DEMONSTRATING STANDARDS-BASED DIGITAL THREADS AT SCALE: CURRENT PROGRESS AT DAF MANTECH

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Agenda

• Overview of Dept of the Air Force (DAF) ManTech Advanced Manufacturing Technology (AMT) Portfolio

• Ongoing Efforts Related to Model-Based Enterprise
  • Technical Data Modernization for As-Built Data
  • Open Digital Thread for Industrial Augmented Reality

• Looking Forward

*Created by DALL-E
AFRL/RXM | Manufacturing and Industrial Technologies Division

- Significant opportunity to realize cost savings by engaging with stakeholders early to promote manufacturable designs and ensure the industrial base will be ready to produce
- Responsive to acquisition programs across the development, production and sustainment lifecycle

AFRL/RXM uniquely addresses manufacturing & industrial base challenges
- across manufacturing development lifecycle
- from process conception through full rate production
- across the spectrum of aerospace technology
- for both acquisition and sustainment

Cost Reduction Opportunity

Cumulative % Cost

MRL 1 2 3 4 5 6 7 8 9
Advanced Manufacturing Technologies

Minimize cost and acquisition timelines through pervasive Industry 4.0 technologies lowering barriers between physical and digital assets in the Defense Industrial Base (DIB) and depots

• Decision-Making Agility across Lifecycle
  – Consistent Data Exchange
  – Efficient Commissioning for Manufacturing Assets
  – Governance and Provenance for Sensitive Data

• Responsive and Agile Manufacturing Operations
  – Rapid Turnaround in Depots
  – Weapon System Availability
  – Expanded Process Capability Envelope

• Enabling Pervasive Transition
  – Affordable Technology Insertion of New Processes
  – Robust Robotic Agility in the Depots
  – Open, Modular, Standards-Based Architectures

• Intuitive Human-Machine Cooperation
  – Situation Awareness in Austere Environments
  – Upskilling Operators, Maintainers, and Assemblers

2-10x more efficient DIB operations
Advanced Manufacturing Technologies (AMT) portfolio responds to pervasive Industry 4.0 (or Smart Manufacturing) Investments.

Currently, AMT includes three ManTech programmatic foci:

**DIGITAL ENTERPRISE (DE)**

**Thrusts:**
- Digital Twin / Thread / Engineering
- Digital Supply Chain
- Moving Manufacturing Left

**Deliverables & Impacts:**
- Data governance for distributed manufacturing systems
- Controlled schema capture of supply chain activities
- Model-based consideration for manufacturing
- Templates for modernized technical data packages

Aligned with MxD MII

**ADDITIVE MANUFACTURING (AM)**

**Thrusts:**
- Affordability
- Transition Support
- AM at Scale

**Deliverables & Impacts:**
- Driving affordable processes and materials into practice
- Can print at the scale of critical DAF applications
- AM transitions with the ease of traditional processes

Aligned with America Makes MII

**AUTOMATION, ROBOTICS, & MIXED REALITY (ARMR)**

**Thrusts:**
- Robotic Agility
- Robotic Mobility
- Multi-Robot, Multi-Human Teaming
- Advanced Process Visualization

**Deliverables & Impacts:**
- Robots that adapt to task, work piece, & environmental variability
- Robots that perform manufacturing processes in situ
- Systems of robots and humans that physically collaborate
- Visualization for process interaction

Aligned with ARM MII
Automation, Robotics & Mixed Reality

Manufacturing Vision

DEVELOP, MATURE AND DELIVER AGILE, ADVANCED ROBOTS, XR-ENHANCED SYSTEMS FOR SEAMLESS INTEGRATION WITH DIGITAL DATA, AND SENSOR-BASED ADAPTIVE PROCESS CONTROL THAT WILL DECREASE COST AND IMPROVE MANUFACTURING PROCESSES THAT MEET DAF-SPECIFIC NEEDS

Manufacturing Goals

• **AGILE, ADAPTABLE, REDEPLOYABLE, & FULLY RECONFIGURABLE MULTI-PURPOSE ROBOTS CAPABILITY PILOTED IN PRODUCTION ENVIRONMENT BY 2026**

• **XR-ENHANCED SYSTEMS FOR SEAMLESS INTERACTION WITH ROBOTS, PROCESSES, & DIGITAL DATA PILOTED IN PRODUCTION ENVIRONMENT BY 2027**

• **NATURAL HUMAN-MACHINE COLLABORATION FOR SENSING, COGNITION, & ACTION PILOTED IN PRODUCTION ENVIRONMENT BY 2028**

• **MULTI-AGENT AUTONOMOUS MOBILE ROBOTIC MANIPULATORS WITH SUPERVISED AUTONOMY AND INTELLIGENT TEAMING DEMONSTRATED IN SUSTAINMENT ENVIRONMENT BY 2028; FLIGHT LINE ENVIRONMENT 2029**

• **MANUFACTURING PROCESS INFORMATICS FOR UP- & DOWN-STREAM ADAPTIVE PROCESS CONTROL PILOTED IN PRODUCTION ENVIRONMENT BY (?)**
Digital Enterprise

**Manufacturing Vision**

A highly connected, digitally-enabled acquisition and sustainment enterprise with impacts to downstream manufacturing activities fully characterized as early as possible.

**Manufacturing Goals**

Development, adaptation, and transition of digital technologies to improve manufacturing enterprise processes to transform connections to and from other parts of the lifecycle.

- Demonstrate 50% reduction in “time to market” for defense products
- Increased participation in Defense marketplace for SMMs
- Greater efficiency and resiliency in production supply chains
- 10X increase in manufacturing decisions supported by simulation
Open Digital Thread / Twin

**Manufacturing Vision**

Advance “open” technologies to form “baseline” DIG TWIN/THREAD TOOLS/STANDARDS FOR MANUFACTURING, INCREASING INTEGRATION BETWEEN AF, SUPPLIERS, AND EXISTING DIGITAL THREAD/TWIN SOLUTIONS TO SUPPORT ENGINEERING, MANUFACTURING, AND LOGISTICS ANALYSES ACROSS THE LIFE CYCLE

**Manufacturing Goals**

- Reduce time (~10x) it takes to verify technical requirements, specs, and physical parts
- Reduce time (~10x) it takes to resolve incident reports by having traceability throughout manufacturing process
- Predict and recommend solutions to quality issues for systems and subsystems. Improve quality X%
Digital Enterprise ManTech Program

 Enterprise-level Data Architectures

 Engineering Data Interoperability

 Sustainment Modernization

 Adaptive Quality Management

 AM Process Qualification

 Large Scale Metal AM

 New Materials

 Additive Manufacturing ManTech Program

 Digital Enterprise ManTech Program

 LEVERAGE

 LEAD / PARTNER

 WATCH

 Automation, Robotics, and Mixed Reality ManTech Program

 Communication Protocols

 Mfg Process Informatics

 Mfg System Integration

 Machine-Machine Teaming

 Robotic-Assisted Repair

 Metamorphic Manufacturing

 Automated Material Handling

 Joint Cognition

 Enterprise-level Data Architectures

 Engineering Data Interoperability

 Sustainment Modernization

 Adaptive Quality Management

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 LEVERAGE

 LEAD / PARTNER

 WATCH
Technical Data Modernization for As-Built Data
Information Complexities Across the Product System Lifecycle

Industry 4.0 Standards Activities

Challenge:
Harmonizing Industry 4.0 standards at scale

Use Cases of (Particular) Interest

Full-Sized Determinant Assembly (FSDA)

Failure Analysis at Sustainment

Acquisition Support / Data Rights
Vision | Technical Data Modernization for As-Built Data

As-Designed | As-Planned | As-Executed | As-Inspected
---|---|---|---
STEP AP242 | G-code | MTConnect | QIF
.slp, .step | .txt | .xml | .xml

Enables

Integrated Knowledge Base

Translation

Product lifecycle

STEP Files

STEP-QIF Mapping Spec.

QIF Files

STEP Knowledge Graphs

QIF Knowledge Graphs

Integrated Knowledge Base

Linking (SWRL)

Querying (SQWRL)

Designer

Inspector
(NEW!) Project: Technical Data Modernization for As-Built Data

- MBE standards have reached adequate maturity to warrant large-scale testing via demonstrations
- DAF-relevant assembly and sustainment activities would benefit from better data exchange practices
- DAF acquisition service requires guidance in how/what data to purchase up-front
- Two use cases:
  - Project 1: Advanced data linking of part/assembly as-built data to facilitate shim-less assembly
  - Project 2: Better data curation for non-destructive inspection (NDI) in sustainment
Open Digital Thread for Industrial Augmented Reality
How interoperability will impact Industrial Augmented Reality

Potential research and development opportunities for Industrial XR related to data-driven processes

1 Bernstein et al. (2024) ASME JCISE.
Industrial AR suffers from interoperability challenges

Real-world capture → Domain-specific models → XR scene presentation

- Devices
- People
- Spaces
- Plans
- Materials

Lockheed Martin – Partner in FY22 AFRL RXM Discovery Award
Emergent Visualization and Operations Software (EVOS) Team
(photograph approved for public release by LMCO)
Current solutions for Industrial AR development

Platform Lock-in

Rely on 3rd Party Translators

Digital Enterprise / CAx Standards

CAx – Computer Aided "X" Software
Quality Control, Quality Assurance Companion (QQComp)

**DoD Problem**
- Inspection of complex systems is expensive (training, travel, expert personnel).
- Extended Reality (XR) improves efficiency for inspection. However, they suffer from a lack of interoperability between PLM systems and visualization modalities, e.g., headsets.
- Current technical data package (TDP) practices do not lend themselves to low-level mappings between authoritative design data and inspection reports.
- COTS toolkits do not adequately address automated instruction delivery.
- DoD depots and industrial base procure one-off XR apps, lacking scalability and agility.

**Approach**
- Collaboration between DoD labs to create end-to-end, platform-agnostic, standards-based pipeline for presenting product manufacturing information (PMI) on 3D mesh models with a DoD-developed computer vision toolkit for automated work instruction delivery.
- Leverage NIST open-source software, e.g., STP2OWL, STP2X3D, STP-QIF integration
- Develop graph database schema to store standardized data, e.g., inspection and design.

**Warfighter Benefits/Impacts**
- Represents a collaboration across 4 DoD services, leveraging funds from OSD, OUSD, DLA, ERDC, AFRL, and NIST, with 7 support letters and 9 potential transitional partners: DLA, NAVSEA, NAVWAR, Warner Robins ALC, PEO Aviation, AFRL Rapid Sustainment Office, Pier Side Support Equipment, Strategic Systems Programs, and Missile Defense Agency
- Reduces time (-66%), human errors (-70%), and cost (-30%) for inspection and maintenance activities
- Government developed open-source software can be reused and shared by the larger community. QQComp has unlimited data rights to its deliverables.
- Implementing an end-to-end pipeline in the manufacturing process helps unify the process from product design through manufacturing to quality inspection translating into time and money savings.
- Broad collaboration builds relationships to best leverage XR-related R&D
Goals of QQComp – Build Authoritative Models for AR

Goal 1. Develop computer vision (CV) module to support instructional guide authoring for XR applications
- Define inspection and maintenance procedures in machine-readable format
- Develop CV toolkit for object recognition and view segmentation
- Relate CV module to XR-assisted inspection/maintenance app

Task 1: Computer Vision Toolkit on Cloud
Demo: Automated XR presentation of instruction for inspection activity

Goal 2. Enrich mesh representation w/ semantic Product Manufacturing Information (PMI) through knowledge graphs
- Leverage open-source translators, e.g., NIST STP2X3D Translator
- Improve and harden translators beyond NIST publications
- Collect and use DoD use cases

Task 2: Mesh model w/ PMI on Cloud
Demo: Semi-automated Translation of CAD to XR Model

Goal 3. Relate real-time inspection data to mesh model via QIF on the cloud
- Leverage open-source translators, e.g., XML2OWL Translator
- Build secure cloud-based QIF-compliant database
- Relay outcomes from measurement tools

Task 3: Real-time Inspection Data to Mesh on Cloud
Demo: Automated push of digital micrometer data to QIF database

Goal 4. Demonstrate MRL 7 technology in a production environment
- Package Task 1 and Task 2 in Unity3D application
- Deliver hardware with software running to transition partners
- Test and report on findings

Task 4: Test with Customer and Harden Tech
Demo: Remote update between at least 2 distributed teammates
QQComp Timeline

**Goal 1: Develop CV module**

- Develop model training pipeline
- Benchmark against COTS tools
- Develop QIF database
- Develop translator for STP model to mesh with PMI
- Develop capability for visualization real-time status of inspection data
- Develop data input tool to support entry of diverse data for authoring
- Develop AR applications per workshop outcomes
- Develop test cloud-based messaging protocol

**Goal 2: Build mesh with PMI via KGs**

- Improve and support

**Goal 3: Relate real-time inspection data to mesh via QIF**

- Develop reasoning capability on QIF and glTF graphs to demonstrate semi-automated AR content generation

**Goal 4: Demonstrate AR applications in production environments**

- Deploy CV module onto cloud

- Improve and support

- Improve and support

- Improve and support

- Improve and support

- Improve and support

- Improve and support

- Improve and support

- Improve and support
Transition Workshop and MVP Demonstrations (07 AUG 2024)
Other Examples of Interoperability-Related Projects for Industrial AR

- **Content reuse/adaptability for animations**
- **Process planning for robot-assisted manufacturing**
Plans Forward – Both ManTech and Internal Research

- Leverage Joint Defense ManTech Panel (JDMTP) Advanced Manufacturing Enterprise (AME) Subpanel to work cross service **technical data modernization**
- DAF ManTech support technical data initiatives and help proliferate best practices across defense industrial base (e.g., low tier suppliers) and **organic industrial base**
- Continue to support and demonstrate manufacturing innovations across technology readiness level (TRL) spectrum

**Collaborative Automation for Manufacturing Systems (CAMS) Lab coming soon!**
QUESTIONS?

Got use cases?
Please find us at lunch!