Digital Engineering in Complex Systems: From Leadership Understanding through Application

Kristen Baldwin, Acting Deputy Assistant Secretary of Defense, Systems Engineering

Across Government, communication among our engineering disciplines is cryptic, disconnected and subject to varying interpretation. We are faced with steady growth in system complexity and risk, variability in threat capability, reduced buying power and complex processes. We seek to generate new engineering practices for our workforces to regain our edge. One of the methods being explored is the adoption of model-based practices to our acquisition process, a.k.a., digital engineering. Digital engineering moves the engineering discipline towards an integrated model-based approach through the use of digital environments, processes, methods, tools, and digital artifacts to support the planning, requirements, design, analysis, verification, validation, operation, and sustainment of a system. A digital engineering ecosystem links our data sources and models across the lifecycle. It provides the authoritative source of truth.

Changes are required to cultural, historical and business processes to realize a digital model-based engineering vision, and we seek to learn from what is already working in Government and Industry, in order to transform these practices and experiences.

Ms. Kristen J. Baldwin is the Acting Deputy Assistant Secretary of Defense for Systems Engineering (DASD(SE)) within the Department of Defense (DoD) Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics (OUSD(AT&L)). Ms. Baldwin acts on behalf of the DASD(SE) and is responsible for engineering and technical workforce, policy, and systems engineering planning for major defense acquisition programs. Her oversight includes concept engineering and analysis, design, development and manufacturing, and independent program review and assessment. She supports the DASD role of functional leader for more than 40,000 defense acquisition professionals in the Department of Defense (DoD) Engineering (ENG) and Production, Quality, and Manufacturing (PQM) workforce. She oversees the DoD strategy for Trusted Systems Design.

A member of the Senior Executive Service (SES), Ms. Baldwin leads modeling and simulation, system security engineering, program protection, system of systems engineering, and systems engineering research and development initiatives. She oversees the DoD Systems Engineering Research Center, a university-affiliated research center dedicated to advancing systems engineering methods, and the MITRE National Security Engineering Center, a DoD federally funded research and development center.

Ms. Baldwin has been with the Office of the Secretary of Defense (OSD) since 1998, where she has led the application of capabilities-based planning in the acquisition process and served as Deputy

Director, Software Engineering and System Assurance. Before working with OSD, Ms. Baldwin served as a science and technology advisor in the Army's Office of the Deputy Chief of Staff for Operations and Plans. Ms. Baldwin began her career at the U.S. Army's Armament Research, Development, and Engineering Center, Picatinny Arsenal. Ms. Baldwin was a recipient of the Meritorious Presidential Rank award in 2014, in recognition of exemplary service. Ms. Baldwin received a Bachelor of Science degree in Mechanical Engineering from Virginia Tech and a Master of Science degree in Systems Management from the Florida Institute of Technology.

Is Systems Engineering Really Engineering?

Steve Jenkins, Chief Engineer, JPL Integrated Model-Centric Engineering

Engineering is a creative process. The object of engineering is to bring about a desired state of the world, typically through the creation of artifacts that use scientific principles to nudge the state of the world in a desired direction. Although engineering disciplines differ in their problem domains and solution techniques, there are fundamental principles that unite them and distinguish engineering from other creative activities such as painting and writing. This talk will explore some of these fundamental principles and consider the degree to which systems engineering does or does not respect them. Finally, it will argue that “Model-Based Systems Engineering” is just a label for a much-needed effort to firmly establish systems engineering as a legitimate application of engineering.

Steven Jenkins is a Principal Engineer in the Formulation and Systems Engineering Division at the Jet Propulsion Laboratory, California Institute of Technology. He serves as the Chief Engineer of JPL’s Integrated Model-Centric Engineering Initiative, an institutionally-funded project aimed at enhancing the value of the engineering process through modeling. His interests include the integration of descriptive and analytical modeling and the application of knowledge representation and formal semantics to systems engineering. He holds a B.S. in Mathematics from Millsaps College, an M.S. in Applied Mathematics from Southern Methodist University, and a Ph.D. in Electrical Engineering from UCLA. He was awarded the NASA Outstanding Leadership Medal in 1999 and was a co-recipient of the NASA Systems Engineering Award in 2012.

Model Centric Engineering - Insights and Challenges: Primary takeaways from a Government-Industry Forum

Dinesh Verma, Dean Emeritus, School of Systems and Enterprises, Professor, Executive Director, DoD Systems Engineering Research Center (SERC)

Model-centric engineering can be characterized as an overarching digital and visual approach to engineering. It also involves integrating different model types with simulations, surrogates, systems and components at different levels of abstraction and fidelity across disciplines throughout the system or solution lifecycle. The use of such digital engineering technologies and model-centric engineering practices are advancing, and adoption is accelerating. While this is happening, a number of technical and business/acquisition model challenges remain. The current business models may not be appropriately aligned for acquisition in such a model-centric ecosystem.

These digital technologies are changing how organizations are conceptualizing, architecting, designing, developing, producing, and sustaining. Some use model-centric environments for customer engagements, as well as design engineering analyses and review sessions. Some are integrating mission and system-level modeling and simulations originally created for design and development and expanding them into new cloud-like services enabled by the industrial Internet. Most organizations today have a unique capability realized by integrating commercial technologies and tools with their own innovations.

The Systems Engineering Research Center (SERC) organized an Industry-Government Forum to gain insights from key stakeholders in the "user community" on how to transform our engineering and acquisition culture in light of these advancements; how to align engineering and business/acquisition models; and explore ideas and concepts to improve the efficiencies and speed development, deployment, and sustainment of needed capabilities to the warfighter.

The intent of this Forum was for key stakeholders in industry, government, and academia to converge and identify high-value "air gaps" that remain as hurdles in model-centric engineering, and that can be addressed through focused research and policy. This presentation will highlight the primary insights and challenges identified during this forum.

Dinesh Verma received his Ph.D. and M.S. in Industrial and Systems Engineering from Virginia Tech. He served as the Founding Dean of the School of Systems and Enterprises and Professor in Systems Engineering at Stevens Institute of Technology from 2007 through 2016. He currently serves as the Executive Director of the Systems Engineering Research Center (SERC), a US Department of Defense sponsored University Affiliated Research Center (UARC) focused on systems engineering research. During his fifteen years at Stevens he has successfully proposed research and academic programs exceeding $150m in value. Verma served as Scientific Advisor to the Director of the Embedded Systems Institute in Eindhoven, Holland from 2003 through 2008. Prior to this role, he served as Technical Director at Lockheed Martin Undersea Systems, in Manassas, Virginia, in the area of adapted systems and supportability engineering processes, methods and tools for complex system development and integration.

Before joining Lockheed Martin, Verma worked as a Research Scientist at Virginia Tech and managed the University's Systems Engineering Design Laboratory. While at Virginia Tech and afterwards, Verma continues to serve numerous companies in a consulting capacity, to include Eastman Kodak, Lockheed Martin Corporation, L3 Communications, United Defense, Raytheon, IBM Corporation, Sun Microsystems, SAIC, VOLVO Car Corporation (Sweden), NOKIA (Finland), RAMSE (Finland), TU Delft (Holland), Johnson Controls, Ericsson-SAAB Avionics (Sweden), Varian Medical Systems (Finland), and Motorola. He served as an Invited Lecturer from 1995 through 2000 at the University of Exeter, United Kingdom. His professional and research activities emphasize systems engineering and design with a focus on conceptual design evaluation, preliminary design and system architecture, design decision-making, life cycle costing, and supportability engineering. In addition to his publications, Verma has received three patents in the areas of life-cycle costing and fuzzy logic techniques for evaluating design concepts.

Dr. Verma has authored over 100 technical papers, book reviews, technical monographs, and co-authored three textbooks: *Maintainability: A Key to Effective Serviceability and Maintenance Management* (Wiley, 1995), *Economic Decision Analysis* (Prentice Hall, 1998), *Space Systems Engineering* (McGraw Hill, 2009). He is a Fellow of the International Council on Systems Engineering (INCOSE). He serves on the Core Curriculum Committee of the TU/Graz (Austria) Space Systems Engineering Program, and on the inaugural Board of Advisors of the Jim McNatt Institute for Logistics Research. He was honored with an Honorary Doctorate Degree (*Honoris Causa*) in Technology and Design from Linnaeus University (Sweden) in January 2007; and with an Honorary Master of Engineering Degree (*Honoris Causa*) from Stevens Institute of Technology in September 2008.

European space developments and main technical challenges

Franco Ongaro, Director of Technical and Quality Management (D/TEC), and Head of ESTEC, European Space Agency

This presentation will provide a short introduction on the European Space Agency programmes and way of working. It will introduce our interest in and use of MBSE in our context and role. An overview of our Systems Engineering and in particular MBSE approach will be provided along with some examples. What we expect in terms of benefits and challenges with it, especially considering our role as a government agency will be described.

Franco Ongaro graduated as a Doctor of Aeronautical Engineering from the University Politecnico of Milan. In 1987 he joined ESA., working at ESA HQ in Paris on the Columbus project. In 1988, he moved to ESTEC in the Netherlands as Head of the Columbus Payload Interfaces Unit. He was shortlisted as candidate in the European astronaut selection of 1991. In 1994, Franco Ongaro moved back to HQ, to join the ESA Strategy Directorate as General Studies Programme Manager. In 2001, he initiated and managed the start of the Aurora exploration programme until 2005, when he became head of the ESA Advanced Concepts and Technology Planning Department, issuing the first ESA Technology Long Term Plan and creating the Advanced Concepts Team. From 2007, he led the preparation and implementation of the Iris programme to develop a 'satcom' component for air traffic management. In 2009 he became Head of the Telecom Technologies, Products and Systems Department in the Telecommunications and Integrated Applications Directorate at ESTEC. From 1994 until 2009, he taught a one-semester graduate course in spacecraft design at the University Politecnico of Milan.

INCOSE SE Vision, Model-Based Engineering and the journey towards Digital Enterprises

Alan Harding, President, International Council On Systems Engineering (INCOSE), BAE Systems Global Engineering Fellow

This presentation will describe the current context for systems engineering, the INCOSE Systems Engineering Vision 2025 "A World in Motion" and its imperatives for the future of systems engineering as a transformed discipline, and a view of the path forwards towards effective digital enterprises.

Alan Harding is the head of the information systems engineering discipline for the BAE Systems Military Air and Information business in the UK. He was also appointed a BAE Systems Global Engineering Fellow in November 2010, recognizing his professional expertise and activities promoting systems within the company and in the wider UK and international community.

Alan is the 2016-2017 President of the International Council On Systems Engineering (INCOSE), the global professional society for systems engineering. He is a practicing systems engineer with over 30 years of experience in defense and security applications. His specialist interest areas include capability, systems-of-systems, architecture, and competency development.

Progress Check: How Well Is Europa Clipper MBSE Addressing SE Challenges?

Todd Bayer, Europa Clipper Flight System Engineer and Principal Engineer, JPL

JPL's Integrated Model Centric Engineering Initiative (IMCE) has led the infusion of MBSE at JPL. In 2009 IMCE articulated a set of challenges that confronted systems engineering at JPL, based on examination of issues and lessons from several recent projects (the "Five System Engineering Challenges"). In 2012 this work was augmented to describe specific areas where it was thought MBSE could help address these challenges. In parallel, the Europa Clipper Mission became the first project at JPL to attempt, in close collaboration with IMCE, a widespread adoption of MBSE. This adoption has been, on the whole, highly successful so far. Recently, Europa Clipper completed Phase A (Formulation) with a successful System Requirements Review / Mission Definition Review. This is an opportune time to take stock of the progress and the work yet to go. This talk measures the progress so far on Europa Clipper against those areas where, back in 2012, we thought MBSE could help.

Todd Bayer is a Principal Engineer in the Formulation and Systems Division at the Jet Propulsion Laboratory, where he has worked since 1989. He is currently the Flight Systems Engineer for the Europa Clipper Project. Prior to that he was the Assistant Manager for Flight Projects of JPL's Systems and Software Division. During this time he helped to lead JPL's Integrated Model Centric Engineering Initiative, developing the problem statement (Five System Engineering Challenges) and the Concept of Operations, as well as leading the original Europa System Modeling Team. Todd has participated in the development and operations of several missions including Mars Observer, Cassini, Deep Space 1 and Mars Reconnaissance Orbiter -- for which he was the Flight Systems Engineer during Phase A-D and the Chief Engineer during Phase E. He has been awarded two NASA medals for technical leadership. The Europa System Modeling Team he led received the NASA Chief Engineer's award for Systems Engineering Excellence. In the late 90's, during a leave of absence from JPL he worked at EUMETSAT in Darmstadt, Germany as a member of the Meteosat Second Generation (MSG) Space Segment Systems Engineering Team. Todd holds a B.S. in Physics from the Massachusetts Institute of Technology.

Why is Human-Model Interactivity Important to the Future of Model-Centric Systems Engineering?

Donna Rhodes, Principal Research Scientist and, Director, Systems Engineering Advancement Research Initiative (SEAri), MIT

In our envisioned future, we see engineers, analysts, and decision makers immersed in highly interactive model-centric environments using digital system models as a primary basis for system decisions. While significant progress on modeling languages, modeling practices, and modeling methods has been achieved, insufficient attention has been given to the necessary interactivity between humans and models. Given emerging modeling toolsets, availability of powerful computational resources, and autonomous decision-aiding, the human role in relationship to models must be re-examined. In this talk, Dr. Rhodes will share findings and insights from ongoing research on human-model interactivity. The research is motivated by the need to better understand and enable effective "human-model teaming", while drawing from advancements in data science, visual analytics, and growing knowledge of complex systems. Ongoing areas of inquiry include: how and why individuals interact within model-centric environments, facets of human interaction with visualization tools and large data sets, and underlying fundamentals such as the role of trust in model-centric decision-making. Emerging implications for practice extending from the interim findings are discussed.

Donna Rhodes is a principal research scientist in the MIT Sociotechnical Systems Research Center, and co-founder and director of MIT's Systems Engineering Advancement Initiative (SEAri). She teaches and advises graduate students across multiple programs at MIT, and is principal investigator for numerous sponsored research projects. Her research includes innovative methods for architecting and design of complex systems and enterprises, human-model interaction, model-centric decision making, and empirical studies of engineering systems practice. Prior to MIT, Dr. Rhodes held technical and senior management positions at IBM Federal Systems, Lockheed Martin, and Lucent. She has been very involved in the evolution of the systems engineering field, and is a Past President and Fellow of the International Council on Systems Engineering (INCOSE). She received her M.S. and Ph.D. in Systems Science from the T.J. Watson School of Engineering at Binghamton University.

MBSE for Architecture Trades During Concept Exploration

Jon Blossom, Software Systems Engineer, Human Interfaces, JPL

For more than 20 years, JPL's Team X has conducted rapid concurrent point design studies using a set of subsystem design and cost models, implemented as Excel workbooks linked through a central data store. In the same time, technology has evolved, and the JPL portfolio of formulation teams has expanded to include earlier phase concept generation, feasibility assessments, and trade space explorations, as well as new mission types and smallsat designs.

To address the evolving needs of the formulation community, the JPL Office of Formulation is developing an innovative architecture for its concurrent engineering facilities, adopting many of the practices and philosophies of Model-Based Systems Engineering. The new software – dubbed the Foundry Furnace – leverages advances in the discipline, as well as innovations of our own, and provides a new web-based infrastructure that is general enough to support the full range of project formulation needs and agile enough to support rapid concurrent design sessions. In our architecture, clients collaborate on a shared centralized model that can capture and facilitate the exploration of multiple design alternatives. It includes mechanisms for easy re-use and re-integration of partial designs and analyses and strives for the flexibility, speed, and relative ease of use of the current Excel-based tools. As a Formulation community-wide tool, it will help ease the transition of a concept from concept to point design to proposal, and it will allow export to SysML or other formats as desired by implementation teams.

Jon Blossom is the Software Systems Engineer for the Foundry Furnace, leading the development of the Integrated Modeling Environment application. As a member of the Human Interfaces Group (397F), he works closely with JPL's early formulation design teams to understand how modern software technologies can enhance the exploration and evaluation of new mission concepts. Previously, Jon consulted for Walt Disney Imagineering and other clients in the toy and entertainment industries. As a developer, he has several registered patents and won THEA, BAFTA, and CODiE awards for his work. After graduating with a B.A. in Religious Studies from Yale University, he immediately started his career as a multi-media systems programmer for Microsoft.

Acquisition and Early Evaluation of Architecture with Arcadia and Capella

Stéphane Bonnet, Head of Thales Corporate MBSE Coaching and Design Authority, Capella

The open source Arcadia-Capella duo is a rather atypical solution in the landscape of MBSE tools, as it features a very tight integration between a comprehensive engineering method for architectural design and a dedicated modeling workbench. This solution has been successfully deployed over the last six years on a large variety of engineering domains and contexts. This presentation provides an overview of the Arcadia method and focuses on two of its key drivers: the strong distinction between need and solution and the early evaluation of candidate architectures. It illustrates how the Capella workbench provides concrete guidance and supports definition and analysis activities, using Thales examples from the domain of imaging satellites.

Dr. Stéphane Bonnet is Head of Thales Corporate MBSE Coaching and Design Authority of the Capella open source modeling solution. For the last ten years, he has led the development of Capella and has been an active contributor to the Arcadia model-based method for systems, hardware and software architectural design. He dedicates most of his time to training and coaching activities on operational projects worldwide, helping engineers and managers implement the MBSE cultural change. In Thales, he is animating a wide community of experts from all domains and countries to investigate low-maturity modeling topics, capture end-user needs, and orient method and workbench roadmaps.

NASA’s MBSE Pathfinder and New Community of Practice

Scott Miller, Systems Engineer, NASA Ames Research Center

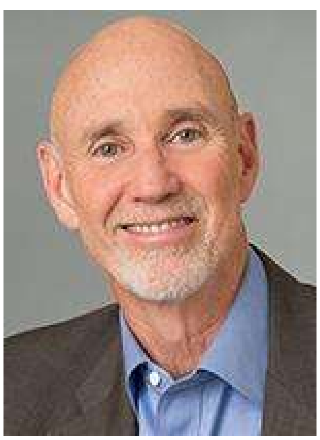
To date the practice of MBSE at NASA has been largely grassroots-driven with particular projects or directorates coming up with their own tool infrastructures, approaches, and best practices. Today’s NASA projects are increasingly collaborative, involving multiple Centers, indicating the need for effective systems engineering across decentralized program and project teams. MBSE Pathfinder was an 8-month effort to bring together participants from across NASA to apply MBSE to real NASA issues, develop a NASA-wide MBSE tool capability, and start to align the practice of MBSE across the agency. The 30-plus MBSE Pathfinder participants applied MBSE to a Mars architecture campaign, rocket engine development, Mars lander development, and a sounding rocket program. The overall effort generated a set of issues and lessons learned, starting points for common model libraries and design patterns, and a new community of MBSE practitioners. This community is now being grown into a formal NASA-wide MBSE Community of Practice, which will serve as the collection point for the knowledge of NASA’s MBSE practitioners and the development of common MBSE tools, best practices, and guidance. These efforts promise to accelerate the adoption and effectiveness of MBSE throughout NASA.

Scott Miller is a systems engineer at NASA Ames Research Center, where he works on Resource Prospector (RP), a lunar ISRU rover mission. During his three-plus years on RP, Mr. Miller has spearheaded the application of MBSE across its multiple participating NASA centers. Mr. Miller is also leading a new NASA-wide MBSE Community of Practice, an outgrowth of the agency’s 2016 MBSE Pathfinder effort, in which he participated. Mr. Miller holds a BS in Aerospace Engineering from CU-Boulder and an MS in Aeronautics & Astronautics from Stanford.

Maintaining 'One Source of Truth' Using MBSE on ARRM

Brian Muirhead, Project Manager, Asteroid Rendezvous & Retrieval Mission, JPL

The Asteroid Redirect Robotic Mission (ARRM) is a key element in NASA's plans for advancing human spaceflight to explore beyond low Earth orbit. The mission will rendezvous with a near-Earth asteroid using advanced solar electric propulsion. Once there, it will map the asteroid to identify 3 m-class boulders. Once an appropriate boulder is identified the spacecraft will land and extract the boulder. The spacecraft will return the boulder (most likely >10t) to lunar orbit where a crewed mission on Orion will rendezvous and sample the boulder material on two EVAs. As if this mission wasn't challenging enough it is being done as a partnership between 6 NASA centers with JPL leading the ARRM mission. A key to managing the technical elements of the project is the use of MBSE to maintain "one source of truth" across requirements, the concept of operations and various other system, and subsystem, process and information elements, across the multi-center (and with a to be selected system contractor) organization. This talk will describe and provide examples of the ARRM approach to MBSE, how it's working, issues and future plans.



Brian Muirhead joined NASA/JPL in 1977, he has worked on various space science missions including Galileo to Jupiter, Mars Pathfinder and Deep Impact. He was the Program System Engineer for Constellation and, most recently, the JPL Chief Engineer. Brian is currently the Project Manager of the Asteroid Redirect Robotic Mission, which is in Phase B.

Digital Environment and MBSE Progress at Airbus Space

Ralf Hartmann, VP SE Support & Digital Transformation, Airbus Space Systems

The digitalization of enterprise processes is one of the major trends which will significantly determine our future working environment. Computer aided design (CAD) was the pioneer engineering domain in the early days followed by computer aided software engineering (CASE). The finance sector developed a rich universe of enterprise resource planning (ERP) applications and the digital factory is a reality since years in the mass production of consumer products.

The challenge today is no longer in the area of information technology capabilities but in the interdisciplinary integration of domain silos along a seamless end-to-end process from early concept development to manufacturing and maintenance. Furthermore, one key domain is lagging behind in the digitalization race: Systems Engineering! The paradigm shift towards MBSE has started late and is by far neither mature nor a standard practice unlike to the situation in other disciplines.
These challenges are specifically relevant for space industry due to the one off nature of our projects (up to now) and due to the essential role of systems engineering in space business since its existence.

The presentation will give an overview of the end-to-end product lifecycle management (PLM) ambition at Airbus Defence and Space as an enabler for:

- More efficient processes from concept design to operations
- Reuse and products family approach
- Agile development processes
- Exploiting the opportunities of modern data analytics

Systems Engineering has a key role in this ambition filling a major remaining gap in the digital landscape through MBSE and by driving the integration of the independent digital silos. Some selected examples will be presented.

Ralf Hartmann is currently Vice President of "System Engineering Support & Digital Transformation" for the Space Systems Business Line within Airbus Defence & Space. Among others this includes the responsibility for processes, methods and tools harmonization and the governance for the space systems digitalization initiatives. Ralf has established the SE excellence initiative for space including an internal SE certification program. He is the Deputy Director for the Operations & Quality organization in Friedrichshafen and Munich.

Before this, Ralf was head of Space Technology Innovation for a period of 2 years and of the "Satellite FVI, Engineering Tools & Control Ground Segment" organization for a period of 10 years. Since 1987 he worked in space for Airbus Defence & Space and its predecessor companies in the area of robotics, automatic control, simulation, S/W development and systems engineering. Ralf is a member of the Airbus Systems Engineering Steering Group (SESG) since the beginning and the INCOSE Corporate Advisory Board representative of Airbus Defence and Space.

Highlights in Ralf's SE related career include the implementation of a comprehensive Systems Engineering Qualification Program and the Satellite Design Office, a conceptual design centre, which he was leading for some years. Furthermore Ralf was one of the key authors of the current European Space Systems Engineering Standard (ECSS-E10). He received a Diploma in Electrical Engineering from the University of Karlsruhe and he is a certified project management professional (GPM/IPMA).

Ralf Hartmann has been an INCOSE member since 1996 and a founding member of GfSE, the German Chapter of INCOSE. He was the president of GfSE in 2000 and the INCOSE Director for Strategy from 2008 until 2014. Under his sponsorship the actual SE Vision 2025 has been developed. Ralf was the chair of the 2^{nd} European SE Conference in 2000 and the co-chair of the 14^{th} INCOSE International SE Symposium in 2004. In 2005 Ralf was selected as an INCOSE Fellow and he received the INCOSE Founders Award in 2008.

System Design and Analysis Models in Concert with Discipline Design Models

Michael Watson, Senior Systems Engineer, NASA/MSFC

Systems Engineering seeks to engineer systems at the system level. Traditional methods of systems engineering involve emphasis on the agreements (requirements) on the system outputs and inputs. These traditional methods depend on the detailed discipline designs to form the structure of the system. Engineering of the system can be accomplished through the identification of the system defining physics and state variables, system interdependencies, and system value. This level of system design involves broader physical approaches than used by the individual disciplines, complementing and not replacing the discipline design methods. Considering these system level aspects, the systems engineer can provide clear guidance on the system functions and relationships and provide a more efficient structure for the system integration. In addition, discipline integration involves sociological influences which effect the system design and must be accounted for in the system integration, design, and analysis activities. Understanding and working with the sociological aspects of systems engineering provides methods to identify information flow gaps and barriers within and between the various organizations working on the system development and operations. These system physical and sociological approaches can greatly improve the efficiency of the system design and analysis process. A set of system models supports these approaches which support the engineering of the system. These models provide an important medium for the systems engineer to perform the system design, integrate discipline designs, and communicate results of the system design and analysis efforts.

Michael D. Watson is in the National Aeronautics and Space Administration (NASA) Marshall Space Flight Center (MSFC) System Engineering Management Office. He is leading the NASA Systems Engineering Research Consortium responsible for definition of elegant product focused systems engineering. He has served as the Space Launch System (SLS) Lead Discipline Engineer for Operations Engineering. He started his career with NASA developing International Space Station (ISS) operations capabilities. He also worked to develop remote operations support capabilities for the Spacelab Program in the United States, Europe, and Japan. He subsequently served as Chief of the Optics Branch responsible for the fabrication of large x-ray telescope mirrors, diffractive optics, and telescope systems. He served as Chief of the Integrated Systems Health Management (ISHM) and Sensors Branch and led a NASA team defining Vehicle Management System capabilities for human missions to Mars. His branch work included the definition of ISHM capabilities for the Ares family of launch vehicles. He graduated with a BSEE from the University of Kentucky in 1987 and obtained his MSE in Electrical and Computer Engineering (1996) and Ph.D. in Electrical and Computer Engineering (2005) from the University of Alabama in Huntsville.

Architecting and Incorporating Large Scale Model Based Systems Engineering Solutions at Boeing

Bob Malone, Brittany Friedland, John Herrold, Systems Engineers, Boeing

Development and design of increasingly integrated aerospace systems presents challenges in managing and validating the large and detailed accompanying specification datasets. Model Based Systems Engineering (MBSE) has become essential in allowing Boeing to meet these challenges. Through analysis of system architecture models, Boeing has been successful in accelerating data release schedules and eliminating specification errors that result in costly rework. Given the scope of some of the large scale system architecture models created at Boeing to achieve these benefits, it is currently necessary for Boeing to customize its own MBSE tool suites from Commercial-Off-The-Shelf (COTS) platforms to accommodate these models. Boeing successfully applies a modified set of Systems Engineering (SE) architectures to specify the required MBSE tool suites and also has developed a unique SE skill set for engineers creating these specifications and developing and deploying the subsequent tool suites. This presentation details the scope of Boeing MBSE models, the benefits achieved through their analyses, and the methodologies Boeing employs in developing and deploying MBSE tool suites.

Robert Malone has spent his entire thirty-five year career as an aerospace engineer and has specialized in systems engineering for the past twenty-six years. He has held positions in aircraft maintenance operations, aviation security system integration, human factors, reliability, maintainability and testability. His current focus is on developing computer-based tools and processes supporting systems engineering, large scale system integration, and system integration modeling.

Brittany Friedland is currently a systems engineer at Boeing working on developing and deploying Model Based Systems Engineering tools and processes across the Enterprise (Commercial and Defense). She spent the beginning of her career in the Oil and Gas Industry before making a career change to work in the Aerospace Industry. Brittany has a BSE in chemical engineering from the University of Michigan.

John Herrold is currently the System Architect for the Boeing enterprise Model Based Systems Engineering (MBSE) tool suite development and implementation. This on-going effort provides a service ready model based systems engineering solution (process, tool and training) for systems and design engineers. John has been a Boeing employee for 36 years and has worked mostly in the engineering analysis domain, supporting many of the Boeing Commercial and Military Airplane products. John is a designated Boeing Technical Lead Engineer and a member of the International Council on Systems Engineering (INCOSE). John has a BSEE from the University of Washington.