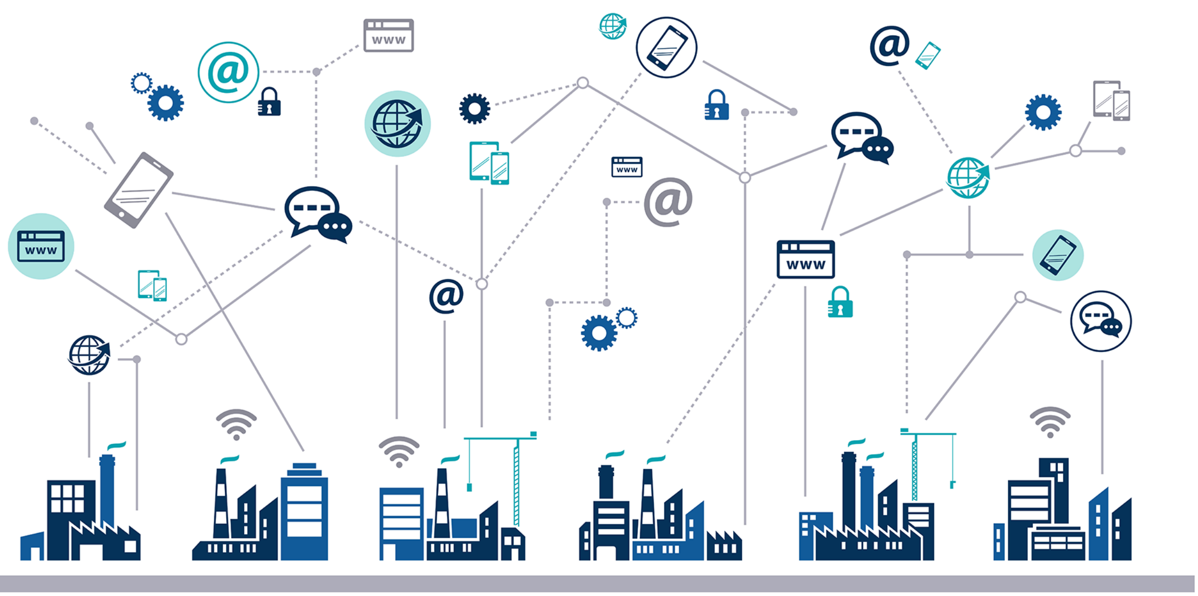
Model-Based Enterprise Summit 2018

April 2-5, 2018

National Institute of Standards and Technology
Gaithersburg, Maryland



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Welcome to MBE Summit 2018

We are delighted to be hosting the ninth installment of the MBE Summit again at the National Institute of Standards and Technology (NIST). This year we witnessed another year-over-year registration growth. This speaks to the growing interest of MBE within the community and the importance of the Summit output.

The Program Committee undertook a significant effort to ensure a high-quality Summit and signal to the community that the MBE Summit is the best place for gathering and sharing information dedicated to the digitalization across the produce lifecycle. We wanted this year's Summit focused on empowering the industrial shift to MBE with recommend practices and how-to guidance. This year's MBE Summit theme is *Empowering the Digital Transformation with an Integrated Lifecycle*, with technical tracks spanning across Systems Engineering and Lifecycle Management, Design Recommended Practice and Model-based Definition, Model-based Manufacturing, and Model-based Quality and Inspection. We had 70 submissions for presentation at this year's MBE Summit, of which we accepted eight papers, 33 presentations, five posters, and two panels. Given the good-quality of the papers and presentation executive summaries we will be publishing a proceedings of the MBE Summit again this year.

The MBE Summit is only possible through the combined efforts of a number of different people. First, I would like to personally thank the Program Committee who dedicated so much of their time in planning the MBE Summit program. Their inputs have been extremely valuable and highly appreciated. I also want to thank the presentation authors, session chairs, and attendees whose participation is vital to the success of the MBE Summit. I specifically want to send many thanks to Mark Carlisle, who helps each year bring the MBE Summit together through numerous hours of planning and organizing. His dedication as the MBE Summit Coordinator ensures the MBE Summit runs as smooth and efficiently as possible. He manages all scheduling and logistics of the MBE Summit, while interfacing with the various NIST offices that support the MBE Summit. In addition, I want to thank Steve Weinman and Fred Constantino from the American Society of Mechanical Engineerings (ASME) for their willingness to sponsor and coordinate the food and beverages during the breaks. Lastly, I want to thank ASME, Digital Manufacturing and Design Innovation Institute (DMDII), and the United States Department of Defense (DOD) for providing administrative and technical resources to the planning and operations of the MBE Summit. I express my appreciation and deep gratitude to all involved with the MBE Summit without whom the Summit would not be possible.

Thank you,
Thomas Hedberg, Jr.

Organization

Program Committee

The Program Committee (PC) was responsible for the functional organization and technical content of MBE Summit 2018. It prepared the final list of conference topics and invited speakers, selected contributed papers, presentations and posters from amongst the submitted abstracts and refereed contributed papers. The PC consists of:

Thomas Hedberg, *Summit Chair* National Institute of Standards and Technology

Mark Carlisle, *Summit Coordinator* National Institute of Standards and Technology

Allison Barnard Feeney National Institute of Standards and Technology

Fred Constantino American Society of Mechanical Engineerings

Daniel Finke The Pennsylvania State University

Kevin Fischer Rockwell Collins

Gregory Harris Auburn University

Anthony Holden U.S. Army

Paul Huang U.S. Navy, Office of Naval Research

Ben Kassel LMI, formerly of the U.S. Navy

Karla Quigley National Institute of Standards and Technology

Tony Still U.S. Army

Kym Wehrle Digital Manufacturing and Design Innovation Institute

Steve Weinman American Society of Mechanical Engineerings

Phil Zimmerman Office of the Deputy Assistant Secretary of Defense for Systems Engineering

Sponsors

We would like to thank the following organizations and institutions for sponsoring the MBE Summit 2018 with financial, administrative, and technical resources:

Useful Information

Registration Desk

The registration desk is located outside the Green Auditorium. All MBE Summit attendees must first stop at the registration desk upon arrival to NIST to pick up their Summit badges. The registration desk will remain open during the entire MBE Summit. Staff at the registration desk can help answer general questions or assist with any logistics matters that may arise.

Participation Identification

Summit badges are essential for admission to the MBE Summit venues and all sessions. Therefore, please wear your badge at all times.

Breaks

Light refreshments will be served near the registration desk during breaks. Lunch will be the responsibility of each attendee. The NIST Cafeteria (`https://www.nist.gov/director/pao/gaithersburg-cafeterias`) has a large assortment of hot and cold lunch items.

Internet

Internet access will be available via the NIST guest wireless network. The SSID of the network is: *NIST-Guest*. A network password is not required. More information for accessing the guest wireless network can be found at: `https://www.nist.gov/document-494`.

Hotel Shuttle Bus

DATE	TIME	PICK-UP	DROP -OFF
Monday, April 2nd, 2018	11:30am	Holiday Inn	NIST Bldg. 101
2nd Run	*ETA 12:00pm	Holiday Inn	NIST Bldg. 101
	5:30pm	NIST Bldg. 101	Holiday Inn
2nd Run	*ETA 6:00pm	NIST Bldg. 101	Holiday Inn
Tuesday, April 3rd, 2018	7:40am	Holiday Inn	NIST Bldg. 101
2nd Run	*ETA 8:10am	Holiday Inn	NIST Bldg. 101
	5:15pm	NIST Bldg. 101	Holiday Inn
2nd Run	*ETA 5:45pm	NIST Bldg. 101	Holiday Inn
Wednesday, April 4th, 2018	7:40am	Holiday Inn	NIST Bldg. 101
2nd Run	*ETA 8:10am	Holiday Inn	NIST Bldg. 101
	5:15pm	NIST Bldg. 101	Holiday Inn
2nd Run	*ETA 5:45pm	NIST Bldg. 101	Holiday Inn
Thursday, April 5th, 2018	8:10am	Holiday Inn	NIST Bldg. 101
2nd Run	*ETA 8:30am	Holiday Inn	NIST Bldg. 101
	12:30pm	NIST Bldg. 101	Holiday Inn
Pick up for guests going to 2nd meeting	4:30pm	NIST Bldg. 101	Holiday Inn
Pick up for guests going to 2nd meeting	5:45pm	NIST Bldg. 101	Holiday Inn

"Overflow" drop off and pick-up times are estimated based on when the shuttle return from the 1st run. If the shuttle returns to hotel earlier than the scheduled time, it will leave for the second run once the shuttle is full.

Summit Schedule

Monday, 2 April 2018

Track	Keynote and Invited Speaker Presentations	Registration & Information Desk
Date	**Monday, April 2, 2018**	**Monday, April 2, 2018**
Time	Red Auditorium	Outside Green Auditorium
11:30-13:00	*Registration Check-in*	Open
13:00-13:10	Welcome	
13:10-13:40	Welcome Address Dr. Walt Copan -- Director, NIST	
13:40-14:40	Invited Speaker Dr. Thomas Kurfess -- Georgia Tech	
14:40-14:50	*Break*	
14:50-15:50	Invited Speaker Dr. Don Kinard -- Lockheed Martin	
15:50-16:50	Invited Speaker Mr. David Gregory -- Ursa Major Technologies	
16:50-17:00	Summit-at-a-Glance & Staff Introductions	
17:00-17:30	*Networking in Poster Hallway*	

Tuesday, 3 April 2018

Track	Systems Engineering	Design & Recommended Practices	Manufacturing & Quality	Registration & Information Desk
Date	Tuesday, April 3, 2018	Tuesday, April 3, 2018	Tuesday, April 3, 2018	Tuesday, April 3, 2018
Time	Lecture Room A	Portrait Room	Lecture Room D	Outside Green Auditorium
8:30-9:30	Plenary in Green Auditorium	**Plenary in Green Auditorium** MBx Enablers of Distributed Intelligence in Manufacturing *Russ Waddell*	Plenary in Green Auditorium	Open
9:30-9:40	*Travel to Breakout*	*Travel to Breakout*	*Travel to Breakout*	
9:40-10:10	Empowering the Digital Transformation via Digitalization within the Integrated Lifecycle *Gerald Deren*	Inter-Domain Model-Based Workflows at Baker Hughes GE Using SOLIDWORKS *Hadi Jafari and Oboe Wu*	**Paper Presentation** Common Shared System Model for Evolvable Assembly Systems *David Sanderson, Jack C. Chaplin and Svetan Ratchev*	
10:10-10:40	The Model-Based Enterprise Transition Initiative (MBET-I): An NNSA Stockpile Services Solution To The Challenges Of Model-Based Enterprise (MBE) Implementation In The National Security Enterprise *Ryan Kuhns*	Robust Strategy for using Authoritative Source Standard Part data for MBD/MBE Assemblies *Timothy Thomas and Jennifer Herron*	**Paper Presentation** Integrating Data Visualization Software with Manufacturing Facility Databases: Reference Implementation and Lessons Learned *William Bernstein and Christopher Ricigliano*	
10:40-11:10	Connecting the MBE: Integrating 3D Technical Data throughout the System Lifecycle *Bruce Kaplan, Ben Kassel, Thomas Parks, Dick Tiano, and Scott Truitt*	ECN Cost Improvement *Rich Eckenrode and Annalise Suzuki*	**Paper Presentation** Digitally Enabling the Supply Chain *Gregory Harris, Chris Peters, Roy Whittenburg, Rendell Hughes, Kevin Fischer, Daniel Hartman, Kong Ma, Jeff Shubrooks and Thomas Hedberg*	
11:10-11:30	Discussion	Discussion	Discussion	
11:30-12:30	*Lunch*	*Lunch*	*Lunch*	
12:30-13:00	*Poster Hallway*	*Poster Hallway*	*Poster Hallway*	
13:00-14:00	Plenary in Green Auditorium	**Plenary in Green Auditorium** Invited Speaker Mr. Thad Henry -- NASA & Rick Steiner -- Skygazer Consulting	Plenary in Green Auditorium	
14:00-14:10	*Travel to Breakout*	*Travel to Breakout*	*Travel to Breakout*	
14:10-14:40	Tradespace Exploration of MBSE and MBE Integrated Workflows *Anthony Davenport, Joseph Simmons and Scott Ragon*	Ensure solid GD&T practices with Model-Based Definition *Oboe Wu*	On-machine measurement use cases for digital thread standards *John Horst*	
14:40-15:10	Maturing MBE Deployment via a Collaborative Model Authorized Product - Realization (MAPR-R) Project *Curtis Brown and Adrian Miura*	**Paper Presentation** Toward the Standardization of Digital Verification Technology, Development of Guidelines for Creating 1DCAE Models of Mechano-Electrical Products *Masatomo Inui and Tomohisa Fujinuma*	Computer Aided Inspection and Quality *Toby Maw and David Ross-Pinnock*	
15:10-15:30	Discussion	Discussion	Discussion	
15:30-15:50	*Break & Poster Hallway*	*Break & Poster Hallway*	*Break & Poster Hallway*	
15:50-16:20	Linking Technical Requirements beyond PLM vault *Tatyana Vidrevich and Rupert Hopkins*		**Paper Presentation in Green Auditorium** An Integrated Process for the Manufacture of On-Demand Small UAS *Nathan Beals, Eric Spero and John Gerdes*	
16:20-16:50	A Matrixed Approach to Model Based Product Implementation *Philip Jennings and Mark Debbink*		**Paper Presentation in Green Auditorium** Issues in Implementing a Model Based Enterprise *Gregory Harris, Daniel Abernathy, Roy Whittenburg, Anthony Holden and Anthony Still*	
16:50-17:10	Discussion		Discussion	
17:10-17:30	*Poster Hallway*	*Poster Hallway*	*Poster Hallway*	

Wednesday, 4 April 2018

Track	Systems Engineering	Design & Recommended Practices	Manufacturing & Quality	Registration & Information Desk
Date	**Wednesday, April 4, 2018**	**Wednesday, April 4, 2018**	**Wednesday, April 4, 2018**	**Wednesday, April 4, 2018**
Time	Lecture Room A	Portrait Room	Lecture Room D	Outside Green Auditorium
8:30-9:30	Plenary in Green Auditorium	**Plenary in Green Auditorium** System Lifecycle Handler for enabling a digital thread for smart manufacturing *Manas Bajaj, Dirk Zwemer and Thomas Hedberg*	Plenary in Green Auditorium	Open
9:30-9:40	*Travel to Breakout*	*Travel to Breakout*	*Travel to Breakout*	
9:40-10:10	Enabling MBE across the Life Cycle through 3Di TDPs *Marc Lind*	Extending and Evaluating the Model-based Product Definition *Nathan Hartman, Jesse Zahner, Thomas Hedberg and Allison Barnard-Feeney*	**Paper Presentation** Realization of the 5-Axis Machine Tool Digital Twin Using Direct Servo Control from CAM *Roby Lynn, Mukul Sati, Tommy Tucker, Jarek Rossignac, Christopher Saldana and Thomas Kurfess*	
10:10-10:40	MoSSEC (Modeling & Simulation information in a collaborative System Engineering Context) Standard Effort *Gregory Pollari, Adrian Murton and Nigel Shaw*	Barriers to MBD and MBE: Real, Perceived, and Self-Inflicted *Bryan Fischer*	**Paper Presentation** Requirements for a digital twin manufacturing framework *Martin Hardwick*	
10:40-11:10	Successfully Integrating MBSE Data Using OSLC *Brian Schouten*	Mathematical Models: Moving Beyond Symbology for PMI *Jami Shah and Joseph Davidson*	**Paper Presentation** Incorporating Standardized Factory Device Data into the Model Based Enterprise *Russell Waddell and Shaurabh Singh*	
11:10-11:30	Discussion	Discussion	Discussion	
11:30-12:30	*Lunch*	*Lunch*	*Lunch*	
12:30-13:00	*Poster Hallway*	*Poster Hallway*	*Poster Hallway*	
13:00-14:00	Plenary in Green Auditorium	**Plenary in Green Auditorium** 3D Data Exchange Project *Howard Owens, Jonathan Scott, Asa Trainer and Ryan Mills*	Plenary in Green Auditorium	
14:00-14:10	*Travel to Breakout*	*Travel to Breakout*	*Travel to Breakout*	
14:10-14:40	Bill of Features *Ryan Gelotte and Jennifer Herron*	*MBD ROI Case Study: CMM Automation from MBD* *Daniel Campbell ,Mark Nielsen, and Bryan Bergsma*	Selecting Dimensional Measurement Equipment in Inspection Planning *Shaw Feng*	
14:40-15:10	Capturing Product Behavioral and Contextual Characteristics through a Model-Based Feature Information Network (MFIN) *Daniel Campbell, Nathan Hartman, Charlie Tokowitz, Michael Sangid, Mark Nielsen and Saikiran Gopalakrishnan*	Proposal of a data processing guideline for realizing automatic measurement process with general geometrical tolerances and contactless laser scanning *Atsuto Soma, Hiromasa Suzuki and Toshiaki Takahashi*	Automatically Calibrated & Collected 3D Scan Data used for Quality Control (QC) across Supply Chain *Mingu Kang and Scott Kruse*	
15:10-15:30	Discussion	Discussion	Discussion	
15:30-15:50	*Break & Poster Hallway*	*Break & Poster Hallway*	*Break & Poster Hallway*	
15:50-16:20	Critical MBE Themes that Enable a Collaborative Government-Industry Digital Engineering Process throughout the DOD Acquisitions Lifecycle *Zhigang Pan*	QIF and the Future of Digital Metrology *Jennifer Herron, Curtis Brown and Daniel Campbell*	Model-based Operational Control Methods for Smart Manufacturing Systems *Timothy Sprock and Conrad Bock*	
16:20-16:50	The System Engineering Vee - It Still Relevant in The Digital Age? *Daniel Seal, Don Farr, Jason Hatakeyama and Scott Haase*	Machine Readable Semantic PMI for Pattern Defintion *Ryan Gelotte*	Optimizing Model Based Inspection (MBI). Development and Integration of key product characteristics and requirements for automatic mapping to the inspection method as color coded tasks for first article inspection. *Curtis Brown and Mark Nielsen*	
16:50-17:10	Discussion	Discussion	Discussion	
17:10-17:30	*Poster Hallway*	*Poster Hallway*	*Poster Hallway*	

Thursday, 5 April 2018

Track	Plenary Session	ASME MBE Standards Meeting	Registration & Information Desk
Date	**Thursday, April 5, 2018**	**Thursday, April 5, 2018**	**Thursday, April 5, 2018**
Time	Green Auditorium	Lecture Room D	Outside Green Auditorium
9:00-10:00	Enabling Facility-Level Interoperability Between Robot Teams and Machine Cell Devices *Josh Langsfeld, Matt Robinson, Shaurabh Singh and William Sobel*		Open
10:00-10:30	ASME MBE Standards *Fred Constantino*		
10:30-10:45	*Break*		
10:45-10:55	Systems Engineering Summary		
10:55-11:05	Design Summary		
11:05-11:15	Manufacturing & Quality Summary		Closed
11:15-11:25	MBE's Next Steps		
11:25-11:45	Closing Address Dr. Howard Harary -- Director, NIST Engineering Laboratory		
11:45-13:00		*Lunch*	
13:00-16:20		ASME MBE Standards	
16:20-16:30		*Break*	
16:30-17:30		DEDMWG	

Invited Speakers

Challenges of using Current Modeling Capabilities in Innovative Technology Development

2 Apr
3:50pm
Red
Auditorium

David Gregory

Ursa Major Technologies

Innovations in CAD tools and processes will enable additive manufacturing to continue to mature as a revolutionary process. Ursa Major Technologies utilizes additive manufacturing extensively in its line of rocket propulsion products and uses conventional CAD tools and processes. However, some parts require non-conventional design information. Examples of additive part and process flows will be presented to highlight challenges and opportunities for future CAD innovation.

Biography David Gregory is the Chief Technology Officer for Ursa Major Technologies, a Colorado-based manufacturer of turnkey propulsion solutions for a wide range of vehicles sized for servicing the micro- and nano-satellite launch community. He oversees technical and engineering processes for Ursa Major's Oxidizer Rich Staged Combustion engine family in a fast-paced R&D environment.

Mr. Gregory graduated with a Master of Science degree in Mechanical Engineering from Tennessee Technological University and went to work as a Research Engineer at the Naval Surface Warfare Center. He transition to the private sector through Pratt & Whitney Rocketdyne. Mr. Gregory later went to work for Blue Orgin, where he successfully led the propulsion design of the BE-3 engine that successfully launched and vertically landed the New Shepard space vehicle. After success at Blue Orgin, Mr. Gregory joined Ursa Major Technologies to pursue his engineering dream of developing and launching micro- and nano-satellite vehicles.

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3 Apr
1:00pm
Green
Auditorium

Model-Based Systems Engineering in the Real World

Thad Henry[1] and Rick Steiner[2]
[1]National Aeronautics and Space Administration (NASA); [2]Skygazer Consulting (With funding from the NASA Engineering and Safety Center)

Use of Model-Based Systems Engineering (MBSE) has been growing across industry, extending beyond defense and aerospace to include various commercial enterprises such as automotive and healthcare. Tool vendors are quick to point out benefits of this model-based approach and practices, but are not always clear how MBSE benefits can be realized on a project. When deployed successfully, several key considerations should be addressed that maximize the value for a use-case, including:

- Digital artifacts that result from MBSE
- Identifying use-cases
- Interoperability and Data Exchange Standards
- Reading and using a SysML model artifact effectively

Our presentation will discuss the nature and purpose of the MBSE approach and how key information is used for successful MBSE deployment within real world projects.

Biography Thad Henry has more than three decades of successfully organizing and managing varied technical projects within many of NASA's flagship programs such as the Space Shuttle Program, the International Space Station Program, the Tethered Satellite Program, the 2nd Generation Reusable Launch Vehicle Program, the Constellation Program, and the Exploration Systems Directorate. Mr. Henry currently serves as the NASA Agency Technical Lead for Configuration Management managing CM policy and best practices within NASA including several initiatives for model-based processes for using configuration management standards and advanced engineering concepts. Mr. Henry received a Engineering degree from Auburn University, an MBS in Systems Management from Florida Institute of Technology, and holds a Professional Engineering Certification. He is also an NDIA Certified Configuration and Data Manager. Mr. Henry serves on several external professional organizations in leadership roles such as SAE Configuration Management Committee, the NDIA Technical Information Division Council, the Association for Configuration and Data Management Board of Governors, and the PDES, Inc. Technical Advisory Council.

Rick Steiner is an independent Model Based Systems Engineering (MBSE) consultant and systems modeling coach, with clients in various Aerospace and Defense companies. He retired after a 30-year career at Raytheon as an Engineering Fellow and a Raytheon Certified Architect. He has focused on pragmatic application of systems engineering modeling techniques and has been an advocate, consultant, and instructor of model-based engineering. Rick has served as chief engineer, architect, and lead system modeler for several large-scale defense programs. He has been recognized by the International Council on Systems Engineering (INCOSE) as an Expert Systems Engineering Professional (ESEP), and has been honored as an INCOSE Fellow. Mr. Steiner continues to be a key contributor to the development and certification of the Systems Modeling Language (SysML). He is also co-author of "A Practical Guide to SysML", currently in its 3rd edition.

The Evolution and Revolution of the Digital Thread

2 Apr
2:50pm
Red
Auditorium

Dr. Don Kinard

Lockheed Martin

The Aerospace industry has utilized the digital thread to improve the design, manufacturing, and sustainment product development processes and has enable increased factory automation. More recently we have provided digital information directly to mechanics on the shop floor, as well as validating the as-designed to the as-built configuration using noncontact metrology. The industry is now tying factory equipment to this digital thread to increase utilization and improve maintenance practices. On the future horizon the burgeoning connections between the major IT systems (ERP, PLM, MES, etc.) is seen as a foundational element of Industry 4.0 transformation – the industrial revolution of data.

Biography Dr. Don Kinard is a Senior Fellow for Lockheed Martin Aeronautics Production Operations. Dr. Kinard established the F-35 Fighter Production System several years ago to manage production transition from the then one aircraft per month production rate to a 20 aircraft per month production rate; their current build rate is eight aircraft/month.

Dr. Kinard has been with LM for 33 years and prior to his current assignment he was Director of F-35 Production Engineering responsible for Joint Strike Fighter Tooling, Planning, Manufacturing Engineering, and Aircraft Systems Testing.

Before joining F-35 in 2004 Dr. Kinard held various positions in both Engineering and Manufacturing during his 18 years on the F-22 Program including Composite Risk Reduction Lead, Covers and Mate IPT Lead, Engineering Lead for F-22 Production Support, and Deputy Director of F-22 Production.

Don is also the lead for the LM Corporate Fellows Manufacturing Team as well as the Corporate Future Enterprise and the Foundational Technology Thread Programs whose task it is to develop and share engineering, manufacturing, and sustainment technologies throughout all of the LM business units. His technical interests include materials and structures, digital thread integration, industry 4.0, manufacturing technology, manufacturing system design, and production management.

Dr. Kinard earned a bachelors degree in Chemistry from Trinity University in San Antonio, TX and a PhD in Physical (Polymer) Chemistry from Texas A&M University.

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2 Apr
1:40pm
Red
Auditorium

Internet of Things for Manufacturing

Dr. Thomas Kurfess

Georgia Institute of Technology

Sensors are ubiquitous in modern manufacturing operations, and they generate significant quantities of data. With the advent of low cost, readily available broad band communication and virtually infinite cloud storage, many of the old stigmatisms related to taking data from a plant are no longer of concern. However, the question still remains as to what to do with the data. This lecture will discuss the use of large scale data sets from production operations and how they can be leveraged to better understand not only traditional operations, but untapped opportunities from data that are readily available today. Such opportunities provide an improved platform for classical analytic techniques as well as more modern, data intensive approaches to process and operations modeling. The talk will then focus on a specific next generation digital representations and their application to low cost, highly flexible implementations. Examples will be given for both manufacturing operations (additive and subtractive) and validation/verification, as well as how this capability is extensible to cloud computing operations, and next generation technology and business models such as Desktop as a Service (DAAS). The talk will conclude with a discussion of the technology, workforce and infrastructural directions and needs to fully enable the next generation digital twin, and where such a capability will drive the future of manufacturing.

Biography Thomas R. Kurfess received his S.B., S.M. and Ph.D. degrees in mechanical engineering from M.I.T. in 1986, 1987 and 1989, respectively. He also received an S.M. degree from M.I.T. in electrical engineering and computer science in 1988. He is the HUSCO/Ramirez Distinguished Chair in Fluid Power and Motion Control and Professor of Mechanical Engineering at the Georgia Institute of Technology. During 2012-2013 he was on leave serving as the Assistant Director for Advanced Manufacturing at the Office of Science and Technology Policy in the Executive Office of the President of the United States of America. In this position he had responsibility for engaging the Federal sector and the greater scientific community to identify possible areas for policy actions related to manufacturing. He was responsible for coordinating Federal advanced manufacturing R&D, addressing issues related to technology commercialization, identifying gaps in current Federal R&D in advanced manufacturing, and developing strategies to address these gaps.

He has served as a special consultant of the United Nations to the Government of Malaysia in the area of applied mechatronics and manufacturing, and as a participating guest at the Lawrence Livermore National Laboratory and at Sandia National Laboratories. He currently serves on the Board of Directors, the National Center for Defense Manufacturing and Machining, and the National Center for Manufacturing Sciences, and on the Board of Trustees for the MT Connect Institute. He is the President for the Society of Manufacturing Engineers. His research focuses on the design and development of advanced manufacturing systems targeting digital manufacturing, additive and subtractive processes, and large scale production enterprises.

Panel Sessions

3D Data Exchange Project

4 Apr
1:00pm
Green
Auditorium

Howard Owens[1], Jonathan Scott[2], Asa Trainer[3] and Ryan Mills[4]
[1]NAVAIR; [2]Razorleaf Government Solutions; [3]ITI TranscenData; [4]Anark Corporation

PMA-261 (CH-53K Heavy Lift Helicopter) is the first 3D Model Based platform at NAVAIR and the first PMA to instantiate a PLM system. A strategy on automatic upload of native CAD files into the PLM system, an automated verification/validation of native CAD files, and a format for non-CAD users to view the data is required. PMA-261 receives technical data from Sikorsky primarily in native CATIA V5 format and in neutral (TIF and PDF) format for lists and specifications. The priority is to have viewable data for non-CAD users to perform their jobs. As a non-CAD user, DLA needs to use PMA-261's technical data for provisioning, cataloging and sustainment. The project was initiated to increase the efficiency and automation of providing verified/validated technical data to all users in a consumable format, because manual conversion and validation of the volume of data appeared infeasible.

Anark Corporation, ITI TranscenData, and Razorleaf Government Solutions were engaged to prototype an automated system for creating and delivering consumable technical data, in an acceptable 3D PDF format. The teams work is ongoing, but the project has advanced sufficiently to allow presentation of the architecture and operation of the automated system along with the projected benefits. The automated system connects Dassault's ENOVIA PLM with Anark Core Server to automate the generation of 3D PDF documents and 3D PDF technical data packages (TDPs) for DLA, as well as ITI's DEXcenter and CADIQ products to generate STEP and verify/validate native CATIA V5, STEP, and 3D PDF file formats.

Moderator: Paul Huang, *Office of Naval Research (ONR)*

Panelists:

- *NAVAIR*: Howard Owens, Brent Gordon, Joe Tolarski
- *ITI*: Asa Trainer, Mark Haines
- *Anark*: Jim Merry, Jim Martin
- *Razorleaf*: Jonathan Scott, Steve Nichols
- *ATI*: Dick Tiano, Scott Truitt, Tim Macon

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3 Apr
8:30am
Green
Auditorium

MBx Enablers of Distributed Intelligence in Manufacturing

Russell Waddell
The Association For Manufacturing Technology

As part of the Model-Based Enterprise, model-based engineering, lifecycle management, manufacturing, quality and inspection (collectively "MBx")promise to streamline many facets of industry by establishing 3D models as authoritative information sources. Much of the promise of MBx has been in productivity and efficiency improvements to existing business models, but emerging business models for manufacturing also have the potential to benefit from and reinforce model-based approaches.

Moderator: Russell Waddell, *The Association For Manufacturing Technology (AMT)*

Panelists:

- William Sobel, *Vimana*
- Dr. Binil Starly, *NC State University*
- Chuck Matthews, *Machining Cloud*

Paper Abstracts

Track 2: Design Recommended Practice and Model-based Definition

Toward the Standardization of Digital Verification Technology, Development of Guidelines for Creating 1DCAE Models of MechanoElectrical Products

3 Apr
2:40pm
Portrait Room

Masatomo Inui[1] and Tomohisa Fujinuma[2]

[1]Ibaraki University; [2]Standardization Committee of New Digital Verification Technology

Although 1DCAE is considered to be effective for supporting the conceptual/functional design of mechano-electrical products, 1DCAE is not popular in the mechano-electrical industry in comparison to the automobile and aircraft industries. To promote the use of 1DCAE, it is necessary to eliminate the obstacles associated with the use of 1DCAE, and to reduce the cost required to create models of mechano-electrical products. In the attempt to reduce the modeling cost, we have started to develop guidelines for creating proper 1DCAE models of mechano-electrical products. In this study, we briefly explain our guidelines and use part of them to develop a specific mechano-electrical component. We also explain our findings in the use of 1DCAE in the mechano-electrical industry.

Track 3: Model-based Manufacturing and Quality

Common Shared System Model for Evolvable Assembly Systems

3 Apr
9:40am
LR D

David Sanderson, Jack Chaplin, and Svetan Ratchev

University of Nottingham

A vital aspect of distributed control in an adaptable production system is coherence between each system resource. The Evolvable Assembly Systems project addresses this challenge using a common shared system model. This paper provides an overview of the project and the shared system model approach as implemented in a real world demonstration cell.

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3 Apr
10:10am
LR D

Integrating Data Visualization Software with Manufacturing Facility Databases: Reference Implementation and Lessons Learned

William Bernstein[1] and Christopher Ricigliano[2]

[1]National Institute of Standards and Technology ; [2]W.T. Woodson High School

The purpose of this study is to support the integration of smart manufacturing systems into the typical manufacturing environment. This paper enumerates challenges and limitations faced as an open source visualization software, namely Keshif, was paired with an SQL database from the NIST manufacturing shop located in the Fabrication Technology Division. The utility of interactive data exploration of traditional manufacturing shop floor data housed in SQL databases is demonstrated. In addition, a Keshif instance representing 6340 active jobs in the NIST shops is showcased.

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3 Apr
10:40am
LR D

Digitally Enabling the Supply Chain

Gregory Harris[1], Chris Peters[2], Roy Whittenburg[3], Rendell Hughes[4], Kevin Fischer[5], Daniel Hartman[6], Kong Ma[6], Jeff Shubrooks[7] and Thomas Hedberg[8]

Auburn University; [2]The Lucrum Group; [3]MBD360, LLC; [4]ITI; [5]Rockwell Collins; [6]Rolls Royce; [7]Raytheon; [8]National Institute of Standards and Technology

This paper describes a project that will deliver a set of playbooks designed to accelerate the depth and breadth of adoption for digital supply chain practices and technologies. The resulting benefits of reduced cost and time along with greater innovation better position the U.S. industrial base to compete in the global market. The team will utilize existing tools and technologies developed in previous commercial and government funded research to create a roadmap and set of playbooks for Original Equipment Manufacturers (OEMs) and Small/Medium Manufacturers (SMMs) to guide the implementation of secure digitally-enabled supply chain practices and technologies.

An Integrated Process for the Manufacture of On-Demand Small UAS

3 Apr
3:50pm
Green
Auditorium

Nathan Beals, Eric Spero and John Gerdes

U.S. Army Research Laboratory

A digital catalog of small unmanned aircraft systems able to be rapidly manufactured on-demand was developed by the U.S. Army Research Laboratory in support of the United States Marine Corps vision for providing Warfighters in small units with mission-tailored, vertical take-off and landing small unmanned aircraft systems near the point of need. The digital catalog was populated by designer-provided vehicle technical data packages which included all information necessary for a Marine to manufacture, assemble, setup, and fly the small unmanned aircraft systems available in the catalog. A crucial part of the technical data packages were parametric computer-aided design models which were used to scale vehicle designs up and down in size based on user-provided mission descriptions, providing a range of trustworthy performance and mission capabilities. The parametric models also allowed for the selected vehicles to be rapidly manufactured using additive manufacturing technology, ensuring that the vehicle was delivered to the user within 24 hours of its original selection from the catalog.

Realization of the 5-Axis Machine Tool Digital Twin Using Direct Servo Control from CAM

4 Apr
9:40am
LR D

Roby Lynn[1], Mukul Sati[1], Tommy Tucker[2], Jarek Rossignac[1], Christopher Saldana[1] and Thomas Kurfess[1]

[1]Georgia Institute of Technology; [2]Tucker Innovations, Inc

This paper describes an architecture for control and monitoring of a 5-axis computer numerical control (CNC) machine tool directly from a computer-aided manufacturing (CAM) system without reliance on the text-based G-Code toolpath definition format that is currently standard in industrial practice. Instead of defining a toolpath as a set of geometric primitives as is done with G-Code, this architecture utilizes a high-speed bidirectional data pathway between the CAM system and the CNC machine to transfer dense time samples of axis position information between the CAM system and the servo controllers of the machine tool's motion control system in near-realtime. Time samples of axis position are created using a time-optimal trajectory planning algorithm instead of a proprietary trajectory planning strategy that is common in industrial CNC systems. The developed architecture is machine agnostic, and can be used both for enhanced control of machine tool motion and powerful visualization and analysis tasks. An implementation of the system using an open-source machine tool controller known as Machinekit is presented, and a Digital Twin of the machine tool is constructed in the CAM system and shown to be capable of visualizing the as-executed toolpath during machine operation.

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3 Apr
4:20pm
Green
Auditorium

Issues in Implementing a Model Based Enterprise

Gregory Harris[1], Daniel Abernathy[1], Roy Whittenburg[2], Anthony Holden[3] and Anthony Still[3]

[1]Auburn University; [2]MBD360, LLC; [3]U.S. Army, AMRDEC

System complexity is constantly increasing while the lead time to develop and move products from design to the customer is decreasing. Early consideration of manufacturability, during the development of the science and technology and the design and acquisition phases, is essential to dealing with this complexity. Organizations have recognized the need to integrate physics-based characteristics into models that enable the simultaneous consideration of the physical configuration, computational elements, and predictable system behaviors to promote products and processes that are designed and built correctly. The purpose of this research is three fold. 1) Develop a comprehensive listing of the most critical issues facing organizations as they engage in digital manufacturing and the model-based enterprise for the creation, use, and sustainment of products and systems. 2) Develop system needs and requirements based upon the issues identified and the desires of the stakeholders to engage in model-based enterprise. 3) Develop a strategy for organizations to utilize in developing their capabilities in model-based enterprise. This paper is concerned with the first purpose, the comprehensive list of issues.

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4 Apr
10:10am
LR D

Requirements for a digital twin manufacturing framework

Martin Hardwick

STEP Tools, Inc. & RPI

In the context of manufacturing, digital twins are evolving models of the physical items used in production. They reduce costs and increase quality by making manufacturing processes easier to operate and supervise. Accuracy is essential so that digital twins can be used to validate production. Timeliness is necessary if the issues are to be corrected before they harm any products or processes. We describe how a digital twin manufacturing framework can meet these requirements by defining end points on a network to read data defined by the digital thread.

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4 Apr
10:40am
LR D

Incorporating Standardized Factory Device Data into the Model Based Enterprise

Russell Waddell and Shaurabh Singh

AMT - The Association For Manufacturing Technology

The Model Based Enterprise depends on a complex ecosystem of standards intermixed with proprietary software and tools. An interoperability-first approach to information standards will allow scale and address a missing interaction layer in the current MBE technology stack. An example of an open but incomplete stack already exists in discrete manufacturing built on ISO13399 and MTConnect, and although end-to-end standards have a poor track record of adoption there remains a considerable risk that proprietary approaches remain or become obstacles to MBE development and adoption.

Presentation Abstracts

Track 1: Systems Engineering and Lifecycle Management

Empowering the Digital Transformation via Digitalization within the Integrated Lifecycle

3 Apr
9:40am
LR A

Gerald Deren

Siemens PLM

Today's reality is that challenges facing global and high-growth innovation manufacturing enterprises are not trivial. For example, dealing with and overcoming "Disruption" in the forms of:

- Growing products or processes complexity.
- Ever changing rapid innovation cycles
- Detailed traceability requirements
- Regulatory requirements
- Complex genealogy
- Massive documentation requirements

Success or failure in dealing with these could be the pivotal point determining success and growth versus lack of competiveness and possible expiration.

"To survive disruption and thrive in the digital era, incumbents need to become digital enterprises, rethinking every element of their business." Digitalization across the entire end2end production lifecycle represents an approach towards solution enablement that helps win in this environment.

Digitalization a fundamentally a new approach that affects Trends in Product Development by

- Changing the way systems come to life
- Changing the way systems are realized
- Changing the way systems evolve

The key to successful adoption is the way companies start their journey in their systems engineering / digitalization practice. The focus of this topic is to discuss a digital enterprise based approach to MBE and discussion on gains and challenges certain customers have seen. Lifecycle

Digitalization is NOT a single answer and does not define a correct way for all to adopt it but it does make visible the need for companies to enable a discipline with respect to communication, collaboration, and measurement throughout the entire product development lifecycle.

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3 Apr
10:10am
LR A

The ModelBased Enterprise Transition Initiative (MBETI): An NNSA Stockpile Services Solution To The Challenges Of ModelBased Enterprise (MBE) Implementation In The National Security Enterprise (NSE)

Ryan Kuhns
Department of Energy

The NSE and NNSA may face a "tipping point" with regards to MBE. The enterprise has absorbed the lessons of previous attempts at integrating model-based design definition technology in NSE processes and implemented technological solutions to those problems. At the same time, current business practices and DOE/NNSA policy disincentivize the use of model-based product definition and a concerted NSE wide effort to implement a MBE in as far as is possible. This presentation will describe how Stockpile Services has programmatized its effort to give MBE the pull it needs to realize its potential in the NSE.

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3 Apr
10:40am
LR A

Connecting the MBE: Integrating 3D Technical Data throughout the System Lifecycle

Bruce Kaplan[1], Ben Kassel[1], Thomas Parks[1], Dick Tiano[2] and Scott Truitt[2]
[1]LMI; [2]ATI

The model-based community is now actively addressing how best to deploy the Model-Based Enterprise (MBE). System engineers and designers creating digital models are vigorously considering and confronting model use throughout the system life cycle. Accordingly, they need to ensure the models can serve the needs of a myriad of processes such as provisioning, cataloging, sustaining engineering, depot work instruction development, parts procurement (sustainment), technical manual development, and a host of other logistics processes. As a future recipient and consumer of MBE products, DLA has been researching 3D technical data for the past 4-5 years to ensure it understands the implications and constraints associated with using such data to carry out its operational responsibilities for cataloging and sustainment. DLA has conducted numerous studies to explicitly identify the specific data and data format requirements necessary in 3D technical data to successfully catalog and competitively procure weapon system parts to facilitate life cycle sustainment. The findings, conclusions, and lessons learned from the procurement studies and the CH53K technical data assessment is critical information for the model-based community as it works to deploy the MBE and effectively integrate it across the weapon system life cycle.

This presentation will address the specific information gathered during DLA's 3D technical data studies and assessments. The presentation also will briefly describe DLAs current

3D technical data outreach project targeted to the Military Service ESAs, PMOs, and other activities that own and manage technical data and regularly supply that data to DLA.

Tradespace Exploration of MBSE and MBE Integrated Workflows

3 Apr
12:10pm
LR A

Anthony Davenport, Joseph Simmons and Scott Ragon

Phoenix Integration

A subset of MBE, Model Based System Engineering (MBSE), has evolved to help system engineers move away from document driven systems by migrating towards a model based approach for capturing system structure, behavior, requirements, and parametrics. By utilizing MBSE, there is now the need for systems engineers to integrate their SE models with more sophisticated MBE tools for requirement verification and system optimization. The overall objective is to minimize program risk, minimize program cost, and maximize system performance while meeting or exceeding program objectives.

Implied in the above is the need for a method to integrate existing domain expert models (physics, financial, etc.,) into a system of system model that can reliably verify and validate the real-world physical system before parts are manufactured and assembled. And do this as early as possible in the product life cycle so that mistakes dont scale as a program moves from affordability (purchase) through the sustainability (field) phases.

This presentation will show how bi-directional integration of MBE with MBSE can provide domain expert simulation models to systems engineers. So that SEs, at the earliest conceptual stages can perform graphical tradespace analysis that includes design sensitivity, design optimization, and risk/reliability analysis through probabilistic analysis. The presentation will show how these methods are used to make decisions during the acquisition process (conceptual design) and transition into manufacturing (production). It will conclude with a description about how this is being accomplished across organizations (not geographically co-located) while securing Intellectual Property and data integrity and model portability.

Enabling MBE across the Life Cycle through 3Di TDPs

4 Apr
9:40am
LR A

Marc Lind

Aras Corporation

The need for a Model-based Enterprise (MBE) approach across the life cycle has never been more critical as defense technologies become increasingly complex. New warfighter capabilities combine sophisticated hardware designs with more and more electronics, software and firmware. The move to 3Di technical data packages (TDPs) is important to gain efficiencies and enable new digital thread processes for manufacturing and support.

Consistent creation, ingestion, verification, change control and distribution of MBE data requires a better TDP delivery process and quality verification, as well as, greater visibility into status and performance data to support PO, SE, LCLS, CM/DM, QA, and PM through the life cycle.

See a real world example of a 3Di TDP initiative that realizes an MBE approach without forcing IT system 'rip & replace'. Learn how to take a targeted and measured path to MBE modernization in an Agile way.

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3 Apr
2:40pm
LR A

Maturing MBE Deployment via a Collaborative Model Authorized Product – Realization (MAPR-R) Project

Curtis Brown[1] and Adrian Miura[2]

[1]Kansas City National Security Campus; [2]Sandia National Laboratories

This presentation reviews the objectives, use-cases, insights, and results from a joint project between Sandia National Laboratories (SNL), a design agency, and the Kansas City National Security Campus (KCNSC), a production agency, for advancing the U.S. Department of Energys National Security Enterprise's (NSE) readiness

towards transitioning into a Model-Based Enterprise (MBE). It covers the collaboration between both agencies in preparation for transitioning to a MBE via the engineering release of an authorized part defining model. The MAP-R project was designed to evaluate our ability to design, manufacture, inspect, and sell a part using an authorized part-centric, model-based approach as compared to our current document-centric, drawing-based practice. Additional project objectives includes quantifying key MBE business benefits throughout the enterprises development lifecycle, identifying existing challenges, and capturing the differences between the 70+ year tradition of drawing-based practices with the processes required to implement a model-based enterprise for product design, manufacturing, inspection, procurement, and acceptance. All of the projects thirteen use-cases have been exercised for both product definition approaches and the project status is on track to be completed this year. The final phase of this project involves reviewing and documenting our findings.

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3 Apr
3:50pm
LR A

Linking Technical Requirements beyond PLM vault

Tatyana Vidrevich and Rupert Hopkins

XSB, Inc

Technical requirements (e.g. drawing notes, tech data, work instructions, and specifications) are primarily published as blocks of text or as pdf documents. This format obscures the complex web of concepts about parts, materials and processes that must be understood to ensure industry acceptable quality, which requires close coordination across the enterprise and its supply chain. The problem is further complicated because these concepts are often drawn from a network of documents generated by different entities residing on both sides of the enterprise firewall. This network of concepts can be modeled using modern linked data and semantic technologies.

In this paper, we describe how SWISS – The Semantic Web for Interoperable Specs and Standards – can be used to model the web of relationships among concepts in non-geometric technical data. Engineers can understand these relationships and their states from within their PLM system and determine, precisely, what changes are relevant to their product. We will show how digital models of Standards enable visibility into the impact of changes in Standards to derivative requirements and work instructions, and will reduce the rework associated with inadvertent reference to obsolete requirements.

A Matrixed Approach to Model Based Product Implementation

3 Apr
4:20pm
LR A

Philip Jennings and Mark Debbink

Newport News Shipbuilding

Overview. Transitioning large complex organizations through technology and cultural changes is a multi-faceted process. How best to manage "Disruptive Technology" and lead change drives organizational evolution and alignment. Leadership readiness with a long term focus, integrated with an end-user bottoms-up approach is critical to ensure the ultimate effectiveness of process and tool adoption.

Background / Objective. This presentation presents a large organization's, Newport News Shipbuilding's (NNS), implementation experiences transitioning from drawing-based products to digital products for Submarines & Aircraft Carrier. We detail the Experience/History of NNS's transition to SIEMENS PLM TeamCenter & NX-3D applications, Organizational & Culture evolution, Leadership & Technology Readiness, and Training necessary to maximize business processes. This supports NNS's objective to move all of our Navy ship programs into Model-Based Enterprise (MBE) ecosystems.

Summary. NNS's experience implementing SIEMENS PLM applications and evolving to model based processes has required organizational agility and has been evolutionary. Critical aspects of the transition are related to implementing a "Matrixed Approach Organizational Theory," which provides "Structure for Complexity" and allows for industrializing large scale innovation practices. The Technology Adoption Theory, Design Thinking, Appropriate Scalability, and Train & Train more, coupled with proper organizational structure form the basis for successful production process transitioning of process and tool adoption.

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4 Apr
10:10am
LR A

MoSSEC (Modeling & Simulation information in a collaborative System Engineering Context) Standard Effort

Gregory Pollari[1], Adrian Murton[2], Nigel Shaw[3], Judith Crockford[2]

[1]Rockwell Collins; [2]Airbus; [3]Eurostep Ltd.

As globally distributed enterprises take on more and more model-based approaches to decision-making, it becomes more and more important to monitor, track, and share information about the process – the "who, what, why, when, where, and how" of model-based development processes. Some examples of of this are, "What is the impact of a requirement change?" or "Who made this assumption and what evidence supported this decision?" or "What range of behavior is this model valid for?" The types and definitions of metadata that supports the model-based decision process is not standardized. An ISO Approved new Work Item (ISO/AWI 22071, AP243) is now established to address this gap. Once this standard is available, collaboration data can then be managed by MoSSEC-compliant tools and exchanged in a standard format. This presentation describes MoSSEC and provides an update on progress in the standardization effort.

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4 Apr
3:50pm
LR A

Critical MBE Themes that Enable a Collaborative Government-Industry Digital Engineering Process throughout the DOD Acquisitions Lifecycle

Zhigang Pan

Northrop Grumman Corporation

Model Based Systems Engineering (MBSE) has great potential to enable rapid and efficient acquisitions, design, and sustainment of next generation weapon systems. In acquiring and designing complex system of systems, the best value with MBSE can only be achieved by successfully realizing two primary areas: 1). All the individual models for the system can be linked together to form one authoritative source of truth, 2). All stakeholders from both government and industry have access to work, develop, and review those models in a collaborative environment. In this context, the "models" in the MBSE collaborative environment contain not only the descriptive models for the system, but the engineering, analytical and mission level models as well. The end goal is a "collaborative" CONOPs environment for executing MBSE throughout the system acquisition lifecycle. In this presentation, we discuss AIA's (Aerospace Industry Association) perspectives on some key issues and themes to realize a collaborative MBSE CONOPs, as well as highlight some key stakeholder concerns about such an environment.

Using Linked Data to Expand Your MBD with OSLC

4 Apr
10:40am
LR A

Brian Schouten and Joseph Lopez
PROSTEP Inc

To reduce costs and remain competitive in the engineering industry, companies must look at successfully integrating Model Based Systems Engineering (MBSE) along with Product Lifecycle Management (PLM), Application Lifecycle Management (ALM), Simulation Data Management (SDM), Requirements and other systems. MBSE integration provides real traceability between system data including domains, departments, organizations and suppliers.

However, this challenge of integrating heterogenous engineering infrastructures can bring many issues. Full centralization is neither feasible nor desirable, point-to-point solutions can become unmanageable and fail to scale, and data duplication works only for a few key systems resulting in synchronization issues. Thus, the goal lies in harmonizing differing domains before consolidating systems.

Open Services for Lifecycle Collaboration (OSLC) allows you to do just that. Linked Data provides a viable solution to meet the challenges of dispersed data models from different software vendors, enabling unified access to resources.

3 Take Aways:

1. Best practice for successful MBSE
2. Leveraging OSLC to consolidate your systems
3. Case Studies

System Lifecycle Handler for enabling a digital thread for smart manufacturing

4 Apr
8:30am
Green
Auditorium

Manas Bajaj[1], Dirk Zwemer[1] and Thomas Hedberg[2]
[1]Intercax; [2]National Institute of Standards and Technology

The NIST "Digital Thread for Smart Manufacturing" project is developing methods and open standards that support validating, certifying, and connecting engineering models across the lifecycle of a product to enable continuous analysis, seamless design-manufacturing transition, high-quality manufacturing, and knowledge reuse.

In this presentation, we will share our vision and progress on the "System Lifecycle Handler" software platform being developed by Intercax to enable a digital thread for smart manufacturing. The System Lifecycle Handler will provide services to: (1) create a digital thread by connecting artifacts in engineering modeling tools and enterprise repositories, such as PLM, ALM, SCM, and databases; (2) lookup and query versioned models and model-elements participating in the digital thread, such as SysML, CAD, CAE, STEP, QIF, and MTConnect models; (3) compare and propagate changes in the connected models on a continuous basis; and (4) visualize the complete state of the digital thread model federation in support of model-based analysis and decision making.

The System Lifecycle Handler leverages the Syndeia Cloud platform, specifically RESTful web-services ready-to-integrate with other service providers in the digital thread.

A key capability in the digital thread is a global identifier system, similar to the Distributed Object Identifier (DOI) system used for documents today, that can be used to uniquely address and locate artifacts (models, hardware, and other resources) participating in the digital thread. The System Lifecycle Handler system will provide services to enable the global identifier system.

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4 Apr
2:40pm
LR A

DMDII 15-11-08: Capturing Product Behavioral and Contextual Characteristics through a Model-Based Feature Information Network (MFIN)

Daniel Campbell[1], Nathan Hartman[2], Charlie Tokowitz[3], Michael Sangid[2], Mark Nielsen[4] and Saikiran Gopalakrishnan[2]

[1]Capvidia; [2]Purdue University ; [3]Digital Manufacturing and Design Innovation Institute (DMDII); [4]TechAzul

Computer Aided Design (CAD) software used to design mechanical parts continues to evolve, and Product Lifecycle Management (PLM) processes continue to advance, but the transfer of data between mechanical designers, manufacturing, and product sustainment has changed very little in the last 15 years. The current state-of-the-art in Model-Based Definition (MBD) is design product geometry centric, typically containing Geometric Dimensioning & Tolerancing (GD&T), annotations, Bill of Material (BOM) and limited processing information stored as Product and Manufacturing Information (PMI). Build data today is comprised of a combination of electronic and paper documents spread across many disconnected files and multiple formats, (i.e., PDF, HPGL, JPEG, STEP, IGES, ASCII, QIF, MatML, etc.). This assortment of delivery formats is unintelligently linked, making data transfer – and more importantly design intent – difficult to communicate and interpret. As a result, todays manufacturers must review, translate & interpret and/or re-enter the design data, causing their manufacturing processes to be labor intensive and prone to error. In addition to the re-creation of the design data, significant amounts of sustainment data captured during the product lifecycle remains disengaged from both design and manufacturing. This full range of lifecycle data can include material properties; design methods; analysis; manufacturing; measurement; inspection; certification test; field service; operations; maintenance; repair and overhaul data. This data is lacking meaningful connectivity to the digital thread, and access to this data is cumbersome at best. The reasons include both the complexity of the data models within which the data must be stored, and the absolute volume of new data, which is fast approaching Petabytes per year.

The DMDII 15-11-08 project is addressing this problem by demonstrating the use of semantic PMI and the capture of materials characteristics at a part feature level and linking those behavioral characteristics to the features in a CAD model via MFIN links. Through the use of semantic PMI and MFINs, enhanced part and feature definitions will be linked to design intent, production information, and sustainment product data to automate inputs into analysis tools, generate planning documents, generate high level measurement plans, and to form a feedback loop to the design decision process.

The diverse project team includes Lockheed Martin, Purdue University, Capvidia, Materials Data Management Inc., MSC Software, PTC, Rolls-Royce, and Siemens PLM. By involving end users, software vendors, and leaders in academic research, this project will bring the leaders in MBE research together with leading software companies to address real-world workflows provided by end users. The objective is to provide real-world MBE software tools and workflows to advance the digital thread for manufacturing.

This presentation will review the current progress and findings of this important and ambitious project.

Bill of Features

4 Apr
2:10pm
LR A

Ryan Gelotte and Jennifer Herron

Action Engineering, LLC

In a world where digital engineering and manufacturing is quickly gaining momentum, there is an increasing focus on the “Engineering Bill Of Materials (EBOM)”. Many EBOM efforts leverage some PLM “Part-Centric” design capabilities to create and manage “Parts”. In many cases the EBOM’s are initially derived from a CAD structure but regardless of how the associations are made, there are associations created between the PLM logical “Part” and the CAD model. The CAD model includes the part’s: geometry, annotations, attributes, and presentations states. A key data item to leverage in Model-Based Defintion (MBD) is the characteristics critical to ensure the quality of a produced part (end item). It is possible to leverage much of the embedded model data at the enterprise using a Product Lifecycle Management (PLM) framework and the software tools associated with that framework (e.g., Enovia, Windchill, Teamcenter). These type of software systems build a logical architecture of data, creating logical relationships that free an enterprise to leverage data in non-traditional ways. Data analytics and Knowledge-Based Engineering strategies can also be leveraged.

You will learn techniques to leverage MBD data (geometry, annotations, attributes, and presentation states) in the PLM architecture and across the enterprise. Key opportunities addressed are a Bill of Characteristics and a Bill of Features.

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4 Apr
4:20pm
LR A

The System Engineering Vee – It Still Relevant in The Digital Age?

Daniel Seal, Don Farr, Jason Hatakeyama and Scott Haase
The Boeing Company

Since its introduction in the early 1990s, the Systems Engineering (SE) "V" has been adopted industry-wide as a clear, intuitive, and instructive framework for understanding the system development process. In general, the SE "V" depicts a roughly sequential development process that starts with concept exploration and requirements development proceeding through design and implementation, progressive integration, verification and validation, and ending with fielding of the system to the customer or user.

What this fails to clearly depict is that later activities on the "V" often provide learnings that feedback into previous activities or even feed forward to change planned later activities. The need to depict this 'missing' integrative activity is heightened by the development of increasingly capable modeling and simulation tools that enable early high-fidelity analysis, verification and validation of system behavior. Many attempts have been made to the update "V" over the years to address this perceived issue. However, these updates are generally both more complex and less intuitive to understand.

Boeing proposes to depict the Model Based Engineering (MBE) process as a "Diamond" with MBE-enabled feedback loops across all phases of the process. The bottom-half of the "Diamond" represents the traditional SE "V" focused on the "physical" instantiation of the product across the lifecycle. The top-half of the "Diamond" represents the "virtual" instantiation of the product. This virtual instantiation, also known as the "digital twin", enables continuous feedback into the product development process leading to better-informed designs that balance performance, producibility, life cycle cost, and operations and maintenance targets.

Track 2: Design Recommended Practice and Model-based Definition

3 Apr
9:40am
Portrait
Room

Inter-Domain Model-Based Workflows at Baker Hughes GE Using SOLIDWORKS

Hadi Jafari[1] and Oboe Wu[2]
[1]Baker Hughes, a GE company; [2]DS SOLIDWORKS

Baker Hughes, a GE company has been partnering with DS SOLIDWORKS to apply the Model-Based workflows to the actual production across multiple domains, such as Modeling, Definition, Inspection, Procurement and the Supply Chain.

The project scope at Baker Hughes GE is to create digital MBD data and derived 3D PDF documents for internal manufacturing and suppliers to build physical components. It is part of the Baker Hughes GE Model Based Enterprise (MBE) and Digital Thread roadmap. Native MBD data is used for both human and machine consumption during production.

The primary goal of using SOLIDWORKS is to directly consume digital 3D models and the annotations for Model Based Machining (MBM) and Model Based Inspection (MBI). 3D PDF is used for human consumption.

Attendees will learn the pragmatic applications and proven successes of the Model-Based workflows at Baker Hughes GE. Upcoming progressions toward more complete and automated Model-Based workflows can inspire attendees to strategize their own specific implementations.

Ensure solid GD&T practices with Model-Based Definition

3 Apr
2:10pm
Portrait Room

Oboe Wu

DS SOLIDWORKS

Geometric Dimensioning and Tolerancing (GD&T) is an engineering language widely used in both 2D drawings and Model-based Definition (MBD). ASME Y14.5-2009 and ISO 1101-2017 are the latest and most popular GD&T standards that specify the required and recommended practices. In MBD implementations, it has become increasingly important to discern the GD&T differences between 2D drawings and MBD. For example, manufacturers, suppliers and service providers may need to convert existing 2D drawings into MBD datasets. However, the GD&T standards were designed and written mostly according to 2D drawing conventions. The 2D-oriented requirements and recommendations are not completely accurate or appropriate in the 3D model space. On the other hand, the model-based approach brings encouraging and significant advantages to ensure solid GD&T practices. Therefore, it is highly recommended that MBD implementations recognize and leverage the model-based differences and advantages, three of which will be shared in this presentation.

1. Define features rather than geometries directly and unambiguously.
2. Ensure compliances with GD&T intelligences in MBD software.
3. Facilitate GD&T interpretations with automatic visual aids.

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3 Apr
10:10am
Portrait
Room

Robust Strategy for using Authoritative Source Standard Part data for MBD/MBE Assemblies

Timothy Thomas[1] and Jennifer Herron[2]
[1]CADENAS PARTsolutions LLC; [2]Action Engineering

In today's design environment, designers are integrating data that has, over the years, become untraceable to its source information. This continued proliferation of rogue data will bring and Enterprise to its knees. The Department of Defense (DOD) requires traceable source authority data when delivering a TDP, and this also applies to standard parts.

In this presentation, you will learn a strategy to mitigate risks in an Enterprise created by the lack of standard part traceability and certification. By exploring the handoff of information between component creator (component manufacturer) and component consumer or integrator (OEMs), we will describe the minimum information needed through that transfer.

Manufacturers (creators) who are producing physical components and assemblies often have unique challenges as compared to challenges the consumers (OEMs) of those same components face. While creators are most concerned with fidelity, accuracy and how well the part will integrate into the consumers engineering systems, consumers may be most concerned with cost-reduction, CAD format interoperability and product revision history. The area where these common interests intersect, from a Supply Chain perspective, is where Model Based Definition (MBD) as part of a larger Model Based Enterprise (MBE) comes to fruition. Learn the minimum amount of information in the model needed to leverage standard parts within MBD assemblies.

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4 Apr
9:40am
Portrait
Room

Extending and Evaluating the Model-based Product Definition

Nathan Hartman[1], Jesse Zahner[1], Thomas Hedberg[2] and Allison Barnard Feeney[2]
[1]Purdue University; [2]National Institute of Standards and Technology

Industrial practice is in a state of transition, away from the use of drawings towards the use of annotated 3D CAD models as a means of communication. Working as a representation of an object or a system, a model-based product definition (MBD) is used to communicate information inside of a model-based enterprise (MBE). Such an enterprise will find itself in a transitional state as well, moving away from paper-based information sharing towards the use of model-based, digital product data. Being able to leverage the communicative power and the depth off information provided by the MBD requires an understanding of the information needs of the various authors and consumers of product information across the enterprise. However, critical information stored in the digital product definition is often lost in translation or not explicitly defined in a way that users in the communications processes can consume it effectively.

This research investigation sought to identify the minimum information model (MIM) – those information elements necessary within an MBD to effectively employ that model as a replacement for a technical drawing in each workflow. Over the course of this investigation, another phenomenon emerged – the common information model (CIM), which represents those information items that are necessary for the workflows targeted in this study. As expounded upon later in this report, the impacts of contextual domain knowledge on the implementation of the common information model is what formed the minimum information model discovered in this project.

ECN Cost Improvement

3 Apr
10:40am
Portrait
Room

Rich Eckenrode and Annalise Suzuki
Elysium Inc

One of the goals of using MBD is that the design errors will move completely to within the design phase of the product lifecycle. This might be possible with more substantial Design for Manufacturing (DFM) functionality within the design process. Currently we do not have enough DFM functionality in design software to eliminate these needs for change.

When we use 2D drawings and incorporate a change there was a process called "Hanging Paper" which was applied to keep track of needed changes but not actually make the product documentation change until there were enough changes to justify the cost of the change. When we produced a product the manufacturing engineer would plan to make the part as documented with the hanging paper included. The process of using MBD does not easily allow for making the product to the model while including hanging paper. We need to modify the model to properly bring products into production without two different sets of product documentation.

Some tasks within a "Change Process" are immediately available for the application of automation routines, which can reduce time and therefore cost of implementing change.

If selected to present at the MBE Summit, we would frame a typical TDP "Change Process" at a government supplier or some commercial design organization. We will present the tasking that requires human labor and will propose which tasks are able to be automated currently. We will also discuss cost of change and describe where cost savings might be realized.

Barriers to MBD and MBE: Real, Perceived, and Self-Inflicted

4 Apr
10:10am
Portrait
Room

Brian Fischer
TDP360 LLC

Many companies are interested in MBD and MBE and have tried to implement model-based methods. Some implementations have been successful, some have shown moderate success, and some were not successful and abandoned. Often, inertia within organizations has stifled even starting attempts at implementation. Misconceptions about the goals and benefits of MBE have also played a role in many cases.

There are many barriers to MBD and MBE. This should not be surprising, as barriers are usually encountered when trying to introduce or implement any change in a business environment. One way to help a new process gain acceptance is to clearly lay out the benefits, the value proposition, and if possible, show a win-win for all involved. In the end, MBD and MBE offer benefits to all involved. However, to get there, change is needed. Some changes are minor, some changes relate to software, some changes relate to hardware, some changes affect infrastructure, and some changes are behavioral and perceptual. Overall, besides having a budget, the main changes needed are vision, commitment, and recognizing and accepting the goals of MBD and MBE.

Most people dont understand the goals of MBD and MBE. Many people see the small steps or incremental improvements possible as their goal. A significant failure mode of MBD and MBE is where interim short-term goals are confused with the final goal. The perceived value of these interim goals falls short of whats possible and may provide insufficient perceived benefit to justify moving toward or continuing implementation.

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4 Apr
10:40am
Portrait
Room

Mathematical Models: Moving Beyond Symbology for PMI

Jami Shah[1], Joseph Davidson[2]

[1] The Ohio State University; [2]Arizona State University

In todays CAD world, the engineering community exchanges data based on mathematical models (BRep, NURBS) and not drawings. So why is PMI data being exchanged with symbols and notations for drawings?

A new mathematical model has been devised for representing the tolerances of all types of geometric features. The model is compatible with the ASME Standard for geometric tolerances. Central to the new model is a Tolerance-Map,1 a hypothetical volume of points which corresponds to all possible locations and variations of the toleranced feature which can arise from its tolerances specification. Every Tolerance-Map is a convex set. Tolerance accumulation can be done with Minkowski sums. We have developed models for all classes of Y14.5 standard. These support material conditions, datum reference frames (clusters) and modifiers. We have demonstrated that these models can be used in worst case and statistical tolerancing. A related development is a data structure call actf that can be used to communicate data needed by tolerance analysis and CMMs. We have demonstrated that tolerance stacks can be automatically derived from actf structures.

Track 3: Model-based Manufacturing and Quality

On-machine measurement use cases for digital thread standards

3 Apr
2:10pm
LR D

John Horst
National Institute of Standards and Technology

Digital thread standards for both dimensional metrology and industrial machine tool operations have been defined in standards organizations and successfully implemented in many commercial manufacturing production operations. A next step is to define a standards-based digital thread for the unique information elements required by on-machine dimensional measurement, for pre-process, in-process, and post-process operations. A step toward this goal is to specify a thorough set of use cases which describe on-machine dimensional measurement tasks commonly performed on the manufacturing shop floor, and then to expose the information elements required by those use cases. Activity diagrams are presented to clarify the use cases and reveal information elements required by on-machine measurement. This work is not expected to lead to a separate standard, but rather be incorporated into existing digital thread standards.

Computer Aided Inspection and Quality

3 Apr
2:40pm
LR D

Toby Maw, David Ross-Pinnock and James Whicker
Manufacturing Technology Centre (MTC)

Effective quality control requires the combination of design, manufacture and measurement domains. Throughout industry, data across these areas are currently being handled and processed by individual departments that each focus on their own domain expertise. This lack of integration limits the creation of usable knowledge from the process chain and makes it difficult to make global process improvements.

Digital technologies now cover the full process chain and those that can share information between stages can enable workflows that are of significant value to industry. One of the critical enablers to this is Model Based Definition (MBD) making use of CAD and product manufacturing information (PMI), which provides the downstream metrology and manufacturing processes with traceable 3D design information.

One of the aims of the digital engineering team at the MTC is to begin to unlock the potential benefits from combining inspection results with design and manufacturing data. Over the last 5 years, the MTC has run several collaborative projects in this area, working with a large group of industrial end users, software providers, standards agencies and research partners around the world. This presentation will focus on efforts towards the integration of the product lifecycle using data standards, such as the Quality Information Framework (QIF) and MTConnect. It will also discuss implementation challenges, which lead to development opportunities for the software and standards communities to raise the suitability of CAD and PMI to facilitate the industries future requirements for Digital Measurement Planning.

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4 Apr
2:10pm
LR D

Selecting Dimensional Measurement Equipment in Inspection Planning

Shaw Feng

National Institute of Standards and Technology

This presentation is on an activity model for selecting dimensional-metrology equipment. The model represents key operations and information flow in dimensional measurement. The purpose of developing the activity model is to facilitate measurement equipment selection rule types development. Rules types provide industrial users with standard formats to capture, exchange, and share equipment selection rules with their collaborators, based on design information and measurement requirements. This paper also provides examples of rules that users can use to plan a measurement process using functionally complex and highly capable dimensional measurement equipment. This activity model provides a basis for developing rule types as a part of the Quality Information Framework standard.

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4 Apr
2:40pm
LR D

Automatically Calibrated & Collected 3D Scan Data used for Quality Control (QC) across Supply Chain

Mingu Kang[1] and Scott Kruse[2]

[1]ARIS Technologies; [2]UI Labs

ARIS has performed automated robotic 3D scanning at UI Labs for the die casted, CNC machined, and additive manufactured real-life production parts. The studies were performed in a way that one automated robotic 3D scanning system emulated manufacturing QC to verify and validate the quality of manufactured components before shipping, and supplier QC to verify and validate the quality of sourced components pre-machining or assembly. This exhibits the relationship between a Tier 2 manufacturing supplier with a Tier 1 OEM.

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4 Apr
3:50pm
Portrait
Room

MBD ROI Case Study: CMM Automation from MBD

Daniel Campbell[1] and Mark Nielsen[2]

[1]Capvidia; [2]TechAzul

CMM programming is currently a tedious, time consuming, and error prone process which requires the active involvement of a highly skilled quality engineer. The GD&T product requirements need to be manually transcribed into the CMM programming software from the product drawing or model. This takes an enormous amount of time, and involves a high risk of transcription or interpretation errors. A further risk is that the quality of the CMM program created is heavily reliant on the skill, knowledge, and expertise of the CMM operator. The time spent and risks involved in this process add up to enormous unnecessary cost to manufacturing industry.

By leveraging a direct machine-to-machine interface between CAD and CMM software, this process can be automated and optimized. Using semantic PMI in the CAD model, CMM measurement uncertainty simulation, and state-of-the-art CMM programming tools, it is possible to highly automate these tasks. This automation lowers costs by significantly reducing time spent creating CMM programs, and eliminating some of the risks identified previously. It also frees up the skilled engineer to add value to their organization in ways other than data transcription. The results would be a CMM program, created with minimal user assistance, which is optimized according to measurement uncertainty requirements and corporate best practices. Overall benefits are: less time spent, less reliance on unpredictable human-in-the-loop, and greater reliance on encoded organizational processes.

The time for this technology is now. This presentation will show how, using commercial, off-the-shelf software tools, highly automated CMM workflows are ready for industry. Pilot projects at large manufacturing enterprises will be explained, including comparisons of traditional workflows to this MBE workflow, and estimated cost savings due to process time reduction.

Model-based Operational Control Methods for Smart Manufacturing Systems

4 Apr
3:50pm
LR D

Timothy Sprock and Conrad Bock

National Institute of Standards and Technology

The U.S. National Institute of Standards and Technology (NIST) is addressing the need for model-based operational control methods in its Systems Analysis Integration (SAI) for Smart Manufacturing Operations project. The project is delivering models and methods for unifying discipline-specific engineering analysis information, and integrating it with existing unified systems modeling techniques, enabling manufacturers and solution providers to design and operate smart manufacturing systems faster and cheaper. Model-based operational control methods use a common representation of the system under control (system model) to integrate multiple sources of information already defined and/or represented in other ways, often from heterogenous systems in incompatible formats, to create an integrated model of the system. System-analysis methods integrate system models with many kinds of analysis models, such discrete event simulation.

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4 Apr
2:10pm
Portrait
Room

QIF and the Future of Digital Metrology

Jennifer Herron[1], Curtis Brown[2] and Daniel Campbell[3]

[1]Action Engineering; [2]Kansas City National Security Campus; [3]Capvidia

Modern metrology systems consist of a patchwork of various individual software packages, each of which produce and/or consume massive amounts of data. The efficacy of these software systems is severely encumbered by the lack of interoperability between its components. Transferring data between software packages is costly both in terms of time required of the human expert to manually process the data, and number of errors involved in manual transcription of quality data.

This presentation will describe the ANSI Quality Information Framework (QIF) and will explain how it can provide the information format necessary to master the challenges of interoperability and data traceability. QIF is an XML-based ontology for quality and manufacturing data, all built on semantic links to 3D model data. This solution arose organically via a body of industry experts ranging from manufacturers (end users), software vendors, research organizations, and National Measurement Institutes, all coordinated by the Dimensional Metrology Standards Consortium (DMSC).

See example QIF workflows that show how a large quantity of product, manufacturing, and measurement information interoperate to beget: automation, optimization, traceability, and data analytics.

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4 Apr
2:40pm
Portrait
Room

Proposal of a data processing guideline for realizing automatic measurement process with general geometrical tolerances and contactless laser scanning

Atsuto Soma[1], Hiromasa Suzuki[2] and Toshiaki Takahashi[3]

[1]JEITA/Elysium Co. Ltd.; [2]The University of Tokyo; [3]3D+1 Lab

Utilizing MBD (Model Based Definition) or 3D Annotated Model in measurement and testing is one of the most important issues in digital engineering arena. In order to optimize the process, minimizing total number of GD&T annotations using general geometrical tolerances is very important. By taking that approach, all the features in a part are classified into small portion where annotation is attached, and the rest of the part where explicit annotations are not attached but general tolerances are applied. Although there are various research and development targeting the former, there are quite a few tackling standard methods to evaluate the latter, where contactless laser scanning is appropriate measurement method. Here, we propose a standard data processing guideline of how large scale point clouds should be processed to achieve reliable result. We conducted several tests using a plastic part, and verified stability of the method.

Optimizing Model Based Inspection, MBI. Development and Integration of key product characteristics and requirements for automatic mapping to the inspection method as color coded tasks for first article inspection.

4 Apr
4:20pm
LR D

Curtis Brown[1] and Mark Nielsen[2]

[1]Kansas City National Security Campus; [2]TechAzul

Streamline your MBD (Model Based Definition) process from Design to Inspection by intelligently mapping product characteristic to be evaluated in first article and production inspections. Using Model Based Definition, with a semantically correct MBD model, we will show the ability to easily organize model dimensions and geometric tolerances into a Bill of Characteristics (BoC), listing each tagged model annotation as a line item for inspection. Further refinement is made by defining and displaying the critically level such as safety, manufacturing, function, etc, and the criticality area of definition using special symbology in the model.

Once the requisite product characteristics are properly presented in the 3D model with appropriate references and confirmed to be represented as semantic, machine readable data elements, then a complete inspection report can be produced automatically. A common excel spreadsheet can be produced with images of the model showing the tagged annotations for each line item in the BoC to create the framework of a First Article Inspection (FAI) report.

Using the Quality Information Framework (QIF) standard, intelligent mapping with QIF Rules can be implemented to define specific techniques and sampling plans. The specific verification method such as visual, manual, point scan, CMM probe or CT can be automatically associated to each line item in the FAI or Initial Sample Inspection Report (ISIR) that is generated. These methods can be colored and organized to simplify and streamline the quality process in-house or sent to an external supplier in an easy-to-use format for fabrication and inspection.

Machine Readable Semantic PMI for Pattern Defintion

4 Apr
4:20pm
Portrait
Room

Ryan Gelotte

Action Engineering, LLC

Products across all industries include parts with patterns of features where the quantity of pattern members can be extremely large. Following accepted MBD semantic annotation standards, a dimension or tolerance quality characteristic that applies to a pattern must be semantically associated with the model topology of all pattern members. While all of the CAD applications offer selection capabilities to efficiently gather the surfaces in order to meet the MBD standards, many quality and inspection applications that can read and use the semantic PMI are not able to recognize that there is one characteristic, patterned many times. In fact, semantically linking the entire pattern topology is often times undesirable due to additional tasks to deconstruct the pattern definition and redefine using the native application pattern definition tools. One work around to this issue is to not annotate the model as a pattern but rather have each member annotated independently of the rest of

the pattern. Then each pattern member is assigned it's own characteristic to be validated. This is also not desirable especially when working with large patterns. A standard definition for machine readable semantic PMI that recognizes pattern members is necessary to fully leverage CAD models for downstream consumption across all industries.

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5 Apr
9:00am
Green
Auditorium

Enabling Facility-Level Interoperability Between Robot Teams and Machine Cell Devices

Josh Langsfeld[1], Matt Robinson[1], Shaurabh Singh[2] and William Sobel[3]

[1] Southwest Research Institute; [2]The Association For Manufacturing Technology; [3]Vimana

Manufacturing equipment is already designed to interoperate within a CNC machine, production cell, or a line. However, device interoperability at a factory-wide level or above still faces significant hurdles. The MTConnect standard and ROS bridge enable a new degree of orchestration with a multi-device interface model, which in turn will lower the cost of automation solutions especially for small and medium sized enterprises. The Cost Effective Coordinated and Cooperative Robotics Enabled by Open Technologies research project is being developed by SwRI, AMT, and Vimana. Funded by a NIST Measurement Science and Engineering (MSE) grant, the project investigates the use and bridging of open standards and technologies. It is exploring application of a flexible automation testbed that demonstrates lowering the cost of automating typical processes, such as in-process inspection, intelligent part management, and automated, just-in time servicing of machine and machine cell applications. Open source software permits free development over a very large workspace to solve complex problems at no cost to the end user. The output from this project is intended to be an enabler for industry-wide adoption of open source technologies by providing a use-case and testbed showcasing lower cost solutions for comprehensive factory floor integration for the small and medium sized manufacturer.

Poster Abstracts

Integrated Statistical Metamodeling Methods for Advanced Manufacturing

Douglas Eddy, Zhuo Yang, Sundar Krishnamurty and Ian Grosse

University of Massachusetts at Amherst

Data to represent advanced manufacturing processes can be costly and rare. Knowledge associated with available data or information can address these data limitations and guide selection of the best methods to take full advantage of emerging data analytics capabilities. Furthermore, the combined use of knowledge with data can improve the effectiveness and efficiency of predictive systems. In this scenario, additional data can iteratively update data-based metamodels based on a-priori knowledge, thus overcoming the lack of accuracy, efficiency, and flexibility in traditional statistical metamodeling approaches that make them ill-suited for advanced manufacturing.

To address these challenges, this poster presents an integrated knowledge-based predictive analytics method. This process seamlessly accepts inputs of initial spreadsheets of data with the option to enable low fidelity computations or other data. Its salient features include selection of the best metamodeling technique based on comparison of distances between vectors constructed based on factors used in various experiments within an experimental design space. Statistical metamodels of the residual between statistical and lower fidelity computational models next predict new data from less expensive computations. By applying an error reduction method iteratively, the metamodel is automatically updated and optimized to find the best and minimum number of additional data points to further improve model accuracy and efficiency. The results show that the dynamic isolation of each data region based on a priori knowledge for successive iterations improves metamodeling efficiency and accuracy for advanced manufacturing scenarios.

MBD Design for Manufacturing (DFM) Verification

Hadi Jafari[1] and Asa Trainer[2]
[1]Baker Hughes, a GE company; [2]International TechneGroup Inc (ITI)

Baker Hughes GE goal is creating engineering 3D digital data which is directly consumed by downstream consumer applications (CAM, CAI, AR, VR, AI) & machines (CNC, CMM, 3D Print). It is part of the Baker Hughes' GE Digital Transformation roadmap. The company has been developing an MBD practice to create 3D digital data which will be directly used in manufacturing & production. This program has significant impact on engineering & manufacturing lead time, cost of quality, & quality of product. Baker Hughes GE has been partnering with International TechneGroup, Inc (ITI), to implement their CADIQ product as a virtual digital tool to verify manufacturability of MBD models before being released to manufacturing, QA, inspection, procurement, & supply chain.

The semantically defined 3D annotations can be acted upon by Computer Aided Manufacturing (CAM) software to automate the Numeric Control (NC) code generation by using Feature Based Machining (FBM) and Tolerance Based Machining (TBM). The 3D size tolerances and surface finishes automatically drive the selections of machining strategies, tools and setups, which can reduce the CAM programing time from hours to minutes and avoid human oversights. Baker Hughes GE use CADIQ as their verification tool to analyze MBD geometry & annotations for direct consumption by MBM & MBI. To achieve the goal, CADIQ is used to analyze MBD models in three aspects:

- MBD Geometry verification configured by CNC team
- MBD PMI & annotation verification
- MBD Tolerance analysis

QIF and the Future of Digital Metrology

Daniel Campbell[1], Curtis Brown[2] and Jennifer Herron[3]
[1]Capvidia; [2]Honeywell FM&T; [3]Action Engineering

Modern metrology systems consist of a patchwork of various individual software packages, each of which produce and/or consume massive amounts of data. The efficacy of these software systems is severely encumbered by the lack of interoperability between its components. Transferring data between software packages is costly both in terms of time required of the human expert to manually process the data, and number of errors involved in manual transcription of quality data.

This poster will describe the ANSI Quality Information Framework (QIF) and will explain how it can provide the information format necessary to master the challenges of interoperability and data traceability. QIF is an XML-based ontology for quality and manufacturing data, all built on semantic links to 3D model data. This solution arose organically via a body of industry experts ranging from manufacturers (end users), software vendors, research organizations, and National Measurement Institutes, all coordinated by the Dimensional Metrology Standards Consortium (DMSC).

See example QIF workflows that show how a large quantity of product, manufacturing, and measurement information interoperate to beget: automation, optimization, traceability, and data analytics.

MBD ROI Study

Daniel Campbell[1] and Ray Stahl[2]

[1]Capvidia; [2]Kotem

How can my organization benefit from Model Based Enterprise? There are many benefits to MBE, including data traceability, optimization, data analytics, and automation. Of all of these, one can expect the fastest ROI with automation.

A traditional workflow for programming CMM software relies heavily on manual entry of GD&T information by a skilled CMM programmer. This task takes a very long time, requires a skilled worker to carry out what is essentially a transcription of data, and carries with it the risk of transcription or interpretation errors.

Leveraging MBD solutions from PTC, Capvidia, and Kotem, we can do much better. This MBD approach to the CMM process involves:

- Starting with a 2D drawing and associated model in a popular CAD system,
- Automatically sync the 2D annotations to the 3D model,
- Export the model to the ANSI QIF format,
- Create a CMM probe path for the measurement, omitting the task of GD&T entry
- Execute the CMM program and collect the point cloud
- Analyze the point cloud against the ANSI QIF model.

Our new process lowers the amount of time spent from beginning to end of a CMM measurement process from a total of 1 hour, 47 minutes to a 42 minute task. This is a 60% savings in time over the previous workflow. And as most parts have many more GD&T callouts than the model in this demonstration, the savings in time between these two workflows would only grow larger.

Model-based Quality Data Management

Larry Maggiano and Gabriel Boiciuc
Mitutoyo America Corporation

Model-based definitions (MBDs) drive model based-manufacturing which should include model-based Quality and Inspection. The ANSI approved Quality Information Framework (QIF) enables uniquely traceable digital measurements and statistical process analytics across both horizontal (machine-to-machine) as well as vertical (design to manufacturing and back) domains. Mitutoyo Americas poster at the 2018 MBE Summit at NIST will share our experience in the interoperability of QIF Plans, QIF Results, and QIF Statistics. Use cases supported by Mitutoyos implementation of QIF include LOTAR, process optimization, process validation, statistical process control and product verification.

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