AFRL

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

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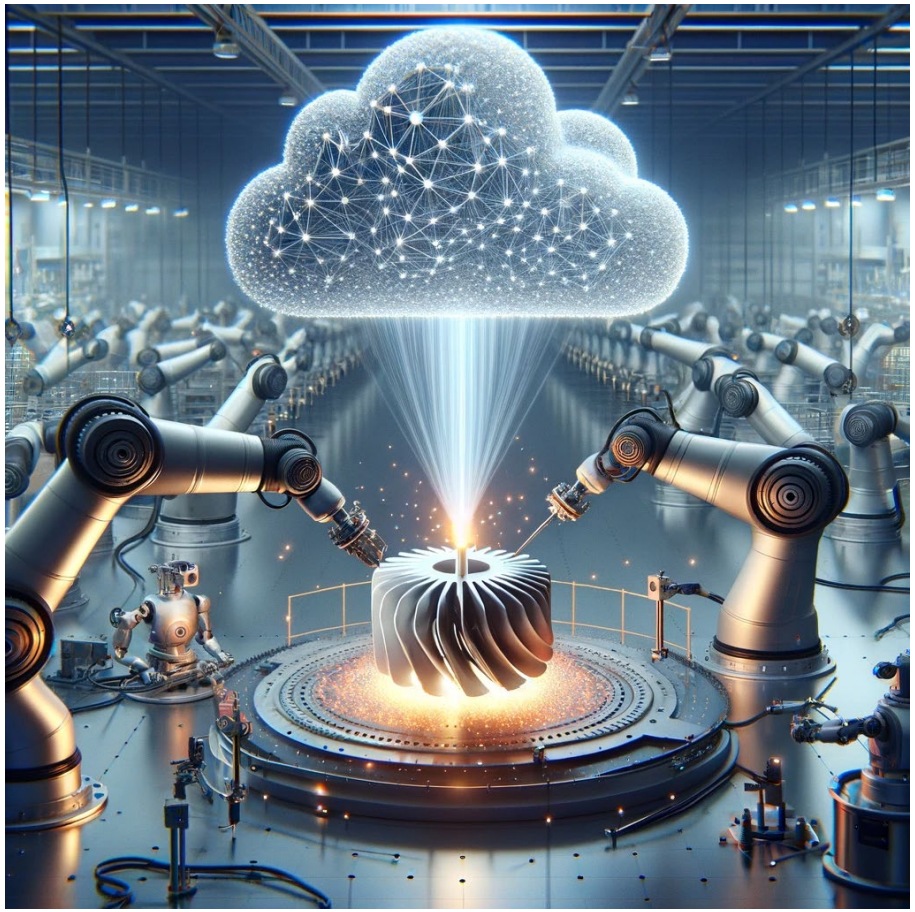
Agenda

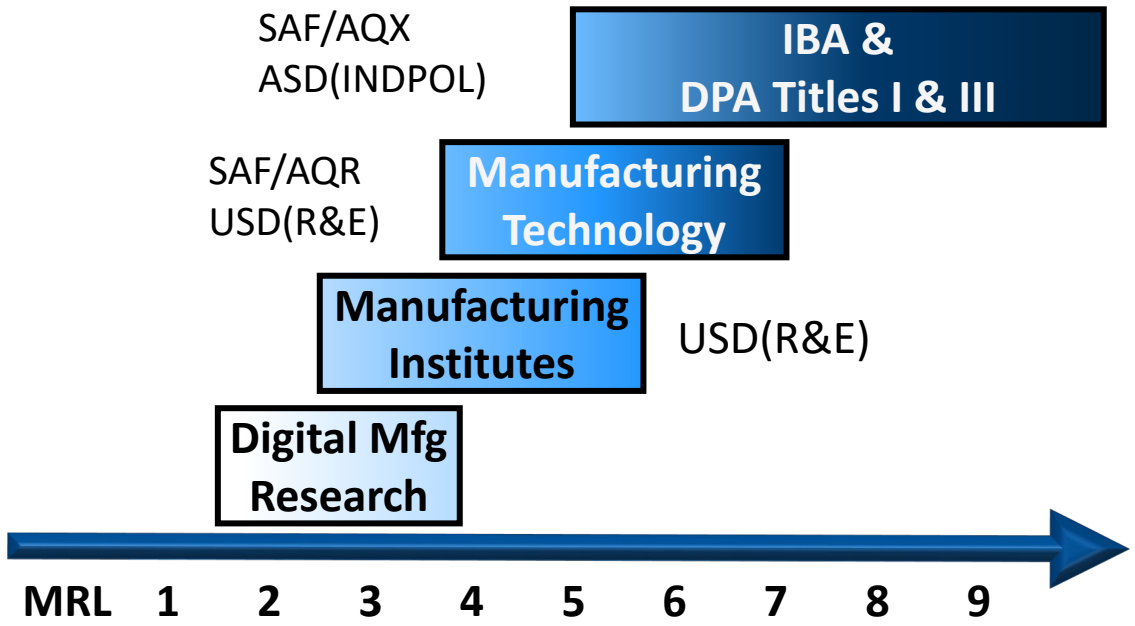
- Overview of Dept of the Air Force (DAF) ManTech **Advanced Manufacturing Technology** (AMT) Portfolio
- Ongoing Efforts Related to Model-Based Enterprise
  - Technical Data Modernization for As-Built Data
  - Open Digital Thread for Industrial Augmented Reality
- Looking Forward

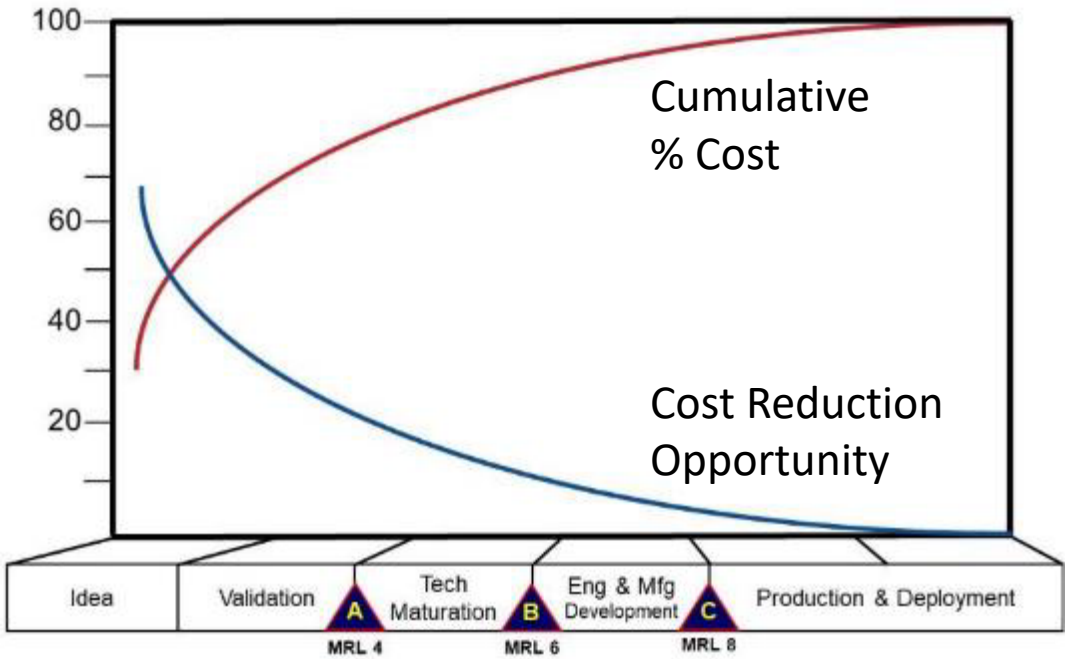


**Created by DALL-E*

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*

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

2-10x more efficient DIB operations

- **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

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*

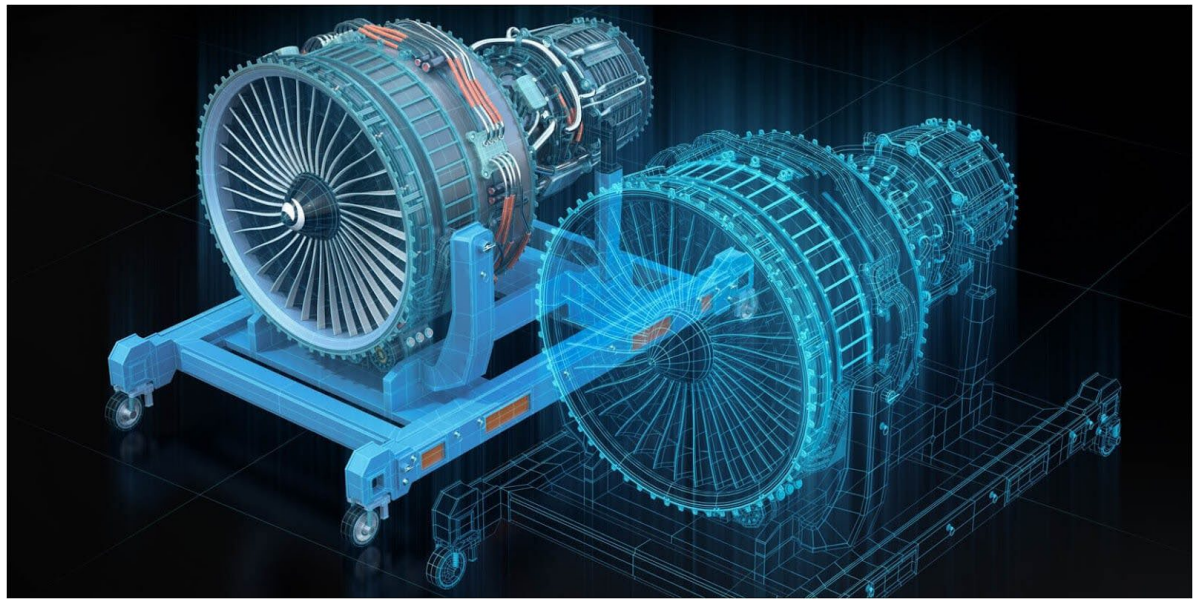
Open Digital Thread / Twin

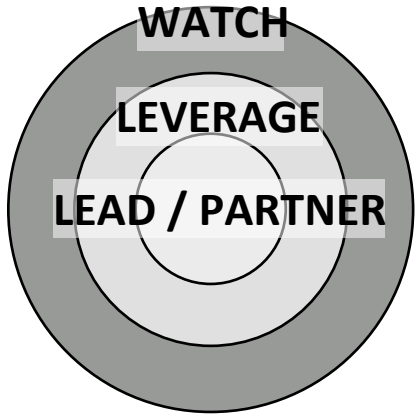
Manufacturing Vision

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

Communication Protocols

Mfg Process Informatics

Standard Data Curation Models

Adaptive Quality Management

Joint Cognition

Machine-Machine Teaming

AM Process Qualification

Mfg System Integration

Large Scale Metal AM

New Materials

Automation, Robotics, and Mixed Reality ManTech Program

Automated Material Handling

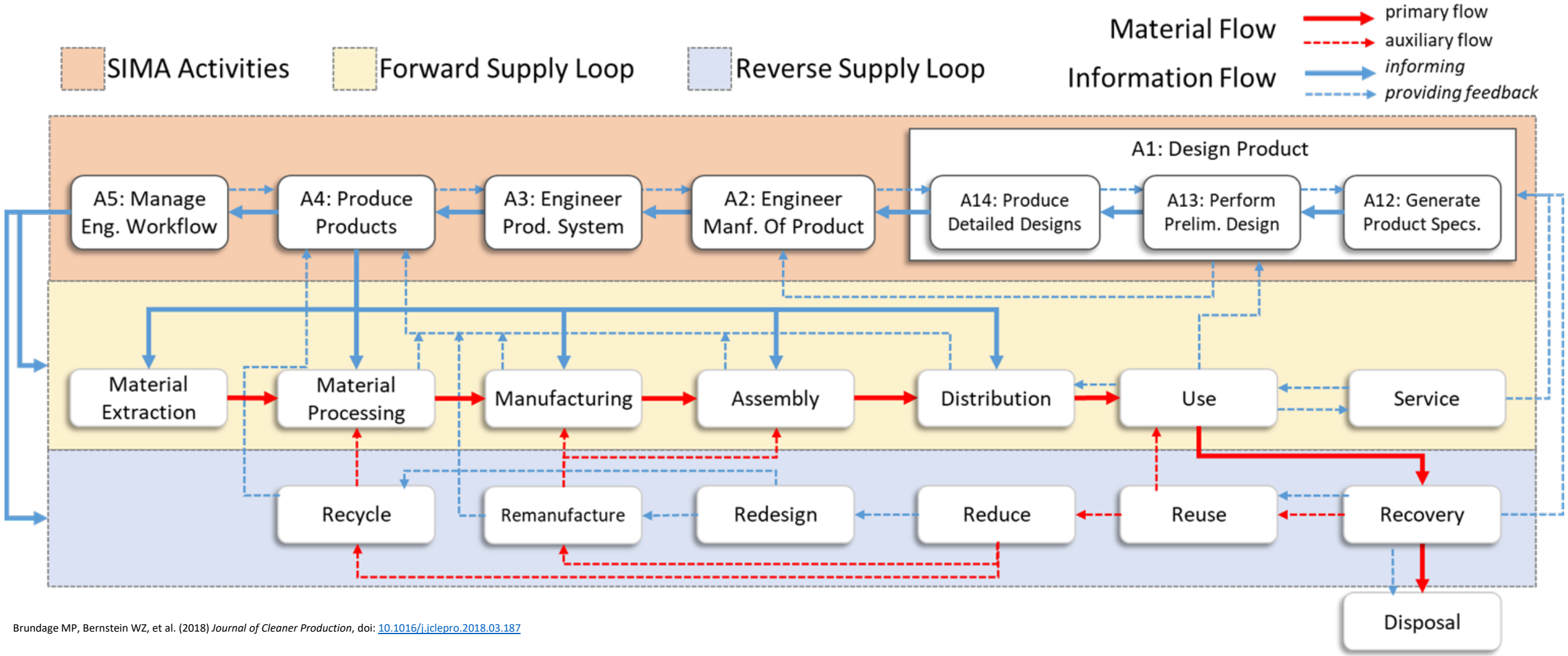
Robotic-Assisted Repair

Metamorphic Manufacturing

Additive Manufacturing ManTech Program

Technical Data Modernization for As-Built Data

Information Complexities Across the Product System Lifecycle



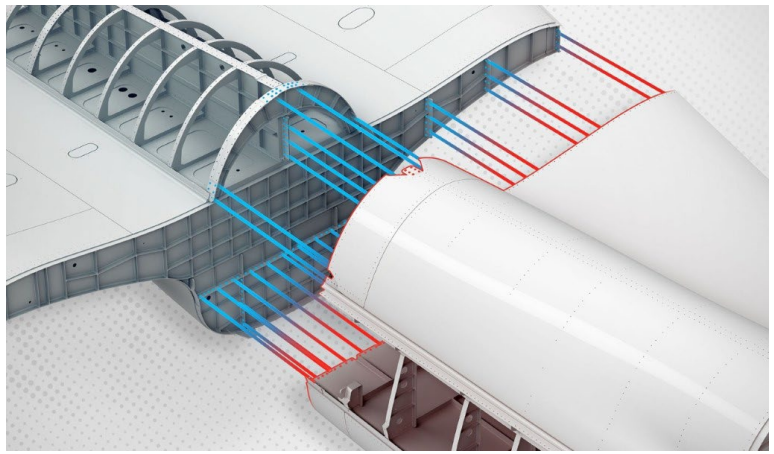
Brundage MP, Bernstein WZ, et al. (2018) *Journal of Cleaner Production*, doi: 10.1016/j.jclepro.2018.03.187

Industry 4.0 Standards Activities

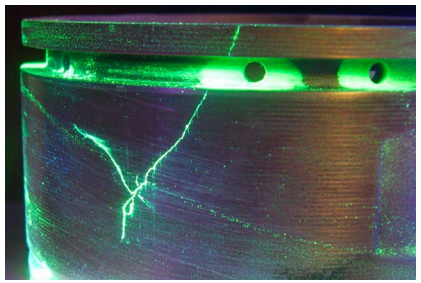
Challenge:
Harmonizing Industry 4.0 standards at scale

Lu, Y., et al., 2016. Current standards landscape for smart manufacturing systems. *NIST, NISTIR, 8107*.

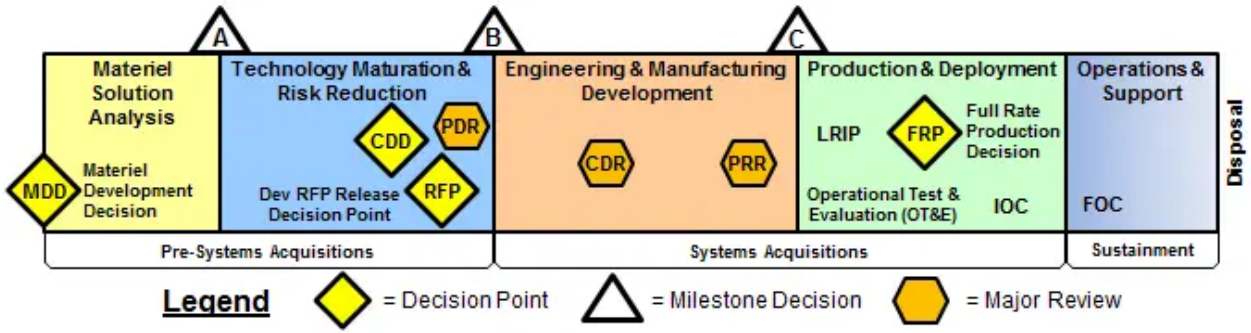
Use Cases of (Particular) Interest



Full-Sized Determinant Assembly (FSDA)

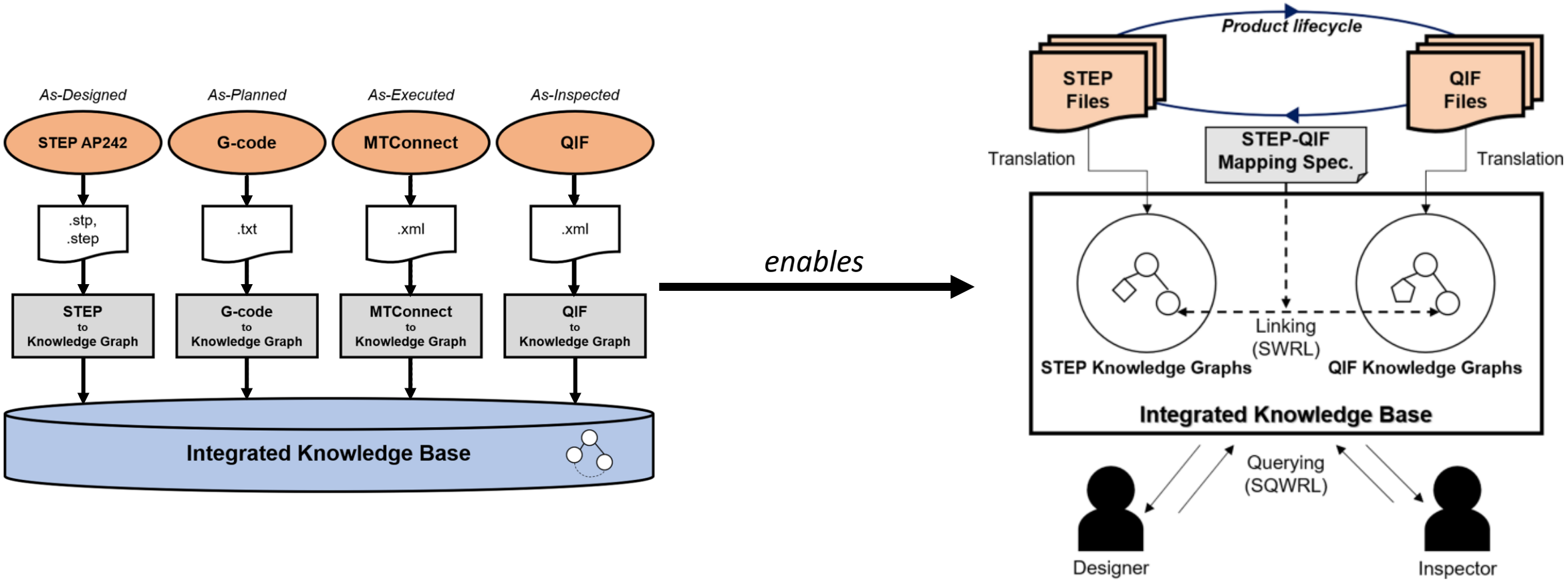


Failure Analysis at Sustainment



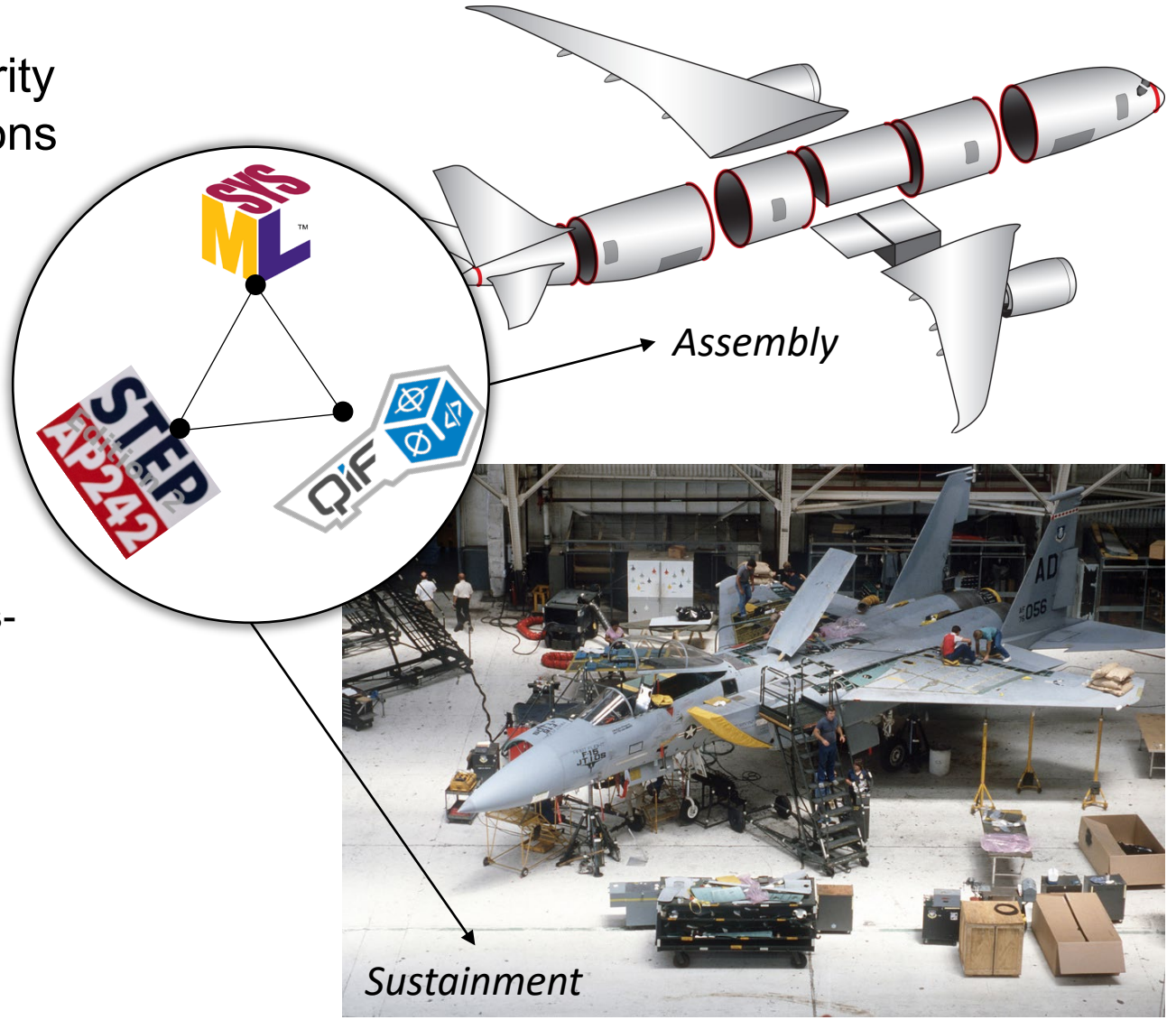
Acquisition Support / Data Rights

Vision | Technical Data Modernization for As-Built Data



(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

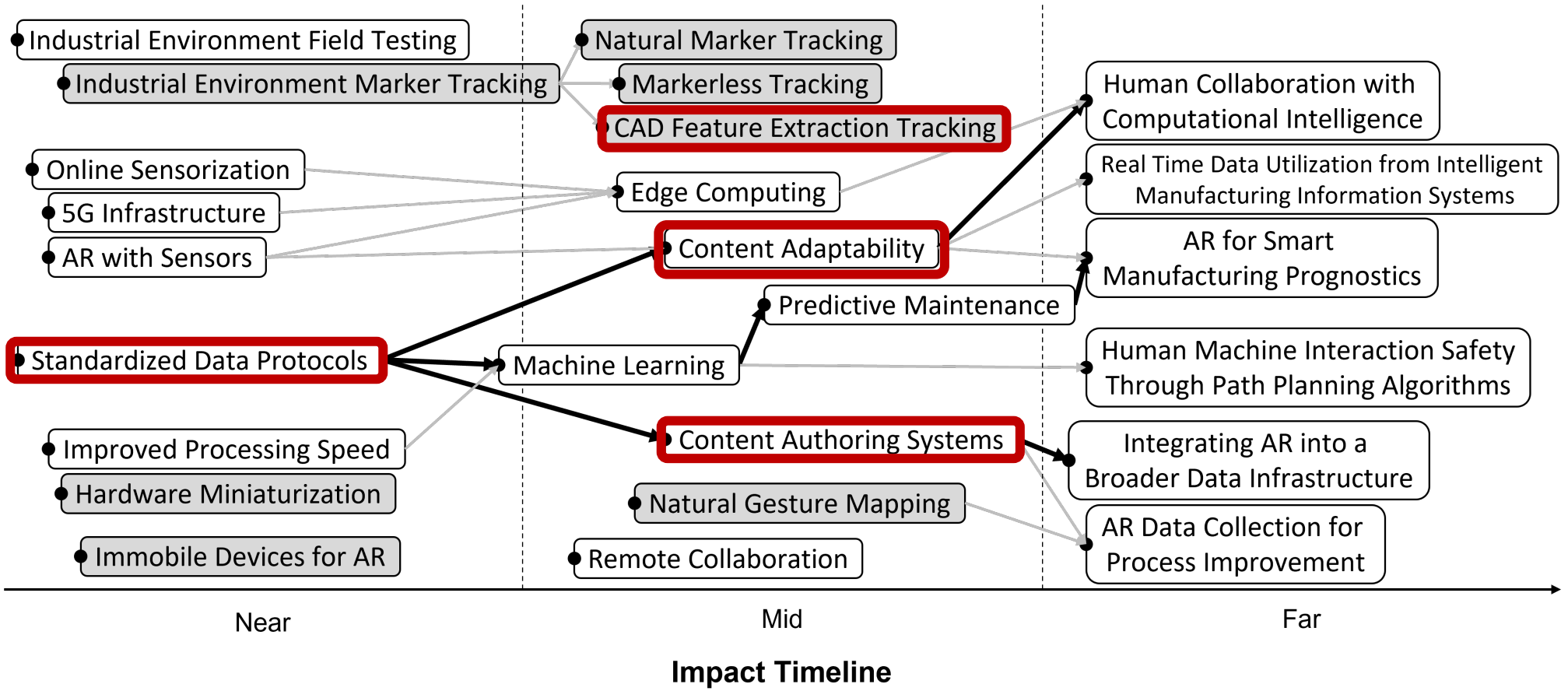


AFWERX

AFMANTECH
UNITED STATES AIR FORCE

Open Digital Thread for Industrial Augmented Reality

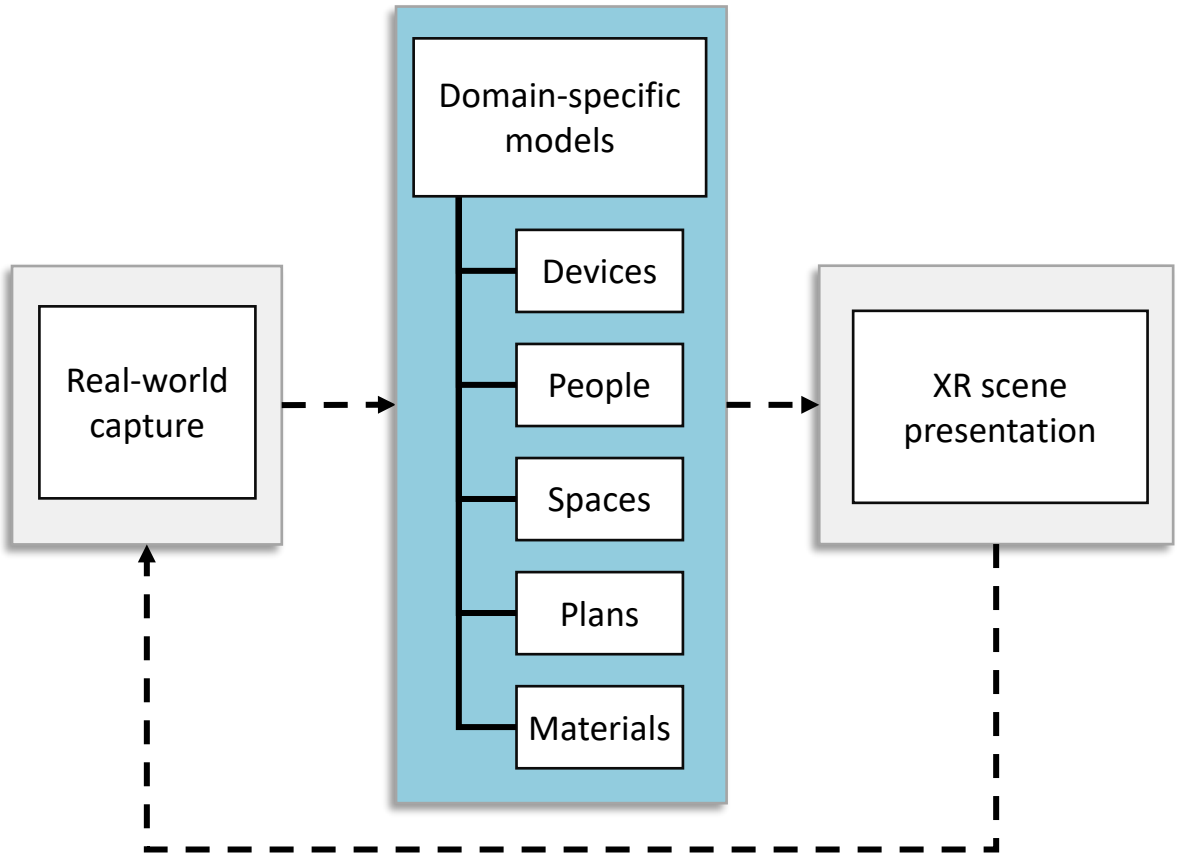
How interoperability will impact Industrial Augmented Reality



Potential research and development opportunities for Industrial XR related to data-driven processes[1]

[1]Bernstein et al. (2024) *ASME JCISE.*

Industrial AR suffers from interoperability challenges



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

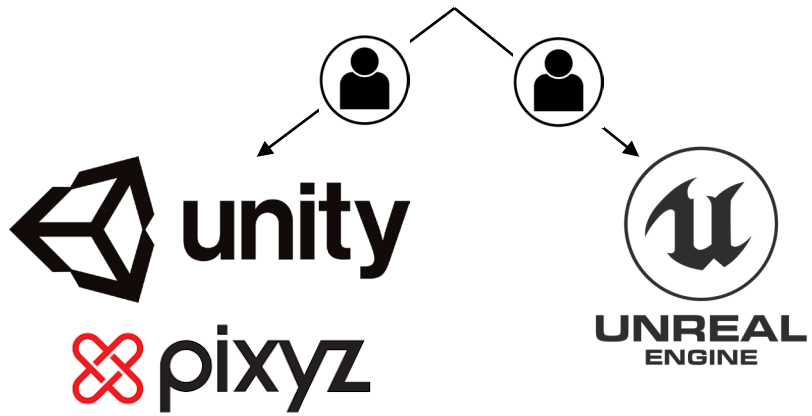
DASSAULT SYSTEMES

thingworx®

SIEMENS PLM SOFTWARE
SIEMENS

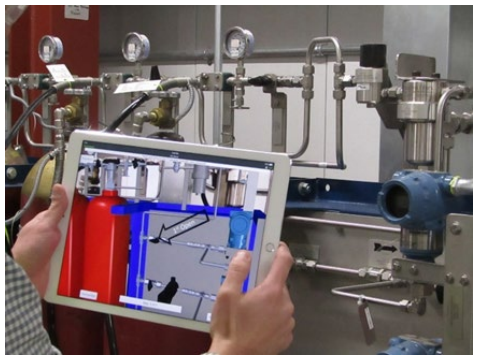
Rely on 3rd Party Translators

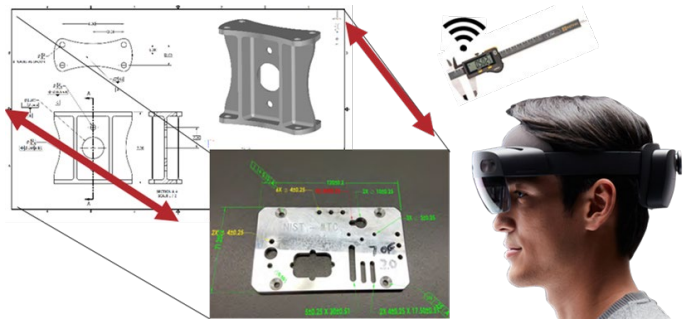
Digital Enterprise /
CAx Standards



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.

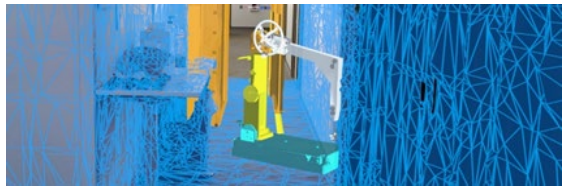
Warfighter Benefits/Impacts

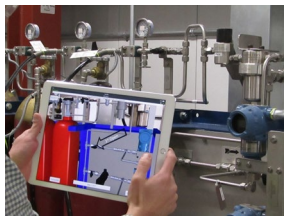
- Represents a collaboration across 4 DoD services, leveraging funds from OSD, OUSD, DLA, ERDC, AFRL, and NIST, with 7 support letters and 9 potential transitional partners: DLA, NAVSEA, NAVWAR, Warner Robins ALC, PEO Aviation, AFRL Rapid Sustainment Office, Pier Side Support Equipment, Strategic Systems 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

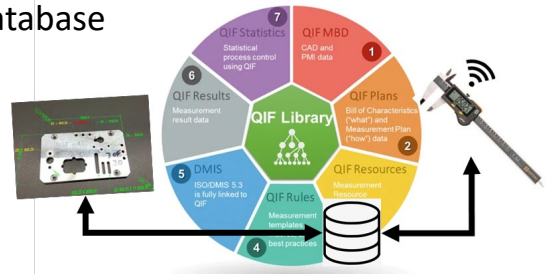
Goal 2. Enrich mesh representation w/ semantic Product Manufacturing Information (PMI) through knowledge graphs

- ✓ 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



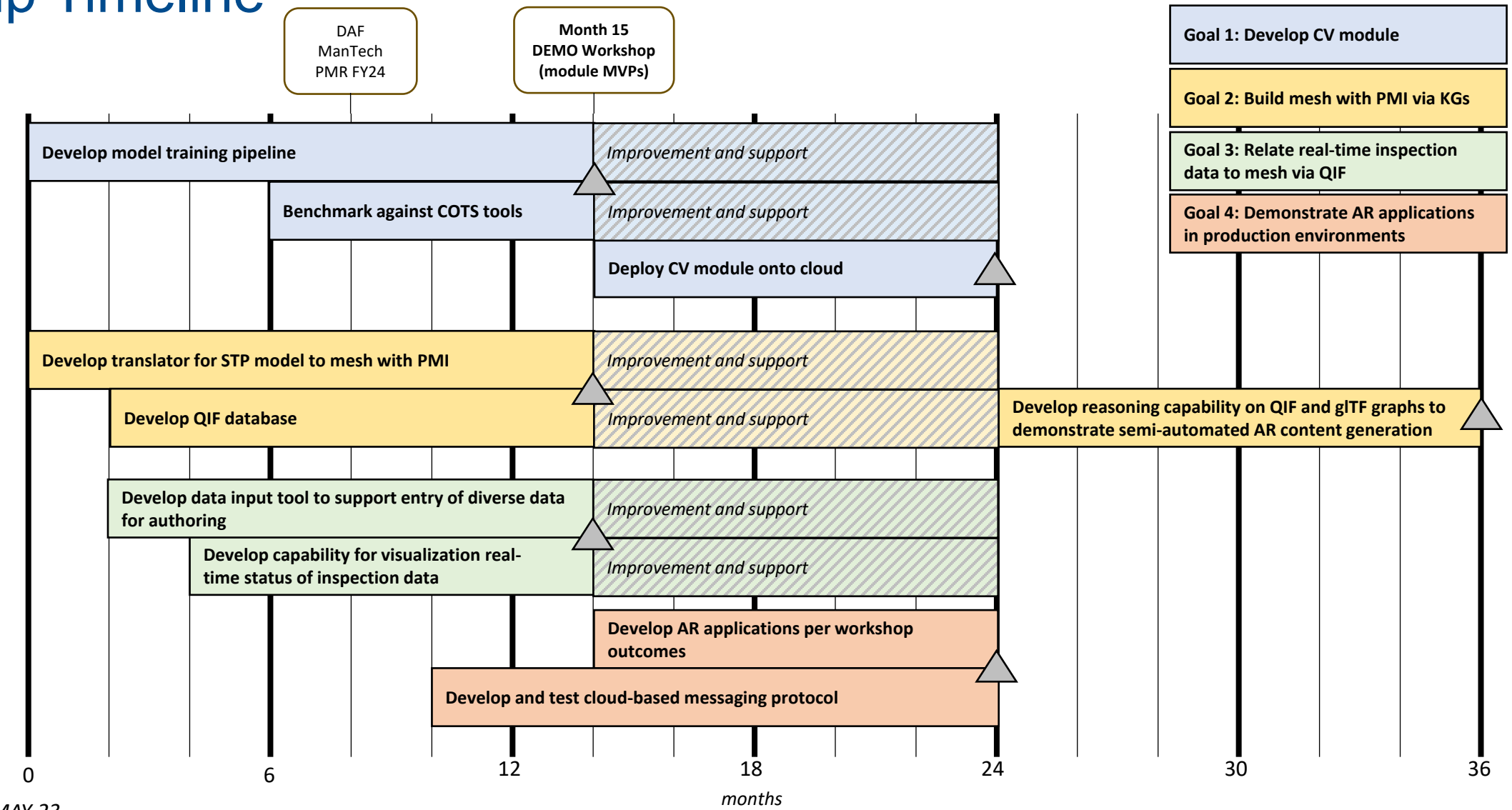
→ **Task 3: Real-time Inspection Data to Mesh on Cloud**
Demo: Automated push of digital micrometer data to QIF database

Goal 4. Demonstrate MRL 7 technology in a production environment

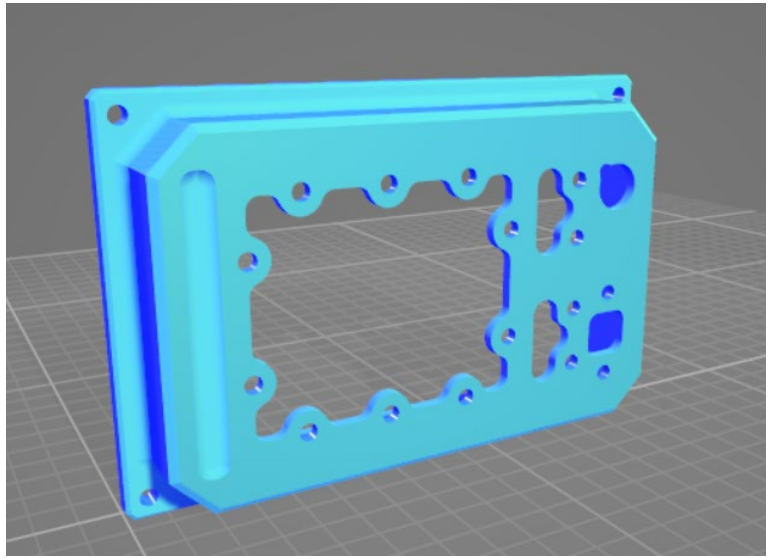
- ✓ Package Task 1 and Task 2 in Unity3D application
- ✓ Deliver hardware with software running to transition partners
- ✓ Test and report on findings

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

QQComp Timeline



Latest Progress on STP-QIF-glTF Pipeline



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584dc975-126d-4bcf-b2cb-31070ea2077d	7e70734b-c21e-45e5-ae34-10e59b41605c	7E9AFA65-3796-4E53-95B7-3D8239DB8F85	FACE [=>[0:1:1:28]]	[63.600000, 79.375000, 22.050000]	Diameter3	Diameter	{'Target Value': 4.5, 'Tolerance Maximum': 0.3, 'Tolerance Minimum': 0.3}
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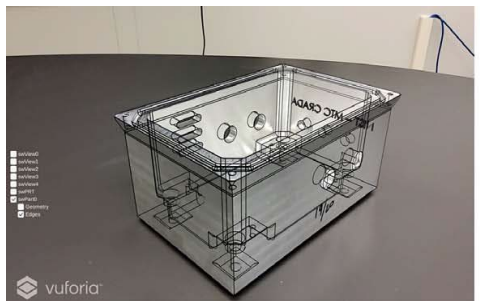
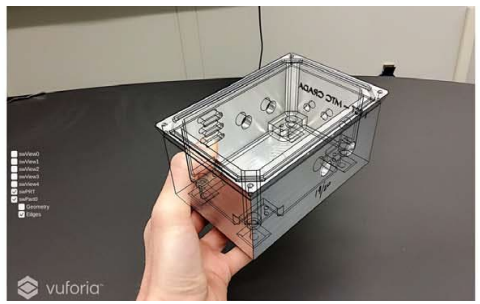
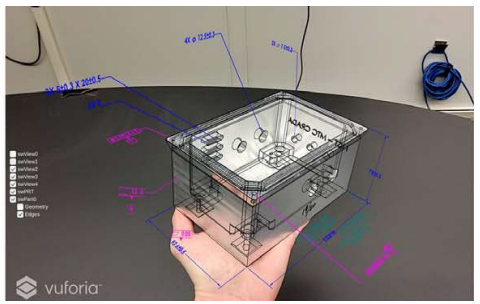
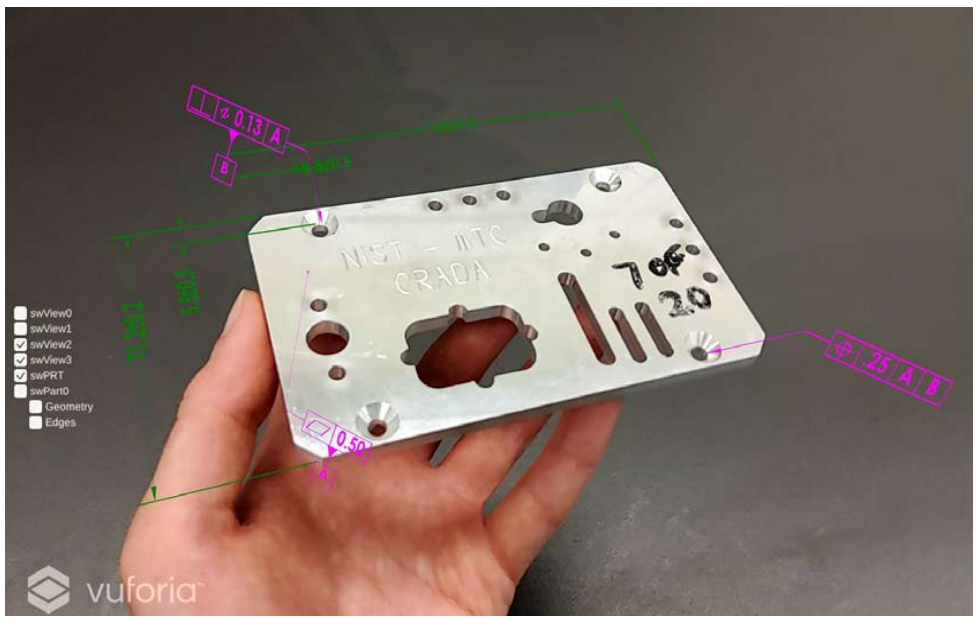
888bb9b0-7ed9-4c8d-ab4b-c26d41a86303	7e70734b-c21e-45e5-ae34-10e59b41605c	7E9AFA65-3796-4E53-95B7-3D8239DB8F85	FACE [=>[0:1:1:32]]	[98.600000, 65.087500, 22.050000]	Diameter3	Diameter	{'Target Value': 4.5, 'Tolerance Maximum': 0.3, 'Tolerance Minimum': 0.3}
60a147d0-26f9-4ee1-bf14-568f0e0c0186	7e70734b-c21e-45e5-ae34-10e59b41605c	7E9AFA65-3796-4E53-95B7-3D8239DB8F85	FACE [=>[0:1:1:34]]	[98.600000, 36.512500, 22.050000]	Diameter3	Diameter	{'Target Value': 4.5, 'Tolerance Maximum': 0.3, 'Tolerance Minimum': 0.3}
e97acaaf-fe79-4268-9cbd-6b70e7add910	7e70734b-c21e-45e5-ae34-10e59b41605c	7E9AFA65-3796-4E53-95B7-3D8239DB8F85	FACE [=>[0:1:1:36]]	[63.600000, 22.225000, 22.050000]	Diameter3	Diameter	{'Target Value': 4.5, 'Tolerance Maximum': 0.3, 'Tolerance Minimum': 0.3}
5c410c43-296d-410e-8b41-09493c7b7709	7e70734b-c21e-45e5-ae34-10e59b41605c	7E9AFA65-3796-4E53-95B7-3D8239DB8F85	FACE [=>[0:1:1:38]]	[41.600000, 22.225000, 22.050000]	Diameter3	Diameter	{'Target Value': 4.5, 'Tolerance Maximum': 0.3, 'Tolerance Minimum': 0.3}
bdc08514-08d5-447b-bb61-1da3fc3ecde5	7e70734b-c21e-45e5-ae34-10e59b41605c	7E9AFA65-3796-4E53-95B7-3D8239DB8F85	FACE [=>[0:1:1:40]]	[120.100000, 41.045967, 22.050000]	Diameter4	Diameter	{'Target Value': 4.5, 'Tolerance Maximum': 0.3, 'Tolerance Minimum': 0.3}
635f21e2-3005-4ada-b325-8c9b30a64511	7e70734b-c21e-45e5-ae34-10e59b41605c	7E9AFA65-3796-4E53-95B7-3D8239DB8F85	FACE [=>[0:1:1:42]]	[120.100000, 60.554033, 22.050000]	Diameter4	Diameter	{'Target Value': 4.5, 'Tolerance Maximum': 0.3, 'Tolerance Minimum': 0.3}
9ea720ce-e4cb-4a3d-8e1b-5c6ea8a38982	7e70734b-c21e-45e5-ae34-10e59b41605c	7E9AFA65-3796-4E53-95B7-3D8239DB8F85	FACE [=>[0:1:1:44]]	[120.100000, 76.045967, 22.050000]	Diameter4	Diameter	{'Target Value': 4.5, 'Tolerance Maximum': 0.3, 'Tolerance Minimum': 0.3}
67f40b1a-00e7-4730-a15e-448c2d05bf5d	7e70734b-c21e-45e5-ae34-10e59b41605c	7E9AFA65-3796-4E53-95B7-3D8239DB8F85	FACE [=>[0:1:1:46]]	[132.050000, 43.800000, 22.050000]	Diameter5	Diameter	{'Target Value': 4.5, 'Tolerance Maximum': 0.3, 'Tolerance Minimum': 0.3}
67c9f66b-0dd4-468e-ba32-f377839deb65	7e70734b-c21e-45e5-ae34-10e59b41605c	7E9AFA65-3796-4E53-95B7-3D8239DB8F85	FACE [=>[0:1:1:48]]	[150.400000, 0.000000, 0.000000]	DistanceBetween2	Curve Length	{'Target Value': 5.5, 'Tolerance Maximum': 0.5, 'Tolerance Minimum': 0.5}
2038e906-17ee-4abe-98fd-f2247cf1dedc	7e70734b-c21e-45e5-ae34-10e59b41605c	7E9AFA65-3796-4E53-95B7-3D8239DB8F85	FACE [=>[0:1:1:48]]	[150.400000, 0.000000, 0.000000]	DistanceBetween3	Linear Distance	{'Target Value': 101.6, 'Tolerance Maximum': 0.2, 'Tolerance Minimum': 0.2}
54a16b20-4a3c-404a-b39d-ec846ca9ef6e	7e70734b-c21e-45e5-ae34-10e59b41605c	7E9AFA65-3796-4E53-95B7-3D8239DB8F85	FACE [=>[0:1:1:50]]	[2.000000, 101.600000, 0.000000]	DistanceBetween3	Linear Distance	{'Target Value': 101.6, 'Tolerance Maximum': 0.2, 'Tolerance Minimum': 0.2}

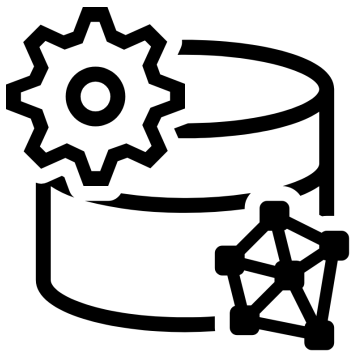
Transition Workshop and MVP Demonstrations (07 AUG 2024)











RSO

U.S. AIR FORCE

WARNER ROBINS ALC

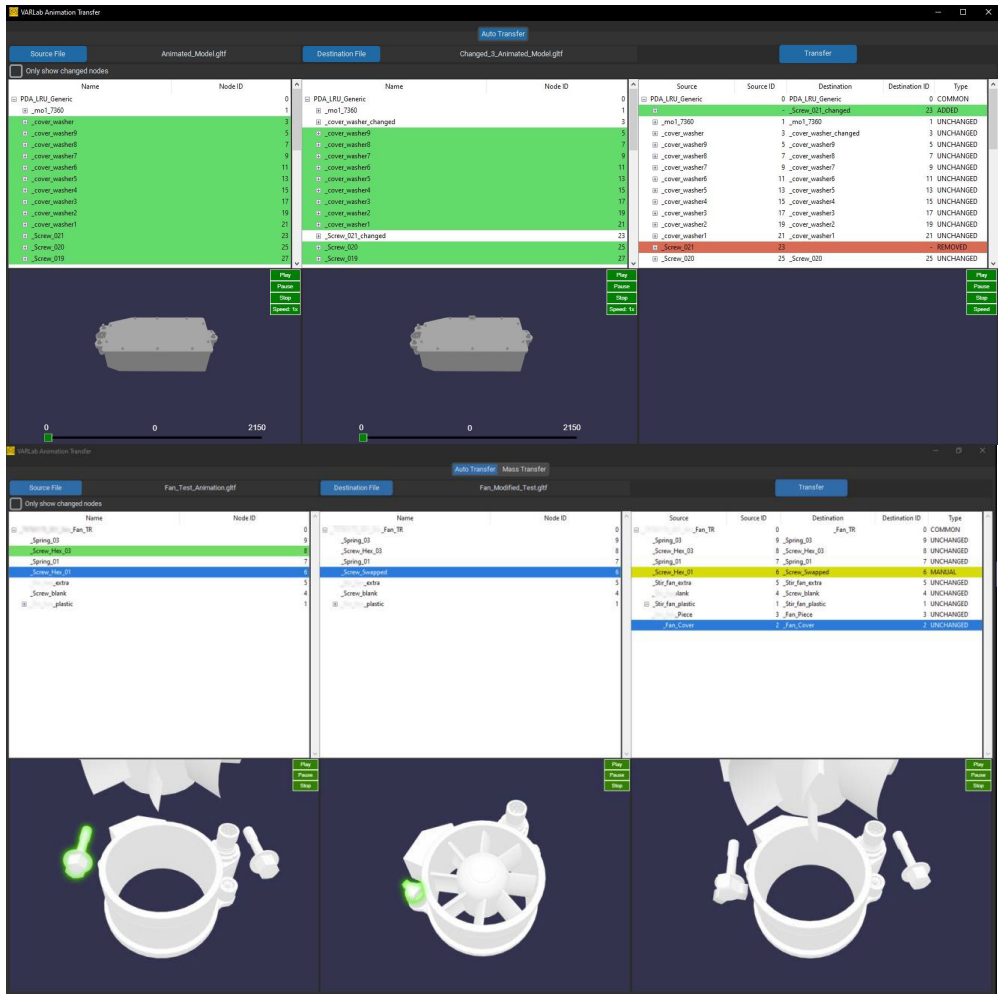
PROGRAM EXECUTIVE OFFICE AVIATION

NAWC Aircraft Division NAVAL AIR WARFARE CENTER

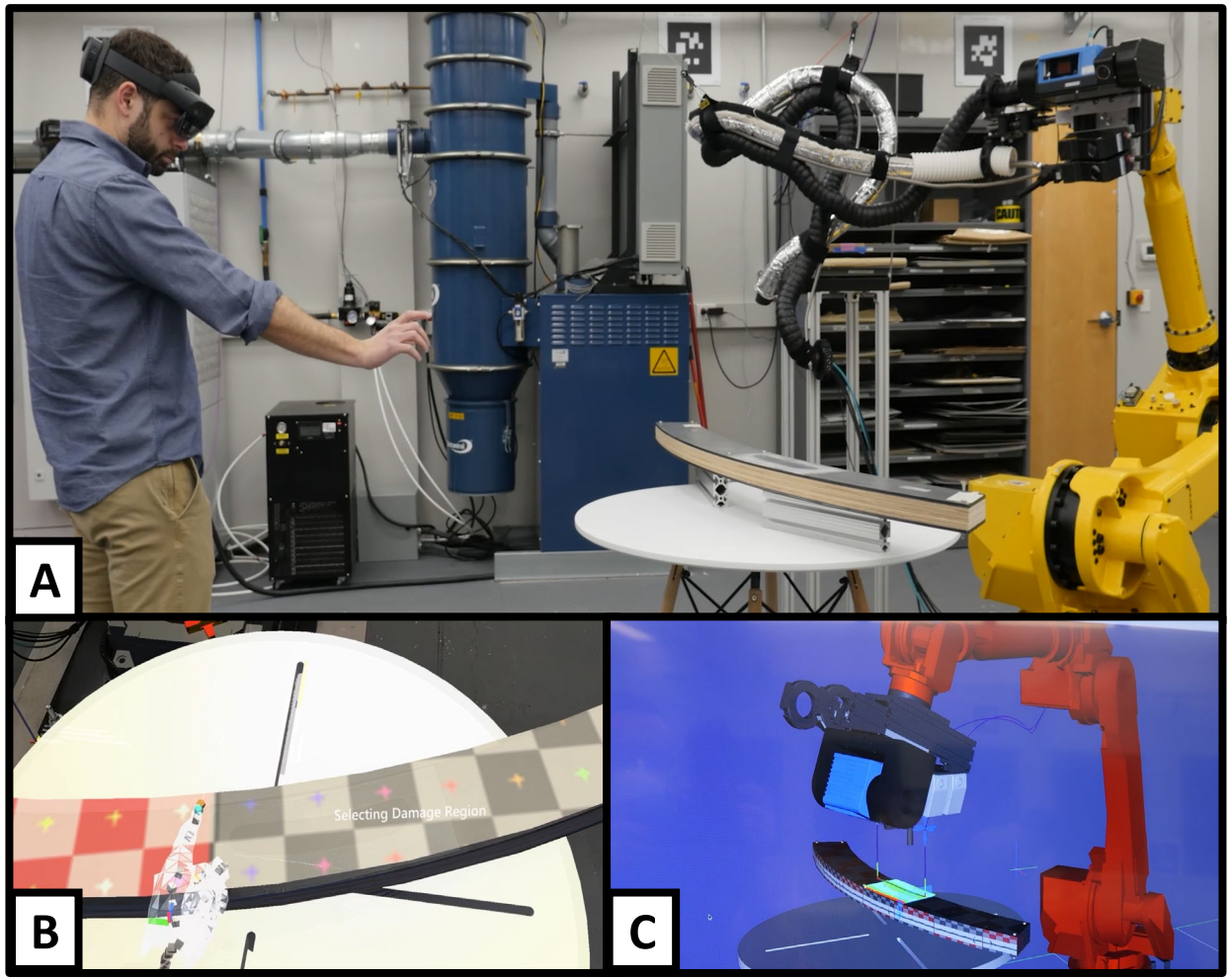
NAVSEA WARFARE CENTERS Port Hueneme

DEFENSE LOGISTICS AGENCY

Other Examples of Interoperability-Related Projects for Industrial AR



Content resuse/adaptability for animations



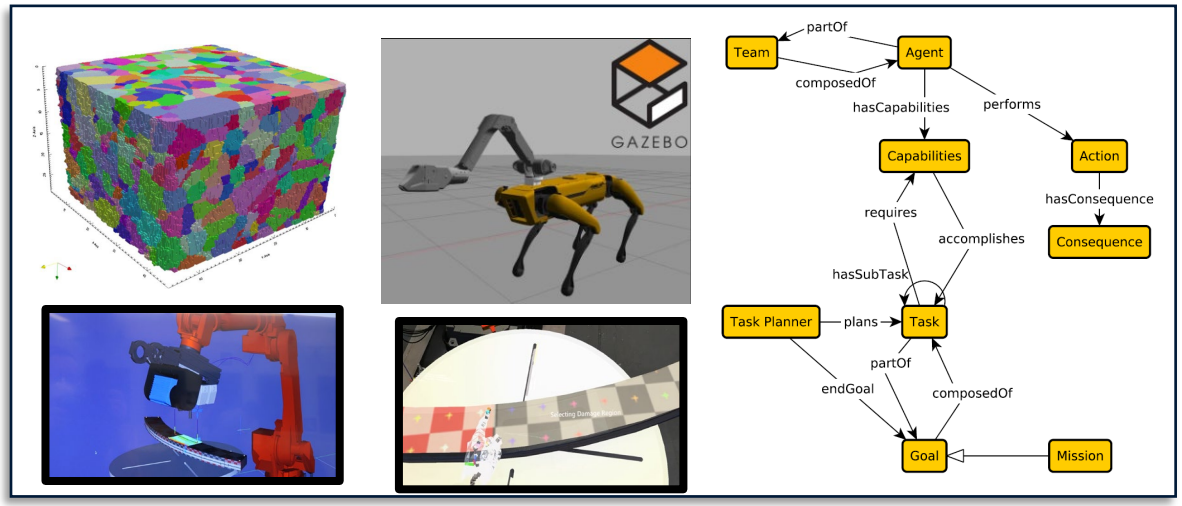
Process planning for robot-assisted manufacturing

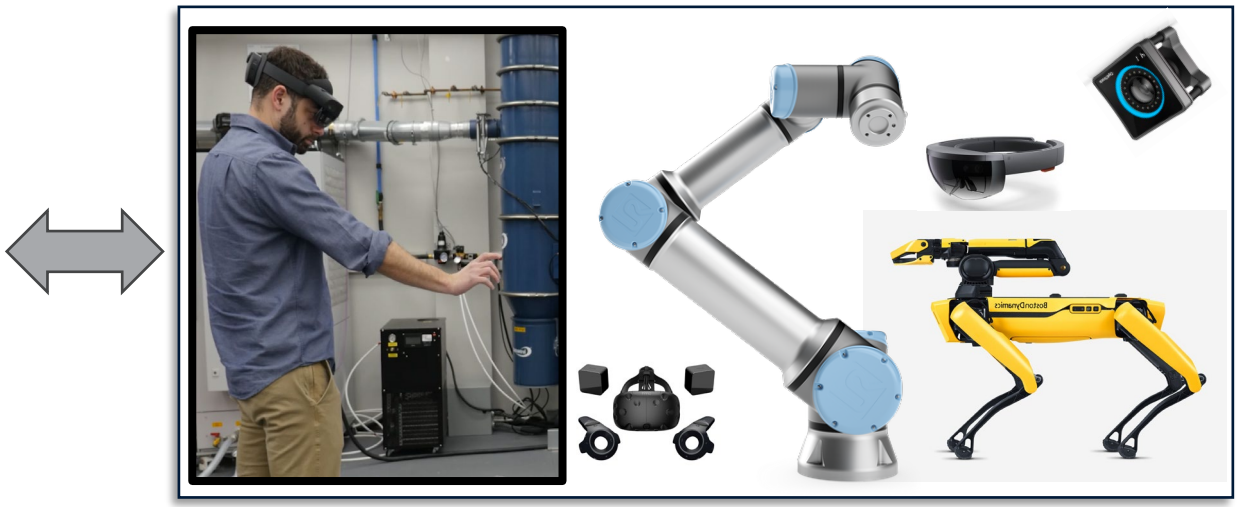
Looking Forward

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!