Integrating Sustainment Throughout the Model-Based Enterprise

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AGENDA

Model-Based X where “X” = Sustainment

Digital Tapestry and Shared Data Perspectives

Industry 4.0 for Sustainment and A/V/MR

Digital Data for Additive Manufacturing for Sustainment

Agility and Affordability Challenge and Acquisition Approach
CASE FOR MODEL-BASED “X” WHERE X = SUSTAINMENT

“Product-Focused O&S Should-Cost Opportunities

Early, Upfront Investment in Reliability, Maintainability and Supportability. Often, the greatest opportunities to save costs are manifested well before a weapon system is produced and deployed. Giving due consideration to reliability and maintainability and electing to pursue thoughtful trade decisions in the design affords the opportunity to reap tremendous life-cycle cost (LCC) savings. We like to talk about “upfront and early” since, notionally, 80 percent of O&S costs are determined during design development.”
CONTEXT AND USAGE MODELING AS PART OF MBE


Understand interaction with world of operations and sustainment (O&S)

Collaborative Human Immersive Lab (CHIL) usage for design for operations and sustainment within context / world

Architecture 3D Modeling and Building Information Management
DESIGNING FOR A MAINTENANCE FREE OPERATING PERIOD

“A maintenance free operating period (M-FOP) is defined as a period of time (or appropriate units) during which a system is both operational and is able to carry out its required function(s) without maintenance activities and without encountering failures”. (Hockley, “Maintenance Free Periods of Operation – The Holy Grail?”, RTO-MP-AVT-144, p 23-3.)

Design up front using MFOP models with mission availability focus
Concept compared to warranties
Additional selected references:

2. Achieve Dominant Capabilities While Controlling Lifecycle Costs

System of Systems Approach:
Primary and Enabling Systems

Apply Affordable System for Operational Effectiveness (ASOE) model

Manage efficient digital tapestry / environment that supports innovation

Assure model based approach supports the lifecycle

Develop data analytics to address system of systems and context complexity
**SYSTEM OF SYSTEM DEFINITIONS**

**SYSTEM**

System: An aggregation of system elements and enabling system elements to achieve a given purpose or to provide a capability.

**System Elements**

System Elements: Also referred to as configuration items, subsystems, segments, components, assemblies, or parts.

**Enabling System Elements**

Enabling System Elements: Provide the means for putting a capability into service, keeping it in service, or ending its service, e.g., processes or products used to enable system development, test, production, training, deployment, support, and disposal.

Each system element or enabling system element may include but is not limited to hardware, software, people, data, processes, facilities, and tools.

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Defense Acquisition Guidebook. Chapter 4.2.1.2. System of Systems. Figure 4.2.1.2 as of June 1, 2015.
AFFORDABLE SYSTEMS OPERATIONAL EFFECTIVENESS (ASOE)

AsOE continues to provide a framework for assessing continuous improvements throughout the life cycle.

Primary & Enabling System Readiness Focus
COMPLEXITY OF THE “X” = SUSTAINMENT

INTEGRATED PRODUCT SUPPORT

Design Interface

Sustaining Engineering
Supply Support
Maintenance Planning & Management
Packaging, Handling, Storage & Transportation (PHS&T)
Technical Data
Support Equipment
Training & Support
Manpower & Personnel
Facilities & Infrastructure
Computer Resources

Product Support Management

AcqLinks and References:
•[1] Website: ACQuipedia – Sustainment Engineering
•[2] Integrated Product Support Element Guidebook, Chapter 3 – Dec 2011
ENABLING DIGITAL ENVIRONMENT HISTORY:
CONCURRENT ENGINEERING

Shared product, process and organization information as 1990s enabler focus of DARPA Initiative in Concurrent Engineering (DICE)


DIGITAL TAPESTRY AND SHARED DATA PERSPECTIVES: INTEGRATED DATA MANAGEMENT AS PART OF MBE


**Main Technical Goals:**

- Use **ALL AVAILABLE INFORMATION** in analyses
- Use **PHYSICS** to inform analyses
- Use **PROBABILISTIC METHODS** to quantify program risks
- **CLOSE THE LOOP** from the beginning to the end and back to the beginning of the acquisition lifecycle

**Make **INFORMED DECISIONS** throughout lifecycle**
Use of DTw to Inform Mx Planning

Digital Twin

Forecast Usage

Loads & Environment Model

System Response & Degradation Model

Update/Refine Digital Twin

Perform Maintenance?

Plan Maintenance

Employ System

Record Usage

Loads & Environment Model

System Response & Degradation Model

Components Response & Degradation Models

System Reliability Assessment

Actual Condition Assessment

DIGITAL MANUFACTURING AND DESIGN INNOVATION INSTITUTE

Mission: Establish a state-of-the-art proving ground for digital manufacturing and design that links IT tools, standards, models, sensors, controls, practices and skills, and transition these tools to the U.S. design & manufacturing industrial base for full-scale application

Announced in February 2014; UI Labs team selected in 2014

Builds on digital thread focus at National Institute for Standards and Technology (NIST)

Rebranding as MxD – Manufacturing times Digital in 2019


PM/Government
- Point Solutions
- Solving Today's Problem Focus
- Process Based

Model Based Enterprise Capability Center (MBECC)
- Model Based Engineering
- Model Based Manufacturing
- Model Based Systems Engineering

Institutes
DMDII/Centers of Excellence
- Industry, Academia, Government, Working Together
- Enterprise Level Solutions
- Technology Based

Model Based Sustainment/Logistics
- Model Surrogate
- Creator of System History Documentation
- System User Training
- Obsolescence
+ MB Definition for System Employment, Use and Support

National Standards
- Processes in Government PM Shops
- Institute Developments in the Digital Thread Capability in Government Organizations

Dr. Gregory A. Harris, P.E.
NIST MBE 2017
SHARED DATA FOR LIFECYCLE SUPPORT

EXISTING LOGISTICS STANDARDS FOR MBE INTEGRATION

ILS Overall Business Process and the S-Series

Aerospace Industry Association S-Series Standards

NATO Acquisition Logistics Workshop of 1993
INDUSTRY 4.0 SUSTAINMENT INTEGRATION

Focus on extending Industry 4.0 technologies to sustainment

Digital transformation life cycle perspectives (PHM Society 2018)

Connected supply chain optimization (CTMA/DLA Partners 2018)

Internet of Things (IoT) for life cycle/service management

Augmented/virtual/mixed reality (A/V/MR) for maintenance
INDUSTRY 4.0 AND A/V/MR

Digital Thread and Industry 4.0 (Don Kinard, NIST MBE Conference, 2018)

Augmented Reality

Guided Work Instructions with Voice Controls (After)

Operator’s view in glasses

Remote Augmented Reality

“Technician” view on Tablet

“Expert” view at Desktop Computer

The Connected Enterprise – Industry 4.0

The Connected Enterprise Enables Automated Metrics, Financial Reporting, Data Analytics, Integration with Factory Equipment, and Real Time Management Visibility
SUPPLY CHAIN AND MAINTENANCE USE CASES

Virtual Subject Matter Expert (SME) – virtual SME can see what maintainer sees

Hands free maintenance - use case synergy with manufacturing (as early as Hopps, AeroDef 2013)

Heads up work instructions— Work Instructions in AR/ MR, with 3D overlays and text that links to a server

TechAssist at DoD Maintenance Conference 2017

Smart Glasses and AR in Aerospace Manufacturing: Finding the Niche (Christi Fiorentini, AWE, 2016)

Aeronautics Global field service collaboration and travel reduction
LIFECYCLE PERSPECTIVES

Early design with Collaborative Human Immersive Lab (CHIL)

Applying Virtual Reality, and Augmented Reality to the Lifecycle Phases of Complex Products (Rabbitz and Crouch, 2017)

A/V/MR leveraging the Bill of Materials (BOM) across the lifecycle (Don Kinard, NIST MBE Conference, 2018)
DIGITAL DATA: ADDITIVE MANUFACTURING FOR SUSTAINMENT

America Makes Maintenance and Sustainment Advisory Group Chair

OSD Additive Manufacturing for Maintenance Operations (AMMO)

Collaboration on AM Business Model Wargames / Workshops

America Makes and Maturation of Advanced Manufacturing for Low-cost Sustainment (MAMLS) Phases I - III

PUBLIC PRIVATE PARTNERSHIP
COLLABORATION TO APPLY SCIENCE AND TECHNOLOGY TO IMPROVE SUSTAINMENT OF LEGACY SYSTEMS
INDUSTRY USE CASES AND VALUE CHAIN
Joint Staff Enterprise Development “JED” Talk June, 2015

Why? Faster, Lower Cost, Improved Readiness, Lower Inventory/Warehousing

Know How

Materials/Processes
- AM/Rapid Prototyping
  - Design for AM/Lifecycle
- Legacy Engineering Services (Design for Mod/Upgrade)
  - Chief Engineer Approval

What/When

Production
- Subtractive Manufactured/Replacement Part
- AM Parts in New Production
- AM Indirect Parts: Tooling, Casting Molds

Sustainment
- AM Parts for Legacy
- Additive Repair (AR) (e.g. Cold Spray, Welding)
- AM Tools

Who

OEM (Vertical)
- Supply Chain
- Small Business/SBIR
- Depot
- End User/Regional Centers

Where

- OEM
- Supply Chain
- Small Business/SBIR
- Depot
- End User CONUS/OCONUS

Model Based Engineering/Digital Thread/Intellectual Property Agreements/Contracts

How Much? Business Model/Business Case

Qualification and Certification (Machine/Design Authority/Quality/Airworthiness)
OSD JOINT ADDITIVE MANUFACTURING WORKING GROUP (JAMWG) RELATED EFFORT

Kelly Visconti, Additive Manufacturing, OSD Perspectives, DoD Maintenance Conference, 2018

Project Managed by America Makes

Joint Additive Manufacturing Model EXchange (JAMMEX)
- Develop a system to share 3D print files in a secure environment

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OSD/AMERICA MAKES ADDITIVE MANUFACTURING WORKSHOPS

Initial Additive Manufacturing Sustainment Business Model Wargames 2016 at LM Center for Innovation, Suffolk, VA

Second Wargame at LM Global Vision Center (GVC), Crystal City, VA in 2017

2018 Workshop event at GVC included Working Group on Additive Manufacturing Model Exchange and Blockchain (see summary)

OSD JAMWG co-sponsoring 4th event June 18-19, 2019 at GVC with Working Groups aligned with Stakeholder Councils including Data and Model Sharing (Register)
AGILITY AND AFFORDABILITY CHALLENGE

Acquisition approach to support lifecycle management

Tech insertion mods and upgrades for enhanced capability

Defect/reliability/maintainability root cause analysis

Obsolescence focus and Modernization Through Spares history

Acquisition reform research (UMD)

Model Based Enterprise supports agile development / DevOps
SUPPORTING ADAPTIVE ACQUISITION CONCEPTS

USD (R&E)
- Mission Engineering
- Rapid Prototyping
- Technical Maturation
- JROC Guidance

Operations
- Supported by sets of systems to achieve mission objectives
- R&M feedback
- Address DMSMS – opportunity for tech / capability insertion

USD (A&S)
- Engineering Product / Sustainment Solution
- Capability Design Insertion
- Production / Mods / Upgrades
- Manufacturing Development

Continuous Capability Optimization

Warfighter Value
Capability
Cost
Acquisition
Production, Deployment and Sustainment
RECOMMENDATIONS

Integrate “sustainment thinking” throughout the Model Based Enterprise

Build models with the life cycle in mind with cybersecurity protections and configuration management / data management (CM/DM)

Leverage use cases in AM and MR to test MBE approaches for sustainment

Extend commercial best practices where possible for A&D domain
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ABSTRACT

This presentation will highlight the importance of a model-based enterprise (MBE) to sustainment and across the life cycle. Model-based X where “X” is sustainment needs to be considered as part of the systems of systems engineering starting early in the life cycle. Computer-aided manufacturing, inspection tools, and approaches should be planned for use in sustainment to include repairs and ease of mods and upgrades to update capabilities. The complexity of managing the digital thread or tapestry is greater when sustainment is considered, with the need to linking and management the “as maintained” bill of materials for each delivered system. Application of data analytics and artificial intelligence (AI)/machine learning (ML) supports prognostics and health management and performance feedback. System of systems modeling methods that include application of the Affordable Systems Operational Effectiveness (ASOE) framework to help organize the sustainment considerations for both the primary and enabling systems to reduce life cycle costs and improve reliability and support return on investment (ROI) case studies. There are several opportunities for leveraging digital thread for sustainment as a concentration area. The first is application of augmented/virtual/mixed reality for maintenance opportunities and supported by global subject matter expert networks. The sustainment community pull for application of advanced manufacturing approaches to include additive manufacturing also relies on distributed access to technical data packages to support manufacturing at the point of need for parts that can be printed. A third focus area is on acquisition reform focus on capability management for legacy systems to meet the challenges of the National Defense Strategy. Systems designed with standards-based architectures and interfaces can support lower cost and more agile modifications and upgrades of both hardware and software in a system.