, design, test and even certify these intelligent systems. An increasing amount of research is focused in this area, aimed at enabling systems engineers to take advantage of new AI technologies safely and securely in transportation, space and defense systems.

InvitedContent#PIC3

Managing the Interstitials: Future of Systems Engineering Suited for Urban Infrastructure 4.0

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Presented on: Tuesday, 16:20-18:30

Keywords. Infrastructure; FuSE;

Abstract. Infrastructure 4.0 and particularly, Urban Infrastructure 4.0, is commonly viewed as the transformation of infrastructure as driven by the Fourth Industrial Revolution (Industry 4.0) and applied to the domains of building construction, roads & highways, bridges, water, railroads, aviation, electric grids, and broadband. These domains are all to be enabled by human, cloud, and broadband infrastructures to provide smart everything. However, it is not apparent that Urban Infrastructure 4.0 currently addresses the critical context of diverse cultural, political, and economic climates. Also, it is not clear that it addresses and accounts for the hidden interactions across domains that can result in the emergence of unintended consequences and does not assure the resilience of these non-deterministic, complex systems of systems at scale.

The Systems Engineering Vision 2025 published in 2014 identified five global trends: increasing stress on the sustainability of natural resources; environmental change; increasing globalization; increasing interdependent economies; and increasing population growth and urbanization. The last trend of increasing urbanization results in changing population distributions, “smart” cities, larger markets and greater opportunities . . . but also great societal stress, urban infrastructure demands, and increased system challenges for agriculture, environmental health and sustainability.

Urban infrastructure touches on all the human and societal needs enumerated in “A World in Motion, Systems Engineering Vision 2025,” and the anticipated Systems Engineering Vision 2035:

1. Food and shelter
2. Clean water
3. Healthy (physical environment)
4. Access to health care
5. Access to information, communication, education
6. Transportation and mobility
7. Economic security and equity
8. Security and safety.

In 2018, 55% of the world’s population was estimated to be living in urban areas with the expectation that it will be 68% by 2050 and 85% by 2100. Eight percent of the world’s population currently live in megacities of more than 10 million people and that fraction is expected to increase with population growth and the numbers of megacities. The urbanized quality of life poses both benefits and challenges as a function of population density.

Our most recent infrastructure challenge is dealing with the novel coronavirus COVID-19 where a major mitigation is to practice social distancing, which may seem an oxymoron in high density urban environments with people densely packed in in all aspects of their lives including the use of mass transit systems.

The Future of Systems Engineering (FuSE) is a systems community initiative to realize the Systems Engineering Vision 2025 and 2035. The enumerated human and society needs are interdependent, that is, they are tightly coupled, and are being holistically addressed in the FuSE initiative, with sustainable urban infrastructure being a pain point to achieving this integration that binds the enumerated needs into the objective human experience.

The intent of the session is to address the challenges we face in the systems engineering of sustainable urban infrastructures, particularly in managing the interstitials, by understanding the context for urbanization; modelling the form and function of cities; fitness for purpose of systems engineering as is and identifying gaps of where we need to be as a discipline; and to benchmark case studies of practice. This will be followed by a Q&A session and input from participants. The output of the session will provide stakeholder inputs to FuSE.

InvitedContent#techops1

Smart Cities: Who are the winners?

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Presented on: Wednesday, 16:20-17:00

Keywords. TechOps;

Abstract. INCOSE is in a unique position to support our communities. Smart Cities initiatives are popping up across the world, many in our back yards. Each has its own application of a technology, process, or connected-ness. The Smart Cities concept is unwieldy; you may even call it “Wicked.” And our cities large and small across the globe are working hard to keep up with available technologies. INCOSE is kicking off the Smart Cities initiative. Much has developed in Smart Cities applications, yet there are many opportunities where systems engineering can positively contribute. The Smart Cities Initiative has developed a draft model for stakeholder consideration and need definition. This product is in the early stages of the INCOSE Technical Product Development process and the team is excited to share the development and receive feedback. Our opportunities to influence our communities through systems engineering are endless, and this is no exception. Join us to learn about the Smart Cities Initiative impact and how INCOSE can help refine the value received by cities.

Key Reserve Paper

KeyReservePaper#22

A Bibliometric Method for Analysis of Systems Engineering Research

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Leon Pretorius (University of Pretoria) - Leon.Pretorius@up.ac.za

Keywords. Bibliometrics - Natural Language Processing - Topic Modelling - Systems Engineering - Research

Topics. 1. Academia (curricula, course life cycle, etc.); 1.2. Cybernetics (artificial intelligence, machine learning, etc.);

Abstract. Since systems engineering is still a relatively young and growing discipline, it requires a periodic analysis, taking into account past research to derive the requirements for future growth. Published research provides a good indication on the progress and maturity of a scientific discipline. Bibliometric analysis is a valuable tool to assess published research. This paper establishes a method to determine the main research topics published in the Systems Engineering Journal (INCOSE) since its inception. The research and associated analysis method applies Natural Language Processing with Topic Modelling to extract the main topics from the abstracts of all the papers published in the journal. The analyzed data provides the trends in topic coverage over time.

KeyReservePaper#86

Applying a Case Study Method in Systems Engineering Research

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Keywords. Case Study;Development Process;Qualitative Methods

Topics. 1. Academia (curricula, course life cycle, etc.); 1.1. Complexity; 3.7. Project Planning, Project Assessment, and/or Project Control; 5.5. Processes; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Systems engineering activities focuses mainly on objective perspectives which can be measured and verified but largely ignores subjective aspects. As systems become more complex, the interactions between humans and systems are also important. There are social influences in a multidisciplinary engineering team and the implication is that a system engineer must be responsible for understanding these social influences on the development and operation of a system. This requires a qualitative method of enquiry. In this paper qualitative methods are briefly introduced and the detailed application of the case study method and its limitations are discussed. The Square Kilometer Array (SKA) Project was used as the case study and the research design and data collection considerations for the study are presented. One of the study's research question (How is the development process structured in the project and why?) is used to illustrate the data analysis and discussion.

KeyReservePaper#147

Applying Model-Based Systems Architecture Processes (MBSAP) Methodology for Diversified MBSE Projects with Efficient Systems of Systems Accomplishments

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Keywords. CDM;LDM;PDM;MBSE;MBSAP;SDLC

Topics. 1.1. Complexity; 1.5. Systems Science; 1.6. Systems Thinking; 10. Environmental Systems; 11. Information Technology/Telecommunication; 12. Infrastructure (construction, maintenance, etc.); 13. Maritime (surface and sub-surface); 14. Autonomous Systems; 17. Sustainment (legacy systems, re-engineering, etc.); 18. Service Systems; 2. Aerospace; 2.3. Needs and Requirements Definition; 2.4. System Architecture/Design Definition; 2.5. System Integration; 2.6. Verification/Validation; 3. Automotive; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 5.5. Processes; 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.); 5.9. Teaching and Training; 6. Defense; 8. Energy (renewable, nuclear, etc.); 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. This is a paper I will like to share with my Systems Engineering Development Life Cycles (SDLC) tactics by adapting to the MBSAP methodology from the text applicable to the real-world MBSE tasks.
These involved diversified MBSE developments and research according to my working projects scope aspects.
The text introduces MBSE as the state of the practice in the dynamic Systems Engineering discipline that manages complexity and integrates technologies and design approaches to achieve effective, affordable, and balanced system solutions to the needs of all stakeholders within the systems development resources.
All my successful accomplishments will be demonstrated that MBSAP is an effective MBSE and Systems Architectures research methodology for any future digital systems engineering development life cycles.

KeyReservePaper#137

Contextually Aware Agile Security in the Future of Systems Engineering

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Keywords. Agile ;Security Future of Systems Engineering; Problem Space

Topics. 2. Aerospace; 4.6. System Safety; 6. Defense;

Abstract. A recurring principle in consideration of the future of systems engineering is continual dynamic adaptation. Context drives change whether it be from potential loss (threats, vulnerabil-ities) or from potential gain (opportunity-driven). Contextual-awareness has great influence over the future of systems engineering and of systems security. Those contextual environments contain fitness functions that will naturally select compatible approaches and filter out the incompatible, with prejudice. This paper provides archetypes that 1) characterize general systems engineering for products, processes, and operations; 2) characterize the integration of security with systems engineering; and, 3) characterize contextually aware agile security. The purpose of this paper is to provide a conceptual understanding of the problem space and derive general security strategies necessary to deal with that problem space, with the intent to provide an initial foundation for subsequent tactical implementations of agile security approaches.

KeyReservePaper#67

Digital Engineering Strategy to Enable Enterprise Systems Engineering

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Keywords. Enterprise Systems Engineering;ESE;Digital Engineering;DE;Model Based Systems Engineering;MBSE;Strategy

Topics. 5.3. MBSE; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. As defined in the U.S. Department of Defense (DoD) Digital Engineering (DE) Strategy, DE is “an integrated digital approach that uses authoritative sources of system data and models as a continuum across disciplines to support lifecycle activities from concept through disposal.” This DoD DE Strategy establishes a set of goals and objectives for DE within the DoD. This paper provides an elaboration of that strategy for organizations who seek to apply DE not only for the improvement of program and project outcomes, but to achieve a more efficient and effective implementation of enterprise systems engineering (ESE) to improve enterprise outcomes. The paper then describes the roles and responsibilities needed for the effective and efficient implementation of DE principles and concepts in support of the systems engineering activities across the enterprise to facilitate the disciplined exercise of ESE at every organizational level.

KeyReservePaper#83

Early Detection of Flaws in System Architecture Model by means of Model Simulation

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Keywords. Model verification - Model simulation - Detection of Flaws

Topics. 2. Aerospace; 2.4. System Architecture/Design Definition; 2.6. Verification/Validation; 5.4. Modeling/Simulation/Analysis; 6. Defense; 8. Energy (renewable, nuclear, etc.);

Abstract. Architecture definition models in system engineering usually include different views and sets of concepts, more or less correlated to each other, such as activities or functions, time-ordered sequences, state machines. Ensuring coherency between these descriptions is in no means trivial, usually requiring either formal checking or behavioral simulation, at the expense of extra modeling work.
This paper suggests a first level of verification of coherency, needing little effort, to detect flaws in in the model as early as possible, before entering more in depth and more costly simulation or formal proofing. To make this verification possible, we define a model execution semantic based on a mix of model exploration and dynamic execution techniques.

KeyReservePaper#139

Envisioning Future Systems Engineering Principles Through a Transdisciplinary Lens

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Paper not presented

Keywords. Transdisciplinary Systems Engineering - Systems Engineering Principles - Systems Engineering Basis - Sociology

Topics. 14. Autonomous Systems; 4.2. Life-Cycle Costing and/or Economic Evaluation; 4.4. Resilience; 5. City Planning (smart cities, urban planning, etc.); 5.10. Diversity (cultural boundaries, diverse engineering teams, training underserved groups, etc.); 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. The purpose of this paper to examine systems engineering principles from a transdisciplinary perspective. The motivation for this investigation is in part in response to the new INCOSE definition of systems engineering introduced in 2019.

Looking back through millennia of engineering, it is possible to identify aspects of the practice of engineering systems which used some trans-disciplinary approaches, but only recently have transdisciplinary systems engineering practices been systematically characterized and described in depth.

This paper identifies areas in the statement of systems engineering principles which can be revised to reflect transdisciplinary systems engineering more effectively. Hopefully, this will help engineering professionals implement systems engineering principles to more effectively engineer systems to meet the needs of stakeholders more cost-effectively, with less conflict among stakeholders.

KeyReservePaper#36

Exploring Inherent Structural Knowledge in Mental Models through a Qualitative System Dynamics Approach

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Keywords. System Dynamics;Structural Knowledge;Qualitative Models;Systems Thinking

Topics. 1. Academia (curricula, course life cycle, etc.); 1.6. Systems Thinking; 10. Environmental Systems; 5.4. Modeling/Simulation/Analysis; 5.5. Processes; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. The purpose of the paper is to explore the inherent structural knowledge contained inside a mental model. Systems engineering and system dynamics share a common relative in the field of Cybernetics and systems thinking but have evolved into different areas of specialization. System dynamics has the ability to integrate more qualitative variables that are not conventionally used by systems engineering due to characteristically high levels of uncertainty or an unquantifiable nature. These qualitative variables are however part of the human mind's mental models of the world and strongly influence decision making. In this paper, qualitative structural understanding is explored through a system dynamics methodology to reveal the inherent knowledge captured in a structure. The structure that is explored is the limits-to-growth system archetype specifically developed into a population Causal Loop Diagram (CLD). The CLD is used as an initial mental model of structure and further expanded into a system dynamics model. The results show that population dynamics is driven by structure in the case of unique population groups such as China, Japan and Africa; but also pro-vided insight into the global population boom in the 1900's. It also exposes that the structure of population has the ability to survive extremely harsh conditions which human tribal ancestors expe-rienced. Results of this study confirm the value of gaining structural understanding and knowledge to support and influence decision making.

KeyReservePaper#16

Finance Function as a Business System

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Keywords. Model-based business design;Finance function as a business;Finance life cycle;Finance function functional decomposition;Finance operating model;Business architecture

Topics. 2.4. System Architecture/Design Definition; 5. City Planning (smart cities, urban planning, etc.); 5.3. MBSE; 5.5. Processes; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Systems are becoming increasingly interdependent and interconnected and the enter-prise charged with developing such systems faces a challenge in ensuring that these dependencies are known and well understand such that the enterprise's portfolio of programs, projects and sys-tems is balanced and robust. Enterprise Systems Engineering (ESE) is an emerging discipline that is designed to handle the challenges of helping to manage this portfolio and ensuring that the var-ious mission and business systems are developed in a coherent, efficient and effective manner. This paper describes the desired features of an ESE capability that can help the enterprise manage its portfolio as well as addressing the various non-system solutions that must be brought to bear. The strategy for realizing this ESE capability is described in terms of the goals and objectives that the enterprise should be expected to achieve.

KeyReservePaper#108

General Modeling Language Supporting Model Transformations of MBSE (Part 2)

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Keywords. MBSE - Code generation - Architecture-driven

Topics. 1.5. Systems Science; 2.4. System Architecture/Design Definition; 3.2. Configuration Management; 5.3. MBSE; 5.4. Modeling/Simulation/Analysis; 5.5. Processes; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. With the increasing complexity of systems, model-based systems engineering (MBSE) has attracted increasing attention in the 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. 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 general language to describe model formalism and transformation for architecture-driven 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 including architecture-driven and code-generation implementations in one modeling tool. Finally, from one auto-braking case of an autonomous-driving system, we find the availability of the Karma language supporting architecture-driven and code generation is verified.

KeyReservePaper#9

Human factors consideration in the automation design of a safety-critical installation

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Paper not presented

Keywords. automation design - automation of safety-critical installation - critical human factors

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

Abstract. With the use of technology becoming more and more prevalent particularly in the operations of safety-critical processes, human factors are increasingly important. Although this concept of human factors is not new, its impact is not always appreciated. The successful implementation of automation depends on the adequate considerations of human factors such as operator workload, mental fatigue and complacency. The research identifies critical human factors specific to automation design of a safety-critical installation. The factors are identified through descriptive analysis of the response from key stakeholders.

KeyReservePaper#145

Implementing MBSE – An Enterprise Approach to an Enterprise Problem

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Keywords. MBSE;Digital Engineering;Enterprise Architecture;Unified Architecture Framework

Topics. 2. Aerospace; 2.4. System Architecture/Design Definition; 3.7. Project Planning, Project Assessment, and/or Project Control; 5.3. MBSE; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Model Based Systems Engineering (MBSE) is now widely accepted throughout the in-dustry, from commercial to aerospace and defense. However, while we understand and accept the principles of MBSE, successful adoption and implementation is still a challenge within the indus-try. The migration from document-based systems engineering processes to MBSE requires more than purchasing tools and a one-week course on Systems Modeling Language (SysML). MBSE does not change the practice of Systems Engineering as defined in the INCOSE SE Handbook or ISO/IEEE 15288, but it does affect the way in which systems engineering processes are imple-mented and supported within and across organizations. Organizations adopting MBSE must ad-dress issues such as new skill and competency requirements for systems engineers, model and data management over the lifecycle of the system, and integration with other engineering tools and processes, among others. It is not a tool problem or a modeler problem. It is an enterprise problem and requires an enterprise approach. The approach must be defined and guided by an enterprise architecture, which is broader than just the engineering tools and their interfaces. It includes the enterprise strategic vision, capabilities, operational concepts, organizations, and material solutions required to achieve MBSE adoption, how they relate to one another, and their evolution over time.
This paper provides a broad overview of the fundamentals of MBSE adoption and the broader effort of digital engineering transformation, presenting the digital engineering environment as a system-of-systems. It presents the use of enterprise architecture as a roadmap for MBSE adoption within the industry.

KeyReservePaper#158

Infrastructure Working Group exploratory study of SE for Complex Buildings - progress year one

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Keywords. Infrastructure - Complex Buildings - Systems Engineering - Tailoring - Architecture Engineering and Construction - AEC

Topics. 12. Infrastructure (construction, maintenance, etc.); 3.7. Project Planning, Project Assessment, and/or Project Control; 5. City Planning (smart cities, urban planning, etc.); 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.);

Abstract. Members of the INCOSE Infrastructure Working Group are conducting an exploratory activity, studying Systems Engineering applied to the life cycle of complex buildings.
This
paper reviews the progress in the study's first year and summarizes the lessons learned about the
major strengths and weaknesses of Systems Engineering and the opportunities and challenges displayed by the building industry.

Innovation Mechanisms in Electronics Industry

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Keywords. innovation - innovation mechanism - knowledge management - technology management - product development

Topics. 2.3. Needs and Requirements Definition; 2.4. System Architecture/Design Definition; 3.4. Information Management Process; 3.5. Technical Leadership; 5.5. Processes; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. This study investigates innovation at Mycronic AB, a company which has seen a decrease in their innovation capacity over the last several years, compared to past development efforts. It studies past projects from a knowledge management perspective to understand if potential barriers towards reusing innovation mechanisms could explain the decrease in innovation capacity seen today. A literature study was performed to deepen the understanding of the field of knowledge management, and technology management, and especially what is important for organization to be innovative. This knowledge was the foundation for a case study, which investigated innovation mechanisms and barriers from past projects. The identified barriers could, in part, explain why the company has been unable to reuse the knowledge from these past projects. The identified barriers could serve as a starting point for continued work with KM. Overcoming these barriers could over time improve innovation.

KeyReservePaper#47

Knowledge Reuse in a Small Company in the Water Treatment Industry: A Case Study

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Keywords. Knowledge reuse;Wastewater;Water treatment;A3;requirements;case study;Small company

Topics. 10. Environmental Systems; 19. Very Small Enterprises; 3.4. Information Management Process; 4.5. Competency/Resource Management;

Abstract. This paper presents a case study that explores how a small company in the water treatment industry can facilitate knowledge reuse. Small companies often find themselves focusing resources on operational activities and fire-fighting, preventing them from properly utilizing previously acquired knowledge in new similar projects.
We conducted in-depth interviews with company employees to establish a set of requirements for the new knowledge system. We then gathered theory through a literature review and developed the system iteratively with frequent feedback from employees at the company. The paper includes a case study on an ongoing wastewater treatment plant project in the company.
The new knowledge management system is built up of interconnected A3s that provide the user with both a system overview and detailed information. We validated the results through a survey. The survey displayed that employees were positive towards implementing and using the new knowledge management system. We observed that employees were curious during the development process and willingly contributed when required. This paper also presents different barriers and benefits related to knowledge management initiatives in a small company.

KeyReservePaper#119

MBSE Methodology Applied for a Technology Demonstrator in the Space Transportation Sector

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Keywords. Technology demonstrator;Composite cryogenic tanks;Model-Based Systems Engineering;Operational analysis;Fully Integrated Operational System;Requirements traceability;Model navigability

Topics. 2. Aerospace; 2.4. System Architecture/Design Definition; 4.4. Resilience; 5.3. MBSE;

Abstract. Over the last 40 years, many composite cryogenic tank (CCT) programs have been sponsored by NASA to improve space launchers' performance. However, lessons learned in terms of risks mitigation, design failures, lack of technology maturation and time constraints during development phases lead to strength the systems engineering perspective given the number of new functions, components and subsystems involved in their performance.
The present paper suggests a Model-Based Systems Engineering (MBSE) methodology to reduce the challenges that CCTs entail in a technology demonstrator program currently in phase A for the “Launcher X” upper stage. Topics such as a strong operational analysis, project variability, a Fully Integrated Operational System (FIOS) model combined with a Manufacturing, Assembly, Integration & Test (MAIT) model, requirements traceability and model navigability issues are studied throughout the modelling process. Results from this approach show and ease the way to obtain information in a complex and large model intended to simulate our System of Interest (SoI) life cycle. Consequently, CCTs can face NASA’s aforementioned lessons learned from an early phase of the project in order to prevent similar adverse situations.

KeyReservePaper#151

Model-Based Systems Engineering for complex rail transport systems – A case study

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Keywords. Model-Based Systems Engineering;MBSE;Complex rail system;Conceptual design;Transport infrastructure

Topics. 16. Rail; 2.3. Needs and Requirements Definition; 2.4. System Architecture/Design Definition; 5.3. MBSE;

Abstract. The replacement of the signalling and control systems on Sydney's critical heavy-rail net-work infrastructure is envisaged to take years and affect many systems across the operational railway. Systems Engineering has been adopted early in the system lifecycle to manage the complexity and risks in a rigorous and consistent manner. This paper aims to document the real-life application of a Model-Based Systems Engineering (MBSE) methodology in the conceptual design stage on Transport for New South Wales' Digital Systems Program. It illustrates how this methodology was applied to capture the operational and maintenance concepts, derive the architecture and interfaces and guide resulting requirements. It provides valuable lessons-learnt for the acquiring organisation on the deployment of MBSE, its benefits and lessons learnt.

KeyReservePaper#100

Orchestrating Human Systems Integration Looking for the Right Mix for Human-Machine Teaming

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Keywords. human systems integration;human-machine teaming;Orchestra model;context;artificial intelligence;automation;autonomy;systems engineering;coordination

Topics. 1.2. Cybernetics (artificial intelligence, machine learning, etc.); 2. Aerospace; 4.1. Human-Systems Integration;

Abstract. Human systems integration (HSI) is commonly thought as the association of human-centered design (HCD) and systems engineering (SE). HCD relies on human-in-the-loop simulation (HITLS) and artificial intelligence (AI). In addition, AI and SE terminologies, methods, and tools should be harmonized in the context of human-machine teaming (HMT). Evolutions from singleagent to multi-agent approaches in AI, and from isolated-system to system-of-systems in SE are comparable. System and agent representations commonly apply to humans and machines. They are defined by their structures and functions. Based on research currently developed on HCD of increasingly-autonomous complex systems, this paper uses the Orchestra metaphor model that supports HMT organization design and management, based on: domain ontology (music theory); tasks and designers (scores and composers); activity and performance coordination (conductors); human/machine operators (musicians); end-users and consumers (audience). This approach requires elicitation, understanding and mastery of new interdependences, co-adaptation, and integration of agents' emerging functions using HITLS.

KeyReservePaper#18

SE Thinking and Application in Planning and Implementation of Single Window Systems

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Keywords. Maritime Single Windows;Master Planning;Business Re-engineering;Mission analysis;Stakeholder needs definition

Topics. 1.6. Systems Thinking; 11. Information Technology/Telecommunication; 13. Maritime (surface and sub-surface); 17. Sustainment (legacy systems, re-engineering, etc.); 2.1. Business or Mission Analysis; 2.3. Needs and Requirements Definition;

Abstract. This paper provides a Systems Engineering (SE) perspective on establishment of Single Window (SW) systems, highlighting the value of SE both on a Master Plan level for SW programmes and on an implementation level of the constituent systems. The author proposes that 1). in SW Master Plan stage, SE thinking could guide vision and capability alignment and project prioritization; 2). in implementation of the sub-systems, SE technical processes should be promoted to ensure successful delivery of SW systems. The paper presents a study on Maritime Single Window (MSW) systems, with a review on the domain conventions and a case of an MSW initialization project. Further, the paper revisits the evolution and lessons of the Singapore MSW and the national SW Programme, and discusses agility and open-source co-development for future SW implementations. Additionally, the author recommends federation approach in SW implementations as preferable to integration approach as the current industry practice.

KeyReservePaper#3

Strategy for Implementing an Enterprise Systems Engineering Capability

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Keywords. Enterprise;Enterprise Systems Engineering;Enterprise Architecture;Model Based Systems Engineering

Topics. 2. Aerospace; 2.1. Business or Mission Analysis; 3.3. Decision Analysis and/or Decision Management; 5.3. MBSE; 6. Defense; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Systems are becoming increasingly interdependent and interconnected and the enter-prise charged with developing such systems faces a challenge in ensuring that these dependencies are known and well understand such that the enterprise's portfolio of programs, projects and sys-tems is balanced and robust. Enterprise Systems Engineering (ESE) is an emerging discipline that is designed to handle the challenges of helping to manage this portfolio and ensuring that the var-ious mission and business systems are developed in a coherent, efficient and effective manner. This paper describes the desired features of an ESE capability that can help the enterprise manage its portfolio as well as addressing the various non-system solutions that must be brought to bear. The strategy for realizing this ESE capability is described in terms of the goals and objectives that the enterprise should be expected to achieve.

KeyReservePaper#34

Systems thinking applied to find underlying problem in enterprise management of induction heating transformers

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Keywords. Systems Thinking;Systemigram;Stakeholder diversity;Product management

Topics. 1.6. Systems Thinking; 3.4. Information Management Process; 5.10. Diversity (cultural boundaries, diverse engineering teams, training underserved groups, etc.);

Abstract. The world is more interconnected than ever which emerge new complexity for organiza-tions and their enterprises. Systems thinking is an accepted approach to deal with the messy inter-connected problems of complexity but is sometimes difficult to tailor for a real-world problem. This paper focuses on applying systems thinking on a real-world problem where the underlying problems are unknown with a case study of a transformer management system (TMS) within an enterprise of a worldwide organization (the umbrella of enterprises). The paper starts out by diversifying the use of systems thinking, systems engineering and traditional engineering to present why this approach where selected. Following is a practical methodology using interviews to find the interconnection of the enterprises and a study of the TMS's current state. The interconnections are graphically displayed through a systemigram used to bring the enterprise on "the same page". The result of this effort is a fishbone diagram to display several possible underlying issues found to the problem, the fishbone diagram's intention is to help the enterprise for selecting what problems to focus on and their order.

The paper found the systemigram as a useful tool as it promoted discussions and debate within the enterprise which resulted in a more defined problem overview. To visually display the overview, a cause-and-effect diagram where selected. The cause-and-effect diagram showed to be an efficient tool to simplify the problems and to be used for communicating them along with the systemigram.

KeyReservePaper#136

Techno-Social Contracts for Security Orchestration in the Future of Systems Engineering

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Keywords. social contract;agile security;future of systems engineering

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

Abstract. Security orchestration is the command and control behind security operations. Command includes governance and adjudication logic and rules. Control includes the messaging infrastructure and message set for bidirectional communication between the orchestration engine and the constituent parts of its enclave. Open Command and Control (OpenC2)
is one effort advancing the messaging infrastructure and message set. Automating the command portion of orchestration remains largely unexplored and will emerge as a symbiosis between people and technology. Technology will have some autonomy including the ability to establish and sustain relationships with other technology. To help facilitate trust relationships and interactions that secure the respective systems and their environment, we explore techno-social contracts as an approach to explicitly encode technolo-gy-to-technology rules of intra-protection and inter-protection as part of security orchestration.

KeyReservePaper#144

The SE Handbook: What Does the It Mean to Me? A Proposal to Improve the Practical Application of the SE Handbook

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Keywords. Handbook;Best practice;Tailoring

Topics. 3.5. Technical Leadership; 3.7. Project Planning, Project Assessment, and/or Project Control; 5.9. Teaching and Training; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. Abstract. The INCOSE systems engineering (SE) handbook (Haskins, 2015) has served our discipline well for the years of its application. The authors foresee the future applicability of the contents in section 1.1 Purpose where it de?nes the discipline and practice of systems engineering (SE) for students and practicing professionals alike. The SE Handbook provides an authoritative reference to understand the SE discipline in terms of content and practice. Additionally, section 1.2 Application describes, while being consistent with the ISO/IEC/IEEE 15288, the handbook further elaborates on the practices and activities necessary to execute the processes, and that it is recommended that the tailoring guidelines in chapter 8 be used.
With the strong baseline of defined systems engineering, Chapter 8 of the handbook addresses the Tailoring Process and Application of Systems Engineering. As of now, only 18 of the 290 handbook pages (6.2%) are dedicated to the tailoring process and applied tailoring. Section 8.2, Tailoring for Speci?c Product Sector or Domain Application is only afforded 5 pages (1.7% of the handbook total). The planned update of the INCOSE SE handbook offers an opportunity to enhance the practical application of the SE handbook. This paper reviews the current SE handbook structure, proposes an envisioned solution, provides a proof of concept, and discusses the recommended adjustments using a holistic systems engineering approach.

KeyReservePaper#95

The Wisest System Engineering Mentor and Mentee of the Year Award

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Keywords. Mentorship of system engineers;Professional development of young graduate system engineers;Mentor-mentee relationship

Topics. 5.10. Diversity (cultural boundaries, diverse engineering teams, training underserved groups, etc.); 5.9. Teaching and Training;

Abstract. In 2016 the Wisest System Engineering Mentor and Mentee of the Year Award was launched as part of the INCOSE SA annual conference. This annual award has now occurred three times, in 2016, 2017 and 2018, with a total of nineteen mentor-mentee teams of which three teams received the award. This paper summarizes the process, results and explains the lessons learnt.

KeyReservePaper#71

Towards a Unified Approach to System-of-Systems Risk Analysis Based on Systems Theory

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Keywords. System-of-systems;Risk analysis;Trustworthiness;Safety;Security;Privacy;DevOps

Topics. 4.6. System Safety; 4.7. System Security (cyber-attack, anti-tamper, etc.); 5.8. Systems of Systems (Internet of Things, cyber physical systems, etc.);

Abstract. In systems-of-systems (SoS), trustworthiness is a key concern, which includes operational risks such as safety, security, and privacy. These are particularly challenging to achieve in an SoS, due to the shared responsibility among independent constituent systems. This paper investigates a unified ap-proach based on systems thinking for analyzing trustworthiness in SoS. Having a common framework is important, since many risk areas are related and affect each other. The paper also discusses how traditional static risk analysis can be complemented by dynamic techniques that collect data over time to fuel SoS evolution with respect to risk reduction.

KeyReservePaper#62

Unlocking Hidden Dimensions of EVMS

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Keywords. EVMS;project management;performance measurement

Topics. 1. Academia (curricula, course life cycle, etc.); 3.6. Measurement and Metrics; 3.7. Project Planning, Project Assessment, and/or Project Control; 9. Enterprise SE (organization, policies, knowledge, etc.);

Abstract. The Earned Value Measurement System (EVMS) is a widely adopted, but not highly acclaimed, technique for measuring and forecasting the status of projects.
Past research has examined some of the perceived shortcomings of the EVMS technique, and more recent research has identified methods for improving the standard EVMS calculation techniques.
This paper proposes that the greatest shortcoming of EVMS is not the calculation technique, but that EVMS is not measuring enough parameters, nor the correct parameters.
This paper identifies a means of capturing additional key project parameters, such as quality and work effort, using existing, established EVMS methods.
This paper also identifies how all critical project parameters (cost, schedule, quality, and work) can be displayed in a single graphic image; thereby providing a more complete and probably more accurate picture of the project status.
