# 2017 MBE Summit Presentation Abstracts

## Keynote

**The Epistemology of Manufacturing or Why Data Will Remake Everything We Know About Making**

Drura Parrish, Chief Executive Officer
MakeTime, Inc.

In terms of the technological timeline, distributed manufacturing is a newcomer. Enabled by the ubiquitous connections made possible through the cloud and the digitization of work, it takes a decentralized approach to manufacturing that localizes supply chains and scatters them. The result is a supply ecosystem that is, by nature, more stable and less precarious than its more traditional counterparts. Until recently, the risk mitigation offered by distributed manufacturing was its primary appeal. As exponential improvements in machine learning come online, however, big data is charting a course for a distributed manufacturing renaissance that belies all expectations. Given that distributed manufacturing just got here, how can it already be in a renaissance?

The answer lies not in what we know, but in how we know. The nature of human knowledge has always been intimately intertwined with the fruits of our labor. It stands to reason that, as our path to knowing transforms, how we make and what we make will transform, too.

Trying to make sense of and apply the troves of data we've generated and collected has been cumbersome due to a lack of proper tools. As powerful neural nets decrease in cost and increase in use, a lack of tools is fast-becoming a wealth of tools. Now, a distributed manufacturing base isn't just a path to more sustainable, local and risk-free production; it's also a mine of relevant information and a playground for deep learning. We're at the edge of making discoveries — about processes, about prices, about parts and products themselves — we could have never made before. The next phase of manufacturing is an epistemological one. Data is remaking how, why and what exists in real time and space.

**Biography**

Drura Parrish is a third-generation U.S. manufacturer and entrepreneur, who started MakeTime in 2013. Conceived as a two-sided online marketplace matching suppliers with excess capacity to manufacturers in need of parts, today MakeTime is a tech company dedicated to streamlining CNC machining production with proprietary technology that automates the procurement process, puts the supply chain online and eliminates the RFQ.

## Invited Talks

**Digital Thread and Logistics: Rugby in a Brooks Brothers Suit?**

Leon McGinnis, Professor Emeritus
Stewart School of Industrial & Systems Engineering, Georgia Institute of Technology

As the program for this MBE Summit amply demonstrates, the ability to specify a product completely in machine-readable form, to communicate that specification, to use it to drive manufacturing processes, and even to make it part of a permanent product-instance-specific pedigree—all is within grasp, or at least within sight. Model-based thinking has driven this revolution, which supports decision making about the product throughout a product's lifecycle. But complex products like airplanes, submarines or cell phones must be manufactured, distributed, and sustained by large scale complex logistics systems. In the logistics domain, decisions about system design, planning and control will have major impacts on the cost and often the quality of the resulting product, yet the logistics decision makers have no unified specification of their logistics systems, few computation decision support tools, and almost no end-to-end integration of decisions or analysis. There is a major untapped opportunity to take the key learnings of MBE and translate from the product domain to the logistics domain. The question is, "How do we do it?" This talk will suggest some promising strategies and describe some major hurdles.

# Technical Presentations

**Digitalization of Systems Engineering – Examples and Benefits for the Enterprise**
*Rob Beadling, Dassault Systems*

The internet is not very good at sending files. It is good at transmitting small data objects and initiating transactions. To take advantage, engineering applications are becoming increasingly more dependent on component-based data and less file-based. The ability to communicate quickly with more discrete information packets is enabling systems engineering and development processes to become more transactional. With an underlying platform architecture, engineering and simulation tools become plug-in apps and communication between them is enabled. Now, a much higher degree of collaboration, and innovation can be achieved. It is now possible to maintain Model-based Traceability - requirements traced to model elements in an architectural context, to the physical, to physics-based simulations, and to program components (schedule, resources and budget, change requests, and contract deliverables).

This presentation will show concrete examples of how Digitalization is advancing the world of systems engineering and product design. Cases from real-world applications will show how mechatronics development can become process-driven with the preceding stage driving the next. Examples will include consolidated requirements feeding functional architecture definition. An electrical design example will show logical definition defining the physical definition of a wire harness. Examples of simulation supporting validation and the end-to-end process will also be provided.

The examples shown will illustrate how the digitalization of systems engineering processes improves our ability to do early validation and frequent, virtually augmented verification to help tackle increasing system and context complexity. Our success in developing the highly automated systems of the future requires that we make development processes faster, more transactional and more integrated. Web-based and platform-based engineering streamline the accessibility and maintenance of consistent information. Technical solutions developed in online digital environments will be able to feed Certification, Contract and Program execution as well as the digital manufacturing and lifecycle support systems currently under development by industry leaders.

**Model Based (x) – Sparking a Systems Engineering leading practice for Innovative Project, Plant and Process Development**
*Gerald J Deren, Siemens*

As is the case with any competitive market, engineers are under constant pressure to finish their projects within tight schedule and at low cost so the company can get their products to market faster. It's a known fact that whoever does it will have an added advantage over their competitors driving many to seek a Model Based approach towards solving that challenge.

Model Based is not a new concept and actually has been become a core competency many companies across many industries over 20+ years. In the early 80’s it was referred to as the “Master Model” concept or part/product centric design.  Numerous companies’ product development domains have embraced this approach with great success and have been able to execute to enjoy a competitive advantage.

Having experienced that success, and seeing their competition do so, many companies are looking towards this approach to better work within their environments.

A key learning is that “Model Based” has started to take on different forms of focus, depending on what part of the life cycle you are actually working in.

- MBSE = Model Based Systems Engineering
- MBE = Enterprise, Engineering, Environment…

- MBD = Design, Definition, Drafting…
- MBM = Manufacturing…
- MBQ = Quality

But the key to success is the way they start their journey in their systems engineering practice. The focus of this topic is to discuss a PLM based MB(x) approach and discusses some of the gains certain customers have seen. MB(x) 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.

**The myth of the single authoritative source: overlap and evolution of product data through the total lifecycle**
*Ben Kassel, U.S. Navy*

From product inception to disposal the information necessary to define and maintain the product changes. The situation is exacerbated by a need for multiple representations during a single lifecycle phase. Take for example the shipbuilding industry. During the early phases, separate models are routinely created to functionally define distributed systems, molded surfaces for arrangements, and finite element models of nominal structure. As the lifecycle transitions through detail design into construction, models are created that more closely resemble the physical appearance of the ship but are still far from photorealistic. But this is nowhere near the end of the list of product model data that needs to be created, maintained, and placed under configuration control.

**Defining the Minimum Information Model for the Model-based Definition**
*Nate Hartman, Purdue University*

3D Model-Based Enterprise (MBE) is an approach to product design, production, and support where a digital, three-dimensional representation of the product serves as the ubiquitous source for information communicated throughout the product's lifecycle. In MBE, the "model" serves as a container not only of shape definition (i.e., geometry, PMI, annotations, etc.), but also of behavior (i.e., materials, functional logic, genealogy, etc.) and context (i.e., supply chain, in-use, assembly, etc.) – a model-based definition (MBD). While products with relatively short lifecycles may not have a need for maintaining data for extended periods of time, the aerospace and defense sectors have vehicle and weapons programs that have lifecycles measured in decades. Understanding the characteristics of the data needed during these lifecycles is important to both adequate compliance and to minimizing costs. As the digital backbone that supports the modern product data enterprise has been propagated throughout the extended product lifecycle, an obvious medium of communication has evolved – the 3D model and its various derivative forms – to support their products in lieu of 2D drawings. This presentation will discuss the results of a research study aimed at identifying and qualifying the information items needed in a model to successfully communicate needed information.

**System Lifecycle Handler for the Digital Thread**
*Manas Bajaj, Intercax*

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 the vision and progress on the "System Lifecycle Handler" software being developed by Intercax to support the NIST Digital Thread. The System Lifecycle Handler will provide services that will enable the digital thread to connect to enterprise model repositories (PLM , ALM , SCM , databases), lookup and query versioned models and model-elements in those repositories (such as SysML , CAD , CAE , STEP , QIF , MTConnect ), connect and subscribe to models/model-elements, track the timeline of information exchanged in the digital thread, compare and propagate changes in connected models, and visualize and traverse the model space interactively to support what-if analyses and model-driven decision making. The System Lifecycle Handler leverages the Syndeia platform, and can be used via a web dashboard or directly via RESTful web-services ready-to-integrate with other service providers in the digital thread.

A key capability in the digital thread is a model identifier system to uniquely locate models and model elements participating in the lifecycle of a product, like the Distributed Object Identifier (DOI) system. The System Lifecycle Handler system will provide services to enable the model identifier system.

**Good Testing is Hard, Bad Testing is Easy**
*Robert Lipman, NIST*

The NIST MBE PMI Validation and Conformance Testing Project created a test system to measure conformance of CAD software to ASME standards for geometric dimensioning and tolerancing. The test system has five main components:

1. Test case definition and expert review
2. Test CAD model creation based on the test case definition
3. Verification of the CAD models against the test case definitions
4. Generation of derivative STEP, JT, and 3D PDF files by the Implementor Forums
5. Validation of the derivative files against the CAD models and test case definitions

The project has completed with the release of the test case definitions, CAD models, derivative STEP files and the verification and validation reports. All of the content is available through the project website http://go.usa.gov/mGVm.

Did the NIST testing project do good testing (hard) or bad testing (easy)? Insights into developing good test cases, testing criteria, testing methodology, and test reporting will be discussed. The lessons learned can provide a basis for doing better testing in your own companies.

**Comply with the NIST PMI Validation Requirements with SOLIDWORKS**
*Oboe Wu, DS/Solidworks*

"NIST initiated the MBE PMI Validation and Conformance Testing Project in 2012 to help measure and improve the product and manufacturing information (PMI) quality by various CAD systems. SOLIDWORKS was selected in the project since the very beginning. In the past five years, SOLIDWORKS has made substantial progress to comply with the PMI validation requirements.

This session will compare the PMI test results in SOLIDWORKS 2012 and the latest status in SOLIDWORKS 2017. Both representational and presentational improvements will be shown with a focus on the PMI representation to drive downstream manufacturing.

Additional PMI improvements beyond the current NIST validation scope will also be shared, such as the feature selection behavior in PMI definitions, 3D PMI comparison between revisions, STEP242 export per the ISO standard 10303-242:2014 and the viewing of CAD models and PMI from other CAD platforms in eDrawings per the military standard 31000A:2013.

Attendees will gain deeper insights into the NIST PMI validation test cases and models. Then understand what these requirements entail in a CAD environment and how they are met in the latest SOLIDWORKS release."

**Evolve or Dissolve - Effective MBD/MBE Strategy and Benefits**
*Jennifer Herron, Action Engineering*

Discovering your organization's primary motivation and pain points are essential to effectively implement an MBD/MBE strategy. Action Engineering's CEO will share the top areas for companies to focus in order to be successful in implementing Model-Based Definition (MBD) inside a Model-Based Enterprise (MBE). Learn answers to our most commonly asked questions like: What does a fully integrated digital enterprise look like? How can MBD enable smart manufacturing systems? How can multi-CAD global operations work with multi-CAD MBD? Why would I bother with MBD?

**Key Enablers of a successful & profitable MBD process for GE Oil & Gas**
*Mark Nielsen*

Modern manufacturing workflows stand to benefit enormously from Model Based Definition—including the application of 3D Product and Manufacturing Information (PMI). Using machine readable PMI from the design model downstream in manufacturing and inspection creates the opportunity for automation of first article inspection reports, optimization of the manufacturing and inspection processes, data analytics for continuous manufacturing process improvement and traceability and linking of design manufacturing and inspection information.

The ability to use legacy models with their associated drawing to create 3D PMI, dimensions, notes and annotations from the existing 2D drawings in Creo is a few button picks away. From within the CAD toolc one can automatically create PMI on a 3D model that will exactly match that of the 2D drawing. It takes the error prone task of manual transcription of GD&T—which can take weeks for a single drawing—to a fully automated process in mere seconds.

In this presentation, we will discuss how GE Oil & Gas uses state-of-the-art tools to enable a streamline and efficient MBD workflow. The implementation and workflow for converting GE's legacy data from traditional CAD model and drawing to annotated MBD model, ready for downstream use and electronic consumption by various groups will be explored, and metrics describing the time and costs savings reviewed.

**Enchasing MBD with Product Performance Information (PPI)**
*Andreas Vlahinos, Advanced Engineering Solutions*

Successful organizations realize that Model Base Definition (MBD) enables the digital thread. Implementation of a digital thread in a Model based Enterprise (MBE) have enormous positive impact on cost and time-to-quality. The modern CAD tools have the ability to imbed Product Performance Information into the model. Characteristics such as Inertia values, Safety factors, Critical Buckling values, Natural frequencies, drag coefficients, HIC are characteristics of the part/assemblies and its attachments. PPIs can be associative to the part and update as dimensions or materials change. Several MBD examples that include PPI will be presented.

**Automatic Generation of Optimized CMM Program from MBD on the DMDII Digital Manufacturing Commons and Enabled by QIF**
*Daniel Campbell, Metrosage*

As GD&T requirements are increasingly incorporated into the Model Based Definition (MBD) in the form of semantic Product and Manufacturing Information (PMI), direct and automated CMM program generation becomes possible, significantly reducing errors and labor costs. Moreover, in recent years the quality community has become increasingly aware of the implications of measurement uncertainty and its role in pass/fail assessments risks. Assessment of task-specific measurement uncertainties in coordinate metrology via simulation is now a reality, and provides a basis for optimizing measurement strategies to reduce measurement uncertainties, and for the reporting of the resultant task-specific uncertainty value for each GD&T assessment. The ability to generate optimized CMM programs directly from the MBD represents a dramatic innovation in dimensional quality control.

To ensure access to this cutting-edge technology by large organizations and SMEs alike, Metrosage, Capvidia, UNCC, and NAVAIR have teamed up with the Digital Manufacturing and Design Innovation Institute (DMDII) to use their Digital Manufacturing Commons (DMC) as a platform. The DMC is an open-source, open architecture communication platform which enables plug-and-play functionality across the entire digital thread. It facilitates systems engineering across the manufacturing enterprise by allowing for the aggregation, storage, and analysis of product data by modular processes.

Software packages from Capvidia, Metrosage, and Origin International will be linked together on the DMC by use of the Quality Information Framework (QIF) data format. This ANSI standard allows for the propagation of semantic MBD and Measurement data.

Deployment of this automated tool on the DMC will enable an online community of users from organization of all types and sizes to benefit from the latest in advanced MBD technology.

**MBD Supplier Readiness**
*Jennifer Herron, Action Engineering*

Your organization may be “all in” – but what about your suppliers? Are your suppliers willing to keep pace or lagging behind? Are you keeping them “in the loop”? The benefits of Model-Based Definition (MBD) for your organization cannot be fully realized until your suppliers are operating at your capability level. Data from ROI of MBD surveys conducted by Action Engineering and Lifecycle Insights will be shared in an effort to learn more from this critical group of MBD users.

**MBD implementation DOs and DONTs**
*Oboe Wu, DS/Solidworks*

Model-based definition (MBD) as a whole is way beyond software or hardware tools. A successful implementation requires significant shifts across the extended enterprises, such as the people, process and product aspects.

This presentation will share the practical implementation experiences learned from dozens of manufacturers around the globe. Both near-term and long-term recommendations will be discussed.

Here are several examples of the DOs and DONTs.

- Secure the leadership team support.
- Don’t take too big a bite at first.
- Automate workflows.
- Don’t exclude printouts
- Organize and present 3D PMI clearly.
- Don’t send only 3D PDF to the supply chain.

In this discussion, relevant and productive software tools will be shared to show how they can add value and support your implementations.

Attendees will understand the lessons learned to avoid repeating the same mistakes. And learn multiple recommended practices to speed up your implementation processes.

**Model-based Product Manufacturing Information (MPMI)**
*Tom Rando, Electric Boat Corp*

Previously, the engineering drawing was the document of record that captured the normative directions for building, inspecting and testing. The drawing-based process had the advantage that its information was authoritative and complete. It had the drawback that it was too coarse grained to support a lean work instruction. An engineering drawing contains appreciably more dimensions than apply to a particular operation. The smallest addressable unit of dimension data is the drawing sheet, but sheets, too, contain many more dimensions than needed for an operation.

The 3D model contains enough information to fully define the form and fit of ship components; paradoxically, it does not contain enough information to build or inspect systematically. From among the infinitude of dimensions latent in the 3D model, there are a handful of dimensions needed to fabricate, assemble, install or inspect each component piece of the submarine. The MBE challenge is to determine automatically which dimensions are those critical dimensions. Each such critical dimension is an entity defined by a set of data, and this entity can be called an MPMI object.

A common misconception is that moving to 3D is what makes an IPDE 'model-based.' In fact, what constitutes 'model-based' is when there is a digital model in which the important components of an enterprise or product model are objects with identifiers (names) that are available to users and to software applications. An MPMI object must have a persistent database-friendly identifier. The paper describes an approach to select, author and manage MPMI objects that support lean 3D work instructions.

**A highly speculative look forward for the Model Data Based Environment**
*Rush Carter, UTRS Inc*

In the long term we need a more connected enterprise that is data driven, user aware and designed to collect information and re-use this data in intelligent methods. The creation of this data needs to be aware of who created it, when they created it and their role in creating it and be able to be generated by multiple users simultaneously.

This presentation will be focused on the possible future requirements for modeling and data methodology in support of full MBE. This will include high level mappings of data and the implied filtering of the data to support downstream users along with requirements for downstream users being able to add their required information onto the models or to re-use existing data. This will also entail a speculative look into the extensiveness of a potential future modeling systems.

**CAD Reusability and the Role of Modeling Information in the MBE Context**
*Jorge Camba, University of Houston*

Modern approaches to product development such as the Model-Based Engineering (MBE) paradigm rely on digital 3D models as the primary data source for all engineering activities throughout the product life cycle. In this context, the quality of the CAD model, which is inherently rich in information, and the efficient flow of information from design to manufacturing and other support processes are crucial. Just like the quality of a software system depends on the correctness and efficiency of its code, the quality of products depends on the quality of their design processes, which then depend on the quality of their data.

Many efforts in the area of MBE have focused on optimizing the flow of information running through the product's lifecycle. But current MBD mechanisms can also facilitate the flow of information across single activities by integrating unstructured information in a manner that facilitates reusability and communication, and centralizes design knowledge, thus creating even richer models.

In this presentation, we will discuss our efforts to improve the quality of the digital model by using current digital product definition standards as formal guidelines for model-based documentation, and discuss how the MBD paradigm can provide the infrastructure necessary to connect design information to the digital model. We will focus on parametric CAD modeling activities and how different information elements can be linked at various levels, and integrated into a PLM system. We will describe some of the tools that we developed to enrich and interrogate digital product models as well as the applications and effects on design reusability and maintainability.

**Activities on Product Service Platforms Interoperability in Europe**
*Christoph Runde, IMS - European Union*

This contribution will present the outcomes of the workshop on product/service platforms interop-erability held in Brussels on November 21st, 2016. Within the European Union's initiative in the area of the Factories of the Future, a number of running European projects deals with the development of integrated product service systems. All these projects such as Diversity, Falcon, ICP4Life, Manutelligence, ProRegio and Psymbiosys follow interoperability approaches. We detected efforts to develop specific own integration platforms as well as contributing largely to existing standards like Open Services for Lifecycle Collaboration or like RAMI4.0. Long existing initiatives like the ProSTEP iViP association - a standardization initiative in virtual product development - demonstrated its strat-egy on pushing its guideline Code of PLM Openness into industrial application to improve future PLM (product lifecycle management) interoperability. Also the European Factory of the Future Research Association (EFFRA), which develops visions of the factories of the future, works on interoperable digital manufacturing platforms to connect manufacturing services. The European Commission fos-ters the coordination of European, national and regional initiatives such as Industrie 4.0 (Germany), Industrie du Futur (France), Smart Industry (Netherlands) in order to build a European platform of initiatives in the relevant field. Having in mind the platform and data economy framing and necessary criterions like security / trust, this European network shall moderate common answers to the key challenges, that we face in manufacturing today, e.g. flexibility, agility, logistics 4.0, mass customiza-tion (lot size 1), autonomous systems, cobotics, AI, zero-defects, energy and resource efficiency, fully linked physical and digital worlds (digital twins both for product and production).

**Digital Twins for Through-Life Support – Setting the Requirements**
*John Erkoyuncu, Cranfield University*

The development of complex computer modelling, simulations and connectivity between products introduces new and unique opportunities to elicit service value. The opportunities, risks and requirements of such technology are not fully understood. Accordingly, this presentation will set-out a roadmap for the use of digital twins within a through-life perspective while focusing on the in-service phase of complex engineering products. Digital Twin is defined as a digital representation of a physical item or assembly. The digital representation holds data from multiple sources across the product lifecycle. This data can be analysed to predict current, future state and simulate conditions in both design and operational environments. The talk will focus on, if we had a through life 'digital twin' or virtual avatar of a product design and/or an individual physical product, what…

- …would its uses be?
- …benefits would it bring?
- …else would be required to achieve those benefits?
- …characteristics and capabilities would the digital twin need to have?
- …impact would the current stage in the product life cycle have on the above?

The presentation will focus on two digital twin demonstrations in areas of remote maintenance and design for service. The demonstrators will allow to:

- Define the cardinal decision points, people and questions that need to be addressed.
- How to design a 'digital twin' that would support more effective decision making.
- Verify the value of the 'digital twin' with selected user communities.
- Map the data sources, transportation and processing routes required to support the 'digital twin'.

**System Analysis Integration for Smart Manufacturing and Logistics Systems**
*Conrad Bock, NIST*

As product complexity increases and lifecycles shorten, methodologies that integrate design of manufacturing and logistics systems early in the product lifecycle are critical to success. This requires engineers of product and manufacturing systems to generate and analyze system designs in a cost-effective manner. Methods that generate analysis models throughout the product lifecycle require manufacturing and logistics systems to be modeled at the same level of detail as the product being delivered. Model-based methods that integrate system and analysis models provide an explicit pathway to generate analysis models on demand and at the desired level of abstraction, approximation, and aggregation.

The U.S. National Institute of Standards and Technology (NIST) is addressing these issues 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. This talk will provide an overview of integration topics addressed in NIST's SAI Project, with particular focus on modeling and analysis of manufacturing and logistics systems. The talk will discuss model-based methods that integrate system and analysis models within this domain, requirements on system models to enable analysis throughout the product lifecycle, and a family of system models that meets these requirements. The result is a cost-effective library of analysis models that support design of manufacturing and logistics systems. This method enables design of these systems to occur in conjunction with design of products.

**MBE, MBSE and MaaS – Unleash Your Supply Chain**
*Tony Davenport, Phoenix Integrations*

Utilizing the combination of MBSE and MBE, Systems Engineers are now able to utilize tools like ModelCenter to connect their domain expert's high fidelity simulation models (both physics and costs) directly to their systems engineering models – creating an environment for making decisions at all levels of the design. The next big step is to look toward Model as a Service (MaaS), where OEM simulation workflows are connected directly to supplier-based manufacturing simulation workflows to drive down production costs while still hitting performance goals; all while ensuring Intellectual Property is appropriately managed at all levels. Phoenix Integration has 22 years working with major defense OEMs helping them realize the benefits of MBE-MBSE-MaaS. Dr. J Simmons of Phoenix Integration will present.

**The Role of Cross-disciplinary Dynamic Models for Functional Verification in Systems Design**
*Paul Goossens, Maplesoft*

Much has been made of the power of Model-based Systems Engineering (MBSE) as a formal method for capturing and managing design requirements for complex engineering systems. But what does MBSE really mean for the engineering design organization? Whenever a proponent of MBSE speaks with a mechanical or electrical design engineer on the topic, it's often like they are speaking different languages: even the phrase "systems engineering" can have very different meanings!

It's this disconnect that can make the difference between a successful outcome and a project not even getting off the ground.

This presentation proposes a solution to bridging the gap between the architectural and analytical processes through the integration of multi-disciplinary system-level models developed in MapleSim, and SysML requirements models, using the process integration platform, ModelCenter.

This will be illustrated with an investigation into the effects on battery requirements to a change in the specified operating conditions for an electric vehicle. By integrating the battery's design requirements with a physics-based model of the complete vehicle for functional verification, the engineering team can readily verify a system design against its specification long before investing in the prototyping stage. This includes the effects of the dynamic behaviors, spanning multiple engineering domains (mechanical, electrical, chemical, thermal…), that are likely to be overlooked in the early stages. Furthermore, design-space investigations - from "what-if" trade studies to rigorous parameter optimizations – can be easily performed on their design to get the best-possible performance.

In this way, the engineering design organization can significantly reduce project risks and costs by minimizing unexpected late-stage design changes.

**MBE Assessment of Rock Island Arsenal**
*Roy Whittenburg, MBD360 LLC*

Army ManTech has funded the development of MBE capabilities for many years. To demonstrate these capabilities, they have partnered with Rock Island Arsenal (RIA) through the Net Centric MBE Phase 2 program. However, before these can be successfully transitioned RIA current capabilities must be baselined. Once that is done the RIA must also determine what capabilities they would like to have. To accomplish this NCMBE2 has contracted a team to perfume an MBE assessment, gap analysis and roadmap. This presentation will show the process and results of this assessment.

**MBE Assessment of Rock Island Arsenal**
*Gregory Harris, Auburn University*

Adoption and implementation of MBE throughout the Army requires a top level, enterprise approach. Key factors required to implement MBE across the Army include a functioning enterprise Product Data Management (ePDM) system, documented business processes to guide MBE tool selection and configuration, policy regarding the acquisition and use of 3D MBD, consistent leadership emphasis to affect cultural change, and digital product data (including fully annotated 3D models). MBE tools and processes must be common, but tailorable to each organization and site based on mission and an enterprise approach is critical. This cannot be achieved through chance and random application, it will take a series of coordinated efforts to guide and manage the initiative and subsequent culture change.

Through the combined efforts of the ManTech Program Office and the Office of Systems Engineering, the Army is making effort to mature MBE capabilities. This presentation will provide insight to the current status of the effort and plans for the success of the project.

**The Model Based Enterprise & Systems Engineering: A Black Swan Inspired Perspective**
*Lisa Murphy, Siemens*

In his groundbreaking book The Black Swan, Nassim Taleb introduces the concept of "silent evidence" while discussing cognitive barriers to understanding highly improbably events. The premise of silent evidence is that we extrapolate not from the starting base to today but from today's outcome backward, leaving us with a misleading understanding of the likelihood of relatively ordinary events, as we only see today what was successful, not all the dead-ends, abandoned paths, and solutions not pursued.

By starting to define what information supports the Model Based Enterprise (MBE) from the product definition needed for manufacturing, we may experience the "silent evidence" fallacy as we move upstream into the product development flow. Situated at the end of the engineering pipeline means that Manufacturing receives deterministic product descriptions from Engineering; conventional approaches which ask what inputs are required given the outputs needed work reasonably well, as the “customer,” manufacturing, has the right to receive the information needed to do their job. However, every step back upstream in the product development chain increases uncertainty, sometimes due to inherent imperfection of solutions (e.g., by prototyping multiple concepts) and sometimes by intention (e.g., defining requirements that are purposefully independent of a particular solution).

In addition to increased uncertainty, early phase engineering information (e.g., concept development, systems architecting, requirements engineering) suffers from a proliferation of information silos, parallelism gaps, and from differences in the nature, format, and dimensionality of the information, the number and types of relationships, and the patterns of change. This presentation will consider how the concept of silent evidence can help us understand differences in Systems Engineering information and how such differences might manifest themselves in development of a complete Model-Based Enterprise product definition and tools such as PLM needed to support its creation, curation, and use.

**Newport News Shipbuilding’s Concept of Operations for Transitioning to a Model Based Enterprise (MBE)**
*Mark Debbink, Newport News Shipbuilding*

This presentation will focus on a Newport News Shipbuilding’s strategic view and concept of operations for transitioning from a drawing centric environment to a “Model Based Enterprise” (MBE). A bottoms-up approach was instrumental to overcome the cultural hurdles within the company; however, a top-down approach will also be needed to integrate data and processes across the value stream and complete the “digital thread”. These efforts include a developing Concept of Operations for Digital Shipbuilding, standing up a data & information architecture team, and addressing the entire life-cycle’s needs, not just construction.
This presentation will address issues and solutions facing Business Process professionals in Design, Engineering, Manufacturing, Construction, Inspection, and In-Service Maintenance, who are responsible for architecture, configuration, performance, and deployment of production-critical activities and software applications.

**3D Intelligent Technical Data in DOD**
*Jeff Windham, ARDEC*

DOD has traditionally procured, created, maintained and used Technical Data Packages (TDPs) based on 2 Dimensional (2D) engineering drawings. While the source of these drawings have been converted to 3D Computer Aided Design (3D CAD) over the last 15 years or so, the legally binding technical data is still largely 2D, black line art, third angle projection, "front, top, side" drawings. Various organizations in DOD have recently begun the transition to 3D intelligent (3Di) pdf based technical data as the core of our technical data packages. This briefing will discuss what 3Di technical data is, how DOD is moving to transition to a better technical data of the future, and how we are updating MIL-STD-31000 to incorporate 3Di based technical data.

**A Bottoms-Up Approach to Executing from a Model-Based Disclosure (MBE)**
*Jim Dorwart, Newport News Shipbuilding*

Newport News Shipbuilding has begun a digital transformation for submarine and aircraft carrier construction and overhaul. Transitioning from a drawing-based business to a model-based enterprise has been a grass roots, bottoms-up effort that focuses on “Only what is needed to execute the work” for the mechanic. This effort has expanded from a concept 2 years ago, through many pilots, to hundreds of tablets being issued and thousands of model-based work packages executed.

This brief will give a snapshot of our challenging journey, lessons learned, opportunities that presented themselves because of the unique way we attacked them, and how our company is moving up Model Based Enterprise (MBE) capability levels.

**A3FAB and NCMBE Tech Transfer**
*Rush Carter, UTRS Inc*

The US Army ManTech programs, Net Centric Model Based Enterprise (NCMBE) and Accelerated Adaptive Army Fabrication Enterprise (A3FABE) were active FY11 thru FY17. This will be a briefing on specific projects currently being identified within these programs that are both transferrable and had measured success. The types of projects may include: MBE Application in Engineering and Product Development, MBE Application in Manufacturing Process Planning, Manufacturing Data Capture, MBE Applications in manufacturing Process Optimization, Quality Assurance and MBE Application in Procurement and Contracting. Also any available material will be shared through this venue contingent on its specific security marking.

**STEP for Downstream Consumption**
*Bob Kirkwood, Integration Guard*

MBE implementations face a dichotomy regarding CAD formats. Standard format (e.g. STEP) versus proprietary formats. Proprietary formats have one remaining advantage, they are better at staying integrated over successive design iterations. The sooner that advantage has been neutralized, the sooner we may expect accelerated adoption of STEP for the authoritative definition of a product.

The speaker shows sustained integration based on STEP files for a range of downstream application like: Mold Design, Fixture Design, NC Programs, FEA-Solids, and FEA-Shells. In each case the files exchanged using STEP files as exported/imported to a variety of CAD applications. Sustained integration meaning that after the initial integration, successive iterations only require an incremental effort.

The approach relies on the concept of virtual persistent identifiers. Proprietary integration and point-to-point translators rely absolute persistent identifiers on the various geometric entities so that downstream applications referencing the model data are able to stay integrated across successive versions. Each translation to/from neutral formats like STEP resequences those identifiers with each iteration, rendering the identifiers different from those in the CAD system and no longer persistent. Virtual persistent identifiers to not attempt to use the same identifiers as are in the source CAD model. Instead, the identifiers in each successive version are mapped back to the originally translated identifiers. Thus, the virtual persistent identifiers present themselves to the downstream application as being persistent even though they differ from those in the originating CAD system.

**Best Practices for Creating MIL-STD-31000A Technical Data Packages (TDP) using (3D) PDF and STEP**
*Jerry McFeeters, 3D PDF Consortium*

In early 2016, the 3D PDF Consortium began planning test round two for the 3D PDF Implementer Forum. Early in the planning stages it became apparent that there was a need to extend beyond the interoperability testing used by traditional implementer forums. The Consortium members wanted to extend the testing to include the document capabilities of the PDF format. A quick survey of our membership determined that the test round should be focused on testing the ability to create an optimized TDP conforming to MIL-STD-31000A using the STEP and PDF formats.

This presentation provides an overview of the process used to identify the scope of this project, the approach taken, and the results of this “TDP test round”. One of the outputs of the process is a paper containing Best Practices for utilizing STEP and 3D PDF to meet MIL-STD-31000A standards. This will be discussed with an emphasis on describing a TDP-generation process that can be standardized, is repeatable, and is archivable for future use.

Included will be a status report on the 3D PDF Consortium's new role in the ISO standards development process, its long-term impact on document formats, and opportunities for the MBE community to provide input into the development of the PDF, PDF/E, PRC, PDF/A and PDF/UA ISO formats.

**Design Decision Support for MBE with Information Modeling**
*Sundar Krishnamurty, University of Massachusetts-Amherst*

Recent technological advances have led to the convergence of several main thematic research scopes to support advanced manufacturing. Specifically, MBE topics converge with both the advancements in additive manufacturing (AM) and the renaissance of interest in semantic representation for knowledge management in support of the product design digital thread. Alignment of these areas is crucial to the success of MBE as the efficacy of the digital thread is highly dependent on the reusability of captured information based on its proper context. Further, the digital thread must support seamless inclusion of new knowledge on AM as our understanding of AM processes increases and new AM processes emerge. Towards such an alignment, ongoing research at the Center for e-Design at UMass Amherst has focused on parallel and interconnected research themes addressing advancements in the state-of-the-art in AM.

In this presentation, we will detail the development and highlight the salient features of our product design architecture by inclusion of design for AM concepts in an information model at early design stage. Our design for AM concepts are formerly modeled using ontologies to represent the appropriate domain knowledge in the engineering product and process realization process. We will present some of the challenges and research opportunities in aligning such information models within a high-level standard knowledge structure. As part of the presentation, we will introduce a novel decision support system to steer a design appropriately towards additive or conventional manufacturing. We will next summarize our ongoing research towards integrating information related to design decisions in semantic information models. We will conclude with a demonstration of its potential significance in the context of a CAD to AM information exchange collaborative project with our industry partner, FTL Labs.

**Using Manufacturing Knowledge Earlier in the Product Lifecycle**
*Thomas Hedberg, NIST*

Design for manufacturing (DFM), especially the use of manufacturing knowledge to support design decisions, has received attention in the academic domain. However, industry practice has not been studied enough to provide solutions that are mature for industry. The current state of the art for DFM is often rule-based functionality within computer-aided design (CAD) systems that enforce specific design requirements. That rule-based functionality may or may not dynamically affect geometry definition. And, if rule-based functionality exists in the CAD system, it is typically a customization on a case-by-case basis. Manufacturing knowledge is a phrase with vast meanings, which may include knowledge on the effects of material properties decisions, machine and process capabilities or understanding the unintended consequences of design decisions on manufacturing. One of the DFM questions to answer is: How can manufacturing knowledge, depending on its definition, be used earlier in the product life cycle to enable a more collaborative development environment? This presentation will discuss the results of a workshop on manufacturing knowledge that highlights several research questions needing more study. This presentation proposes recommendations for investigating the relationship of manufacturing knowledge with shape, behavior and context characteristics of a product to produce a better understanding of what knowledge is most important. In addition, the proposal includes recommendations for investigating the system-level barriers to reusing manufacturing knowledge and how model-based manufacturing may ease the burden of knowledge sharing. Lastly, the proposal addresses the direction of future research for holistic solutions of using manufacturing knowledge earlier in the product life cycle.

**A Digital Product Realization Revolution Enabled by Persistent Model-Based Product Characteristics**
*Curtis Brown, Honeywell FM&T*

Manufacturing Quality is a customer requirement, it is not free, nor is it optional; however it can be achieved faster, better, cheaper, and smarter with model-based innovations and standards-based digital interoperability. Successful manufacturing organizations recognize that production definition is a valuable asset for their companies and it is necessary to realize their product. Traditionally, this was accomplished through 2D static drawings. Today, this product definition can be captured as a digital product definition (DPD). The DPD, aka model-based definition (MBD), uses a native computer-aided design system to fully describe the shape geometry and any product and manufacturing information (PMI) necessary to help communicate design intent.

An added advantage for transitioning to MBD is the significant opportunity to enable the Quality Department with model-based Product Characteristics. A Product Characteristic is a tolerance or specification applied to a feature or product that requires verification to assure that the product satisfies requirements. Product Characteristic designators and their associated criticality levels are essential for the quality and inspection processes. At present, this information is labeled just in time by inspection thru "ballooning the drawing". Imagine the case where this product, manufacturing & inspection information (PMII) could be defined earlier in the lifecycle within the MBD and persists throughout the enterprise.

A Bill of Characteristics (BoC) is a listing of product characteristics required for manufacturing quality to verify. A BoC can be generated from a MBD with PMII and effectively represented via the Quality Information Framework (QIF), an American national standard for digital interoperability. This model-based BoC information would drive downstream processes and allow for closed loop measurement results returned back to the MBD.

This presentation reviews various technologies and digital interoperability standards that have arrived or matured that enable BoCs to be digitally consumed, revolutionizing closed-loop automation within a model-based enterprise (MBE). Furthermore, promoting the fundamental use of a persistent product characteristics, early in the product lifecycle and throughout the enterprise, will transform manufacturing quality into an agile and valued contributor to the business.

**Measurement Data Analytics using QIF**
*Daniel Campbell, Metrosage*

Modern metrology systems consist of a patchwork of various individual hardware and software packages, each of which produce massive amounts of Data. Globalization of industry and vast, connected supplier networks help to add to the available amount of Data. With the advent of Industry 4.0, Data exchange becomes a key part of industrial processes.

A significant problem we now face is: how does an organization best leverage all this available Data? Under current practices, most measurement Data is not exploited at all, and when it is, it is typically accomplished via limited, proprietary tools or complex PLM customizations. To extract Knowledge about industrial processes from this vast amount of measurement Data, it must first be organized into Information with meaning and context.

There exists a better solution which enables Model Based Enterprise to fully leverage all its measurement Data. The context and meaning behind measurement Data can be provided by the Quality Information Framework (QIF). QIF is an XML-based ontology for manufacturing Data, all built on semantic links to the 3D model. 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).

In this presentation, we will show how software tools can be used to analyze enormous repositories of measurement Information in the QIF format. Advanced analytics and Business Intelligence (BI) methodologies can be applied towards this Information to understand trends, root causes, and otherwise increase manufacturing Knowledge.

**Application of Blockchain and Standards-Based Interoperability to Manufacturing and MRO in a MBE**
*Xenia Fiorentini, Engisis*

DoD Depot perform limited manufacturing to support obsolete or other items not otherwise commercially available. This manufacturing is usually identified upon initial evaluation of weapon system arriving for depot-level overhaul. This means that manufacturing must be performed in parallel and closely coordinated with the tight scheduling of overhaul plans. Naval aviation depot, known as NAVAIR Fleet Readiness Centers (FRC) are deploying PDM environments as part of their Model-Based Definition (MBD) project to digitally connect digital data producers and consumers in support of migration to digital manufacturing. In concert with this, they are initiating a project under the Joint Staff's Joint Enterprise Data Interoperability (JEDI) program to enable bi-directional data exchanges between the Engineering, Manufacturing and Maintenance production domains. The JEDI program leverages ISO Standards for Exchange of Product data (STEP), specifically 10303:239 Product life Cycle Support (PLCS) to maintain semantic interoperability between the new PDM environment, and the legacy MRO suite. Until this project, JEDI focused on data exchanges between Joint and Coalition information systems supporting operational and logistics data. Extension to the industrial domain is possible through the vast scope of the PLCS information and activity models.

Additionally, DoD is looking to further enhance this concept through a separate, but related JEDI project to evaluate Blockchain technology to provide integrity of the Digital Technical Data Packages (DTDP) over time, while sharing them across the DoD depots. This concept of pairing JEDI with Blockchain is envisioned to offer the improved interoperability of JEDI across joint services and the different functional domains within them, plus the distributed data integrity provided by the Blockchain as DoD moves further into digital manufacturing. This presentation will provide details and status of these projects to the audience.

**Model-based Visualization for Resistance Spot Welded Assembly Design**
*Joseph Kim, Wayne State University*

Resistance Spot Welding (RSW) is one of the most common sheet metal welding processes in various manufacturing industries including the automotive industry. However, the utilization of the RSW process data is still limited due to disconnected welded assembly design models and associated process data challenges. Model-based engineering provides an opportunity to combine and visualize the data from different lifecycle stages of a welded assembly product in a unified platform. This study presents a model-based visualization framework to integrate RSW weldability knowledge with assembly models. For this study, a knowledge-based semantic weldability prediction method has been developed to effectively predict the weldability of RSW processes, while reducing the data inconsistency effects. For this purpose, real industry RSW quality datasets are utilized to extract weldability decision rules with data mining algorithms and an RSW ontology is developed to build a shareable RSW weldability knowledge. Then, the RSW ontology (OWL) data with X3D is integrated into a unified visualization platform. The unified platform can visualize the 3D assembly models with the predicted weldability. To confirm the visualization capability, different assembly models are tested in this study.

**A Game Theoretic Approach to Minimizing Cybersecurity Risk**
*Scott Musman, MITRE*

Information and Communication Technology (ICT) systems are now ubiquitous in all aspects of our society. With an ability to create ICT incident effects via cyberspace, criminals can steal information or extort money, terrorists can disrupt society or cause loss of life, and the effectiveness of a military can be degraded. These threats have caused an imperative to maximize a system's cyber security and resilience. Protecting systems that rely on ICT from cyber-attacks or reducing the impacts that cyber incidents cause (i.e. cyber security and resilience), is a topic of major importance. In this paper we describe an approach to minimizing cybersecurity risks which can be viewed as a form of model-based system security engineering. We describe a method and supporting software prototype that quantitatively identifies mission outcome focused cybersecurity risks and uses this metric to determine the optimal employment of security methods to use for any given investment level. Our software maximizes a system's ability to operate in today's contested cyber environment by minimizing its mission risk. The risk score is calculated by using a cyber mission impact assessment (CMIA) model to compute the consequences of cyber incidents, and by applying a threat model to a system topology model and defender model to estimate how likely attacks are to cause impacts. To do this we take into account the widespread interconnectedness of cyber systems, where defenders must defend multi-step attack paths and an attacker only needs one to succeed. We employ a game theoretic solution using a game formulation that identifies defense strategies to minimize the maximum cyber risk (MiniMax), employing the defense methods defined in the defender model. This paper describes the approach and the models it uses.