

FUTURE OF TRAINING:

AUGMENTED REALITY & INTERNET OF THINGS

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ptc

October 2019



AGENDA

- Who are we and what do we do?
 - PTC
 - Illumination Works
- What is Augmented Reality, IoT and Digital Twin
- Value to Air Force Logistics?
- Demonstrations
 - AR
 - JLTV
 - Wiring harness Integration and Schematics
 - Warehouse Parts Picker
 - IoT
 - Aviation Common operating picture
 - Predictive Maintenance
 - USAF Log Command and Control
- Case Study – Illumination Works



- Global software company, headquartered in Boston, MA
- Industry leading:
 - IOT & AR Solutions
 - CAD & PLM Solutions
- Helps companies accelerate digital transformation
- Provides AR solutions to drive **operational excellence and increase workforce productivity**



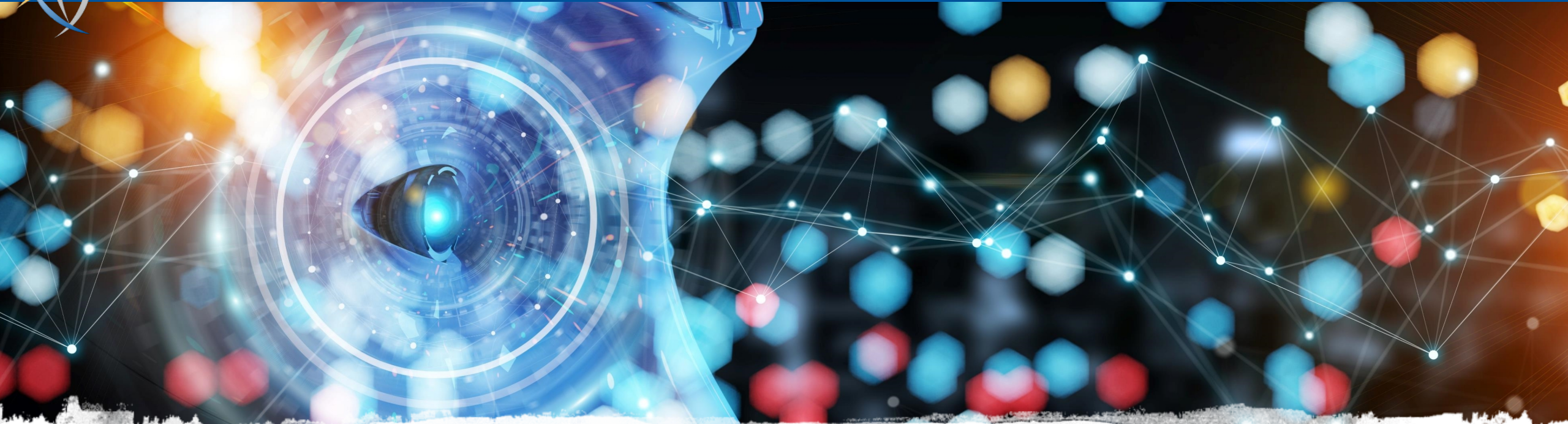


About ILW



Trusted technology partner
in user-centric digital
transformation

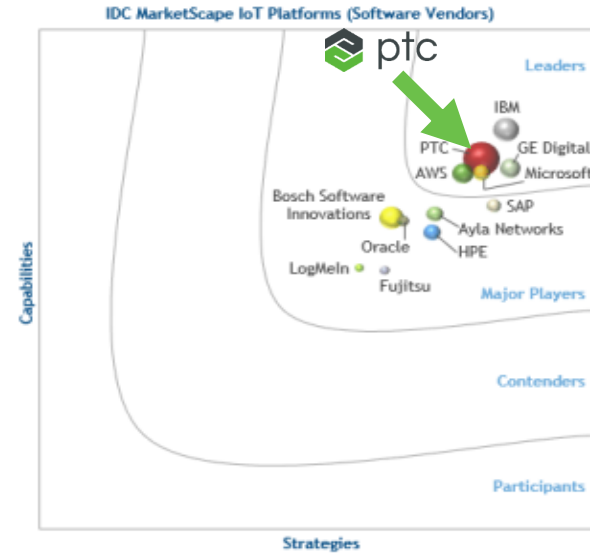
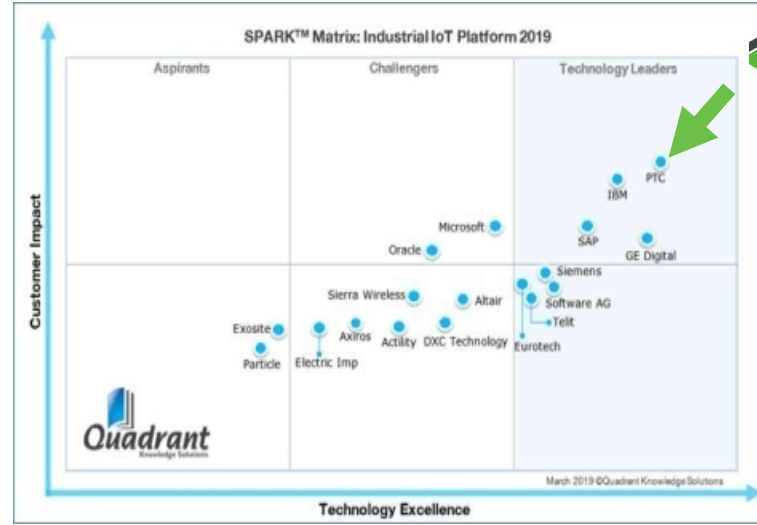
- Delivering impactful business results
- Partnering with customers to solve their unique technology and data challenges
- Empowering smart people to solve today's business challenges through innovative solutions



Solving our customers' toughest challenges

- Augmented Reality
- Data Science
- Big Data Frameworks
- Data Integration
- Data Visualization
- App Development
- Cloud Strategies
- Agile Processes

INDUSTRY ANALYST PERSPECTIVES ON IIOT



INDUSTRY ANALYSTS ENDORSE PTC AS THE DEFINITIVE AR LEADER

PAC RADAR AR platforms for connected workers in Europe 2019



- Teknowlogy's PAC RADAR evaluation names PTC as the clear leader in AR Platforms for Connected Workers.
- PTC earned the highest position on the "Competence" axis, reflecting the strength of its Industrial AR portfolio.
- PTC earned the furthest position along the "Market Strength" axis, reflecting its established success in the market.

AR: DIGITAL TRANSFORMATION OF PEOPLE



WORKFORCE EFFICIENCY



Increase
Productivity

Reduce
Scrap & Rework

Improve Safety &
Compliance

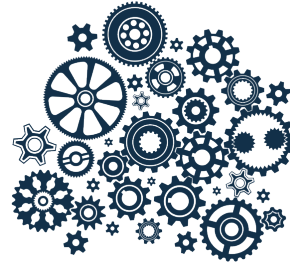


Worker Skill Gap

31% turnover rate¹

10 million jobs unfilled²

Ongoing skills upgrading



Complex Products & Workspaces

Service/maintenance challenge, configurations

Information access & content creation



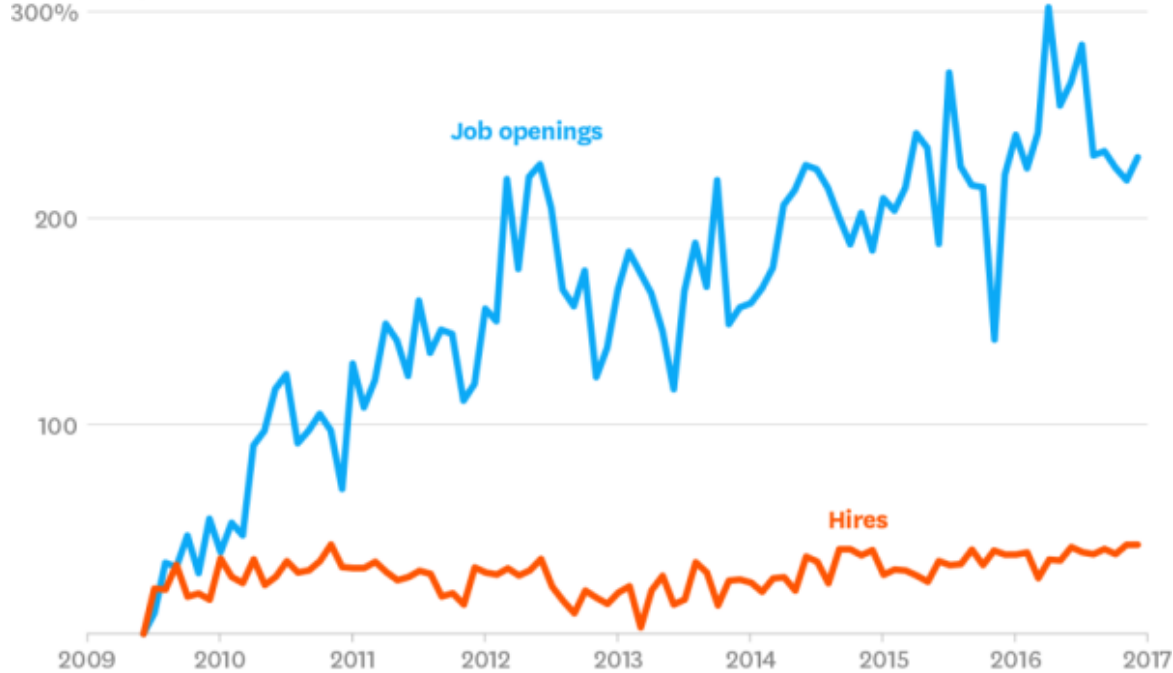
Increased Customer Demands

Expectations of immediacy

Fiercely competitive & shifting marketplace

WHY SCALE AR ACROSS THE ENTERPRISE?

PERCENTAGE CHANGE IN U.S. MANUFACTURING JOB OPENINGS AND HIRES, SEASONALLY ADJUSTED



The growing shortage of skilled manufacturing workers

Source: U.S. Bureau of Labor Statistics







Previous five years' annual growth in output per hour worked



Productivity growth is the weakest since early 1980s

Source: Bureau of Labor Statistics

AR OPPORTUNITIES ACROSS THE VALUE CHAIN

2019 Focus					
DESIGN	SELL & MARKET	MANUFACTURE	SERVICE	TRAIN	OPERATE & LOGISTICS
 <p>11%</p>	 <p>13%</p>	 <p>22%</p>	 <p>24%</p>	 <p>14%</p>	 <p>14%</p>
<ul style="list-style-type: none"> • Digital Design Review • Collaborative Design Review • Fast Product & Component Lookup 	<ul style="list-style-type: none"> • Product Visualization & Demonstration • Augmented Brand Experience 	<ul style="list-style-type: none"> • Maintenance Work Instructions • Assembly & Process Work Instructions • Machine Set-Up and Change-Over Instructions 	<ul style="list-style-type: none"> • Augmented Procedural Guidance • Service Inspection & Verification • Remote Expert Guidance • Augmented Parts Identification 	<ul style="list-style-type: none"> • Job-specific Training • Remote Expert Instruction 	<ul style="list-style-type: none"> • Operator Manual & Work Instructions

Note: These use cases cover 98.67% of responses. The remaining belongs to Other use cases.

Lengthy training pipelines and increasingly complex machines, coupled with a young, rapid turnover workforce requires a new approach to learning, maintenance activities and manufacturing operations.



1.1 Restore Military Readiness to Build a More Lethal Force

Why This Matters

Our armed forces have been involved in the longest continuous stretch of conflict in our Nation's history. The continuous nature of these engagements truncated essential maintenance and training, leading to deficiencies in safety, reliability, and availability of Fleet and Marine assets. Concurrently, these operations led to the depletion of weapons and ammunition stocks, as well as degradations to their supporting systems. Investment uncertainty resulting from budget control actions further complicated our efforts to maintain readiness and stable ordnance inventories, creating an erosion of capability across the force. The DON will make targeted, disciplined increases in personnel, platforms, weapons, ammunition, training, and maintenance to ensure that a larger, more lethal naval force is prepared to conduct combat operations against peer adversaries in any high-intensity conflict around the world.

1.1.A » Fully restore aviation/ship/ personnel readiness to meet missions

Aviation Readiness



Problem: The Navy and U.S. Marine Corps (Marine Corps) aviation assets have experienced years of high-tempo operations that has increased the number of non-mission capable aircraft. The result—restricted flying hours and reduced training—led to decreased readiness rates and reduced operational effectiveness. Depots also lack a sufficient number of skilled workers and available aviation spares, both of which must be addressed to increase the quantity of fully mission capable aircrafts.

Solution: The Navy and Marine Corps aviation enterprise will focus on reducing the quantity of non-mission capable aircraft through focused maintenance and supply chain management, and expand training to develop a broader base of highly trained maintenance personnel.

- Produce a Navy P2P instruction for Aviation, Surface, Undersea, Safety, and Information Warfare
- Implement Marine Corps aviation readiness programs
- Develop and implement pilot program to reduce Long Term Down aircraft trends
- Identify material requirements to increase aviation readiness levels
- Ensure implementation of supply chain improvements to increase material availability and reduce backorders
- Implement a plan to develop artisan-level depot workers and to manage depot workflow

Personnel Readiness

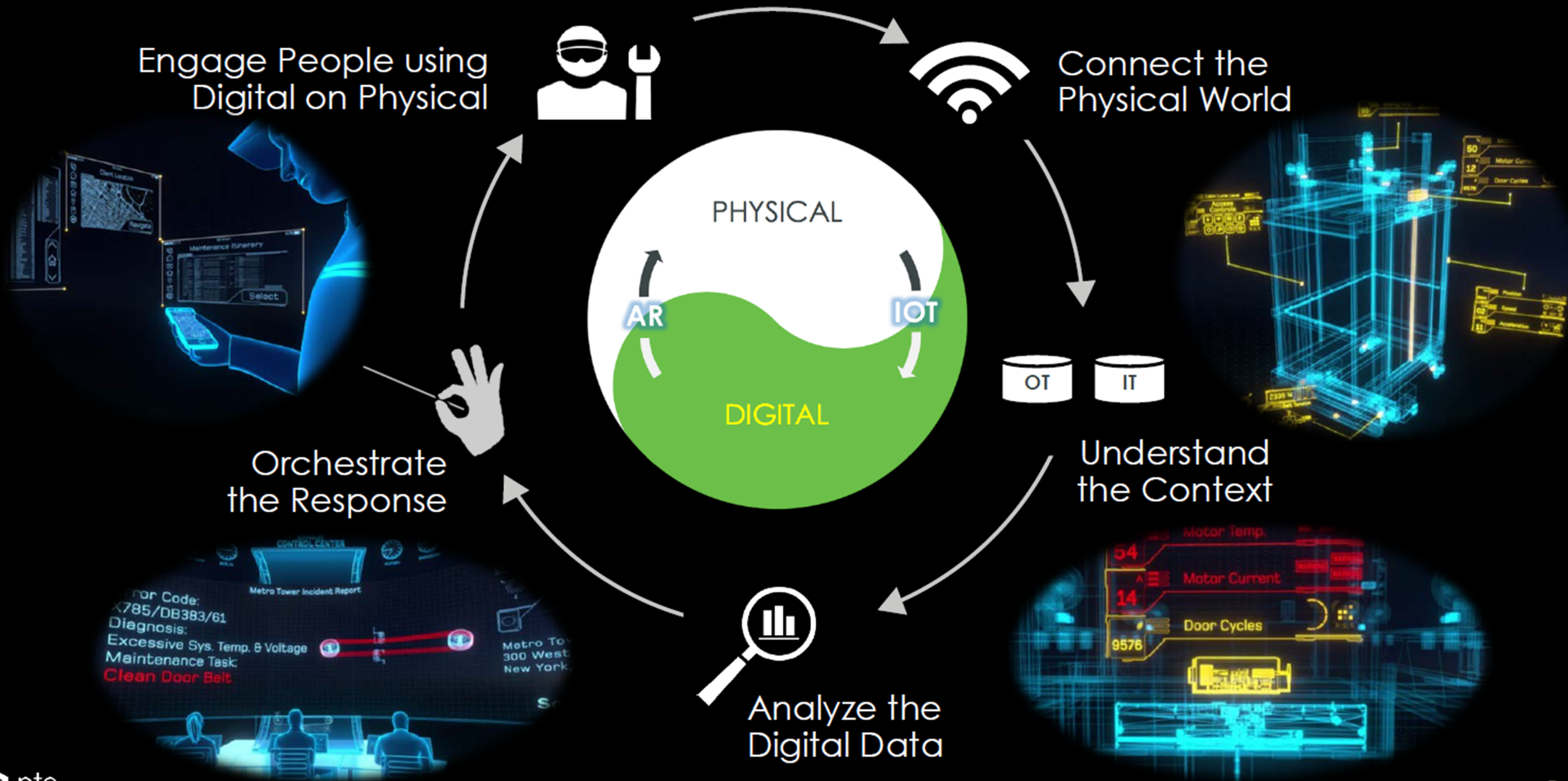


Problem: Readiness begins with Sailors and Marines who are deployable and well-trained. In the past, Navy and Marine Corps manpower policies, processes, and technologies have incrementally evolved to meet the demands of a force continuously engaged in conflict. Although these changes have resulted in many discrete improvements, the collective effect has not necessarily resulted in enterprise-level improvements resulting in increased personnel readiness. Given the rapid rate of change in the technological and warfighting domains alike, the DON's training must reflect greater agility and responsiveness to deliver warfighting effects when called upon. In addition, even when Sailors and Marines are successfully trained, the DON continues to experience non-combat related injuries, fatalities, and mishaps that undermine the DON's ability to execute mission-critical tasking.

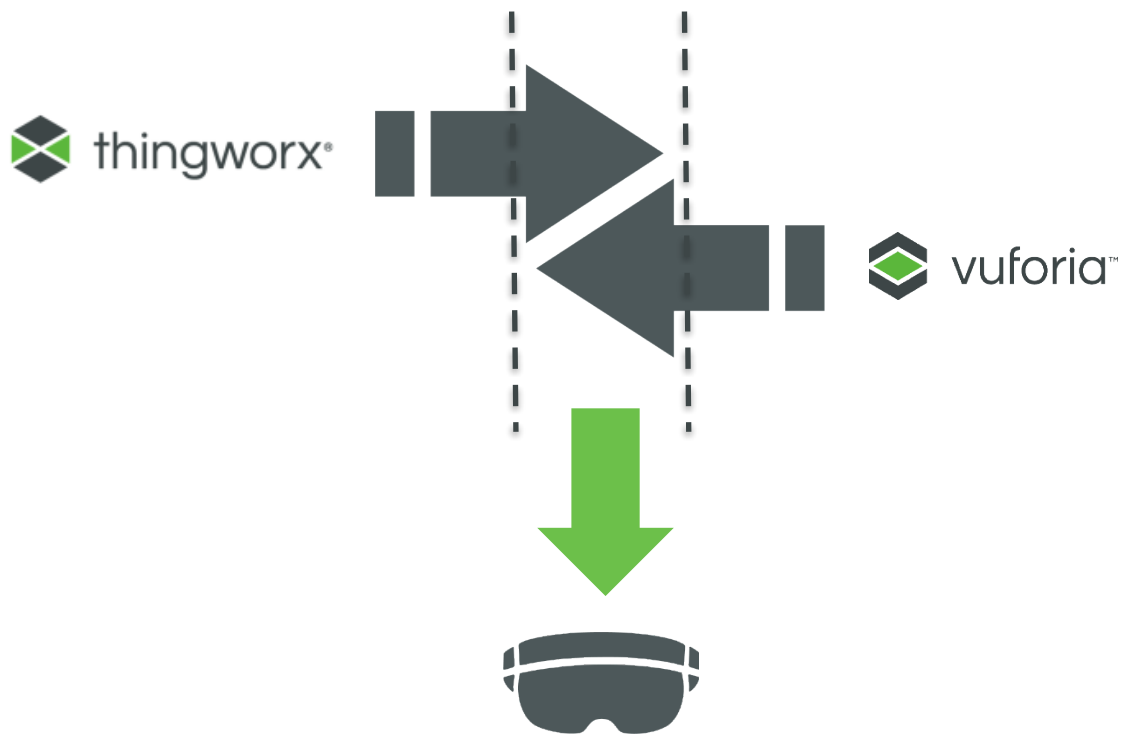
Solution: The DON will use the Navy's Ready-Relevant-Learning effort and the Marine Corps' Manpower Modernization Goals to fundamentally transform its training model and identify modern training solutions, delivered at the point of need, to better prepare Sailors and Marines to operate and maintain their equipment at its technological limits and meet rapidly evolving warfighting demands. The DON will also focus its safety education, tracking and oversight efforts on reducing both mishaps and non-combat fatalities, as well as improve its process for identifying and processing non-deployable personnel.

- Establish a learning and training continuum that will accelerate the performance of every Sailor, timed to optimize Fleet operational readiness

What is Industrial IoT and AR?



THINGWORX (IOT) & AUGMENTED REALITY



Industrial AR Experiences
w/Real-Time Asset & System Data

- ThingWorx and Vuforia come together to **deliver industrial AR experiences** that contain real-time, contextualized asset & system data.



Common IoT Use Cases



MANUFACTURING PLANT

GLOBAL FACILITY INSIGHT



CUSTOMER SITE



GLOBAL OPERATIONS

Monitor production flow in near-real time

Remotely Manage Equipment

Condition-based maintenance. Predictive maintenance

Identify and correct quality issues. Inventory Management

Transmits operational information to the partner (e.g. OEM) and to field service engineers

Provide cross-channel visibility into inventories.

THIRD-PARTY LOGISTICS

Manager



I can see my production line status and recommend adjustments to better manage operational cost.

R&D



I gain insight into usage patterns from multiple customers and track equipment performance.

Plant Floor



I know when to deploy the right resources for predictive maintenance.

CONTROLS ADVISOR

PRODUCTION ADVISOR

ASSET ADVISOR

OPERATOR ADVISOR

Maintenance Production Execution

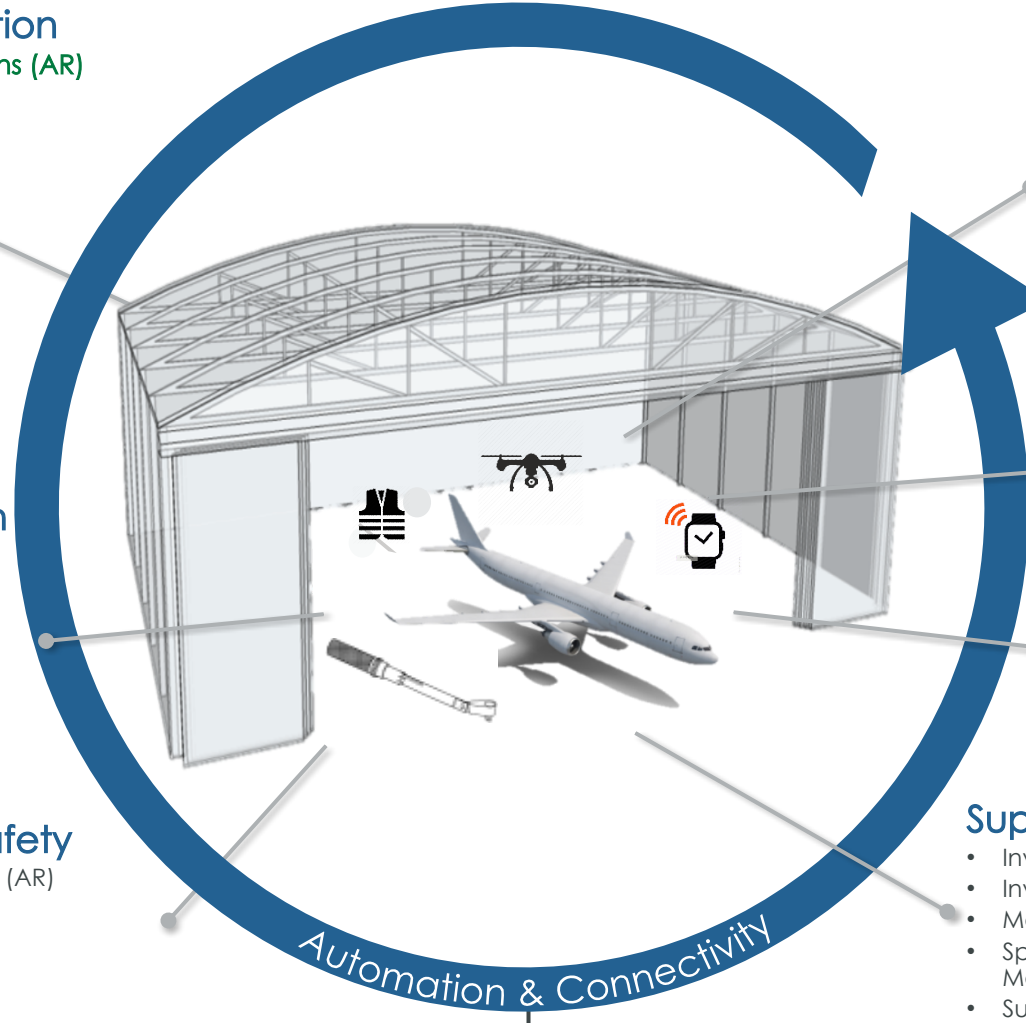
- Digital assembly & maintenance instructions (AR)
- Unified operator screen
- As maintained Digital Twin
- Labor tracking & shift management
- Digital interactive Illustrated Parts Catalog
- Interactive job Cards with Text to speech (AR)
- Tools tracking and monitoring
- Smart tools
- Real time production monitoring
- Augmented workspace management
- Paperless operations
- Remote expert guidance and assistance
- Knowledge management

Maintenance planning and optimization

- Maintenance and service workflow management
- Visualization, Dashboarding and sequencing of maintenance activities
- Maintenance performance KPIs and analysis
- Condition-based maintenance planning
- Service parts utilization planning
- Asset tracking
- Digital repair & service instructions (AR)

Environment, Health, & Safety

- Health, safety, & training procedures (AR)
- Automatic inspections (AR)
- Zone inspections (AR)
- Flexible & adaptable workforce
- Energy management



Asset health and performance monitoring

- Real time alert & fault identification
- Asset trending & troubleshooting
- Monitor operating conditions to alert of anomaly or risk
- Condition-based, Predictive & prescriptive analytics (multiple assets/fleet)
- Deferred defects tracking and monitoring
- Asset condition dashboard
- Advanced algorithms for failure prediction
- Airframe structural damage detection and analysis

Retrofit – Major/Minor Changes

- BOM transformation
- Digital process planning and workflow
- 3D work instruction Authoring (AR)

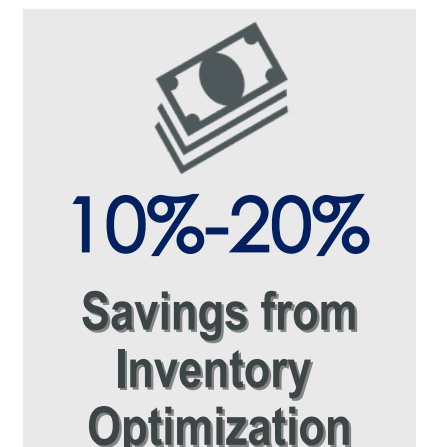
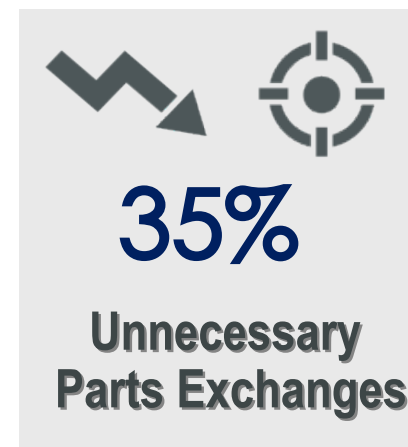
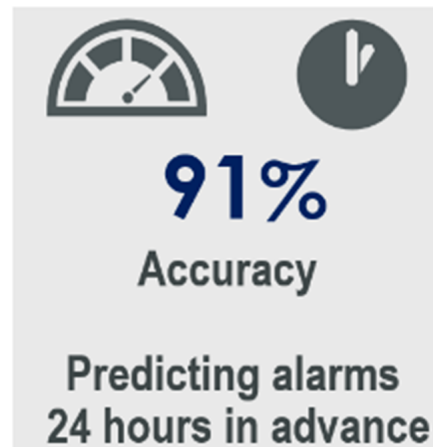
Quality & Test

- Real-time quality KPIs
- Zone quality inspections (AR)
- Robotic inspection monitoring
- Testing monitoring & calibration

Supply chain & Logistics

- Inventory management and tracking
- Inventory levels optimization, demand forecasting
- Materials handling, tracking and availability
- Spare Parts Management (SPM), Life Limited Parts Management (LLP), Parts Catalogs
- Supplier management and visibility

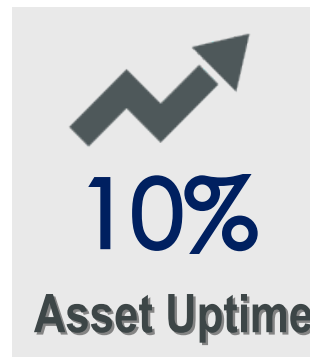
SMART CONNECTED OPERATIONS PREVENTATIVE AND PREDICTIVE MAINTENANCE



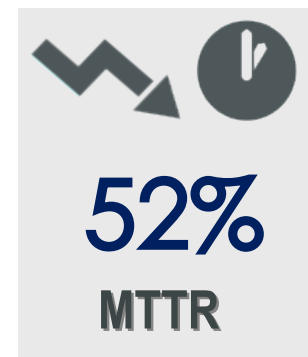
PBL KPIs:



First time fix rates



Systems Operational
availability (AO)



Mean Time to
Repair



More Effective
Maintenance
Training

AR UNLOCKS OPPORTUNITIES ACROSS THE VALUE CHAIN

Maintenance

- Remote service & customer self-service via AR & IOT decreases truck rolls
- Technician productivity, safety, and effectiveness increases via IOT & AR
- Breakthrough digital product experiences via IOT and AR

Sustainment

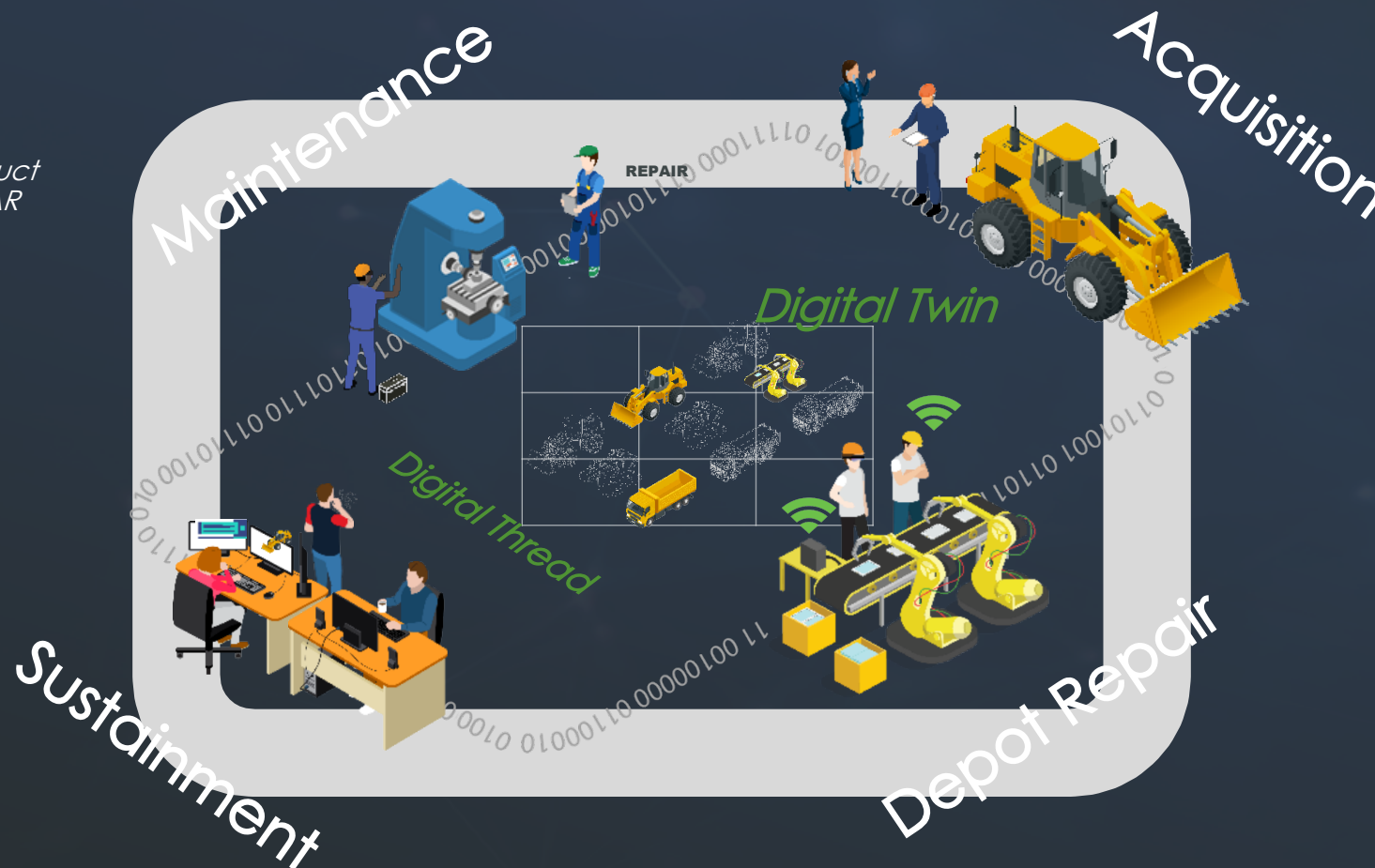
- Virtual team collaboration via AR and VR

Acquisition

- Configured products demonstrated with 3D holograms via PLM & AR
- Differentiated product/brand experiences via IOT & AR

Depot Repair

- Optimized production using digital process twins enabled by IOT/AI & AR
- Increased worker productivity, quality, and safety through IOT/AI & AR
- Less unplanned downtime via IOT/AI & AR



Vuforia Augmented Reality Software from PTC

This technology allows for the creation of secure, scalable AR experiences that leverage 3D content, the Internet of Things and Enterprise Systems data that can be merged to present a holistic representation of not only the physical asset, but layers of data and instruction not before available in a single view point. This software allows one employee to effectively instruct another from a remote location that combines powerful AR technology with real-time video to provide the ultimate solution for remote assistance.

Work Instructions - Technical Training - Technical Orders/Manuals - Remote Assistance

vuforia® engine

For Developers: Allows Apps to “see” and puts content onto the world through environments or objects



vuforia® studio™

For Enterprise Content Creators: Powerful AR content creation and publishing solution for industrial enterprises



vuforia® chalk™

For Remote Assistance: Allows you to “see what I see” and annotate in a shared workspace



vuforia® expert capture™

For front-line workers: Out of box solution that provides hands on training and guided step-by-step instructions

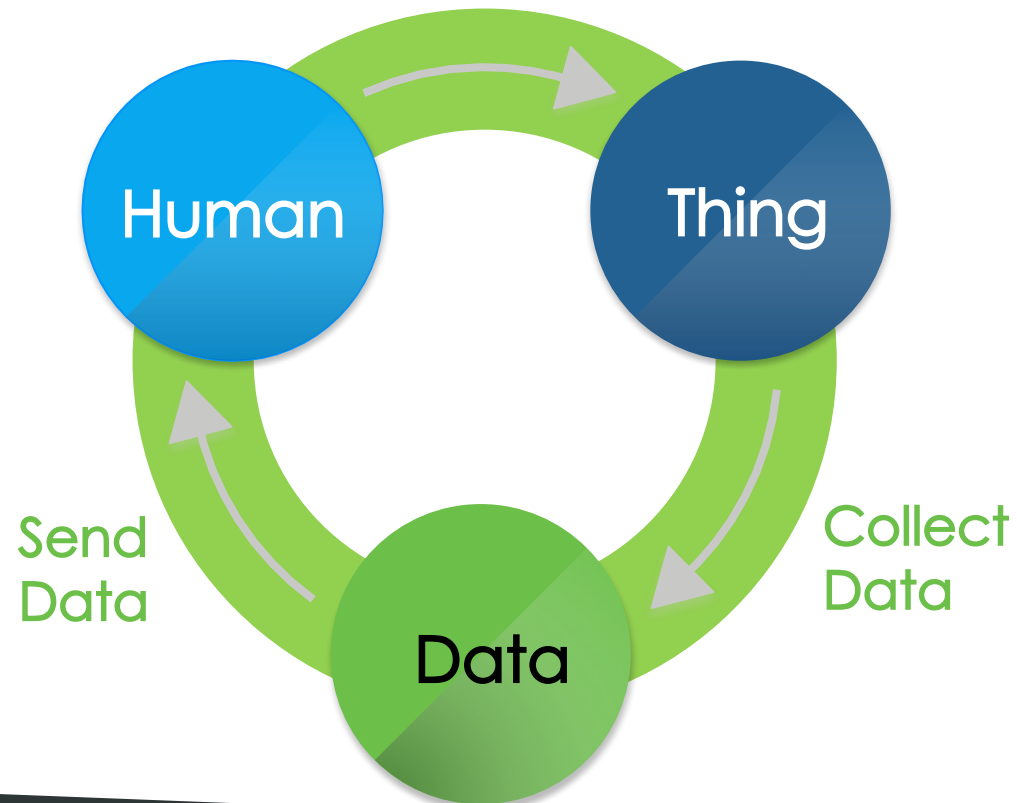


AUGMENTED REALITY COMPLEMENTS IOT

IoT : Ability to digitally talk & listen to physical things to monitor and control

AR : Ability to see & experience the digital attributes of physical things

Monitor & Control Things



Value of Augmented Reality

- **Visual delivery for 3D, machine, performance and business data**
 - Real time Interaction with the physical product or design
 - Increased comprehension and learning
- **Guided, step-by-step instructions**
 - Increased maintenance accuracy
 - Improved Troubleshooting
- **Real-time process and quality validation for error proof execution**
 - View Augmented work instructions
 - X-ray vision for the technician
- **Walk the plant augmented reality experience**
 - Improved oversight of system and human performance
 - Virtual Equipment Inspections



vuforia™

MIXED/AUGMENTED REALITY (AR/MR) STATE OF THE ART FOR INSTRUCTION

– ADVANCING THE



- Augmented Reality experiences rapidly train your workforce on complex tasks, improve productivity, oversight and operations management, and maintenance accuracy.
- Augmented Reality allows the maintainer to experience the digital information and digital representation of the aircraft or equipment in the context of a physical product using digital twins, 3D overlays, augmented work instructions with IoT data in a safe environment with full scale or miniature representations in any location or environment.



AR PROVIDES KEY CAPABILITIES FOR IMPROVEMENT



Augmented 3D Work Instructions >

- Immersive step-by-step instructions boosts worker efficiency, accuracy and safety



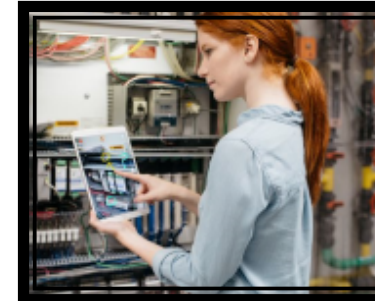
Augmented Expert Guidance >

- Fast and easy knowledge capture and sharing improves productivity, quality and compliance



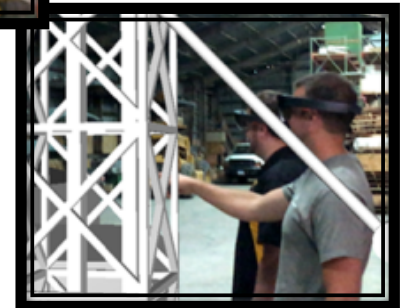
Augmented Remote Assistance >

- Real-time access to SMEs improves communication and speeds problem solving



Augmented Training and Demonstration >

- Virtual product demonstration and in-context instructions reduce training time and costs



BENEFITS

- Improve retention, understanding of tasks
- Reduce errors and improve quality
- Empower technicians with step-by-step work instructions
- Enhance operator efficiency – work faster
- Rapid problem detection/resolution – with remote assistance

SUCCESS STORIES

- 25% faster wiring harness install (Boeing)
- 47% faster training instruction comprehension (SRI)
- 34% faster wiring a turbine control box (GE)
- 20-30% Increase in training rates (BAE)
- 32% more productive workforce (Industry Report on AR)
- 30% Higher quality output (Industry Report on AR)
- 40% Higher on the Job Training retention (Industry Report on AR)

**NORTHROP
GRUMMAN**



U.S. AIR FORCE

BAE SYSTEMS

VOLVO
VOLVO GROUP

WORK INSTRUCTIONS - BAE

BAE SYSTEMS



50%

IMPROVEMENT
IN ASSEMBLY

30%

IMPROVEMENT IN
TRAINING

Challenge:

- Instructions captured on paper or PDF on glass
- New shift workers were slower
- Needed to accelerate assembly process

Solution:

- BAE used Vuforia Studio to cost-effectively create immersive Mixed Reality Experiences

Outcomes:

- BAE reduced training time and increased production throughput for new front-line workers - while maintaining zero-defect quality standards.



VOLVO ENGINE QUALITY INSPECTION

"We're using ThingWorx and PTC's AR solutions in order to route our data from the physical world to the decision-making in the digital world and back"

- Training reduction from 5 weeks to less than 2 weeks
- Documentation changes reduced from more than a day to instant publishing
- Increased competitiveness, employee recruitment attractiveness
- Further advancing to a 0 parts per million quality goal
- Anticipated savings in thousands of Euro per quality workstation per year across their 20 factories.



WAREHOUSE OPERATIONS

DHL is using AR to track pick lists and guide workers through the warehouse to the location of each product to be packed.

Value Metrics

- Reduced errors
- More engaged workers
- Productivity improved by 25%



SERVICE

Caterpillar is now moving into the next layer of technology in the service domain which includes the Industrial Internet of Things (IIoT) along with augmented and virtual reality.

IIoT and AR Strategy

“We have entire mine sites connected and interacting to make split-second decisions. Now we want to connect people and products.”

Terri Lewis,
Digital and Technology Director
Caterpillar



HUMAN RESOURCES TRAINING

Kiewit is using an AR welding system for recruiting and training of new employees.

Value Metrics

- Reduce overall training time
- Reduce training material cost
- Improved safety

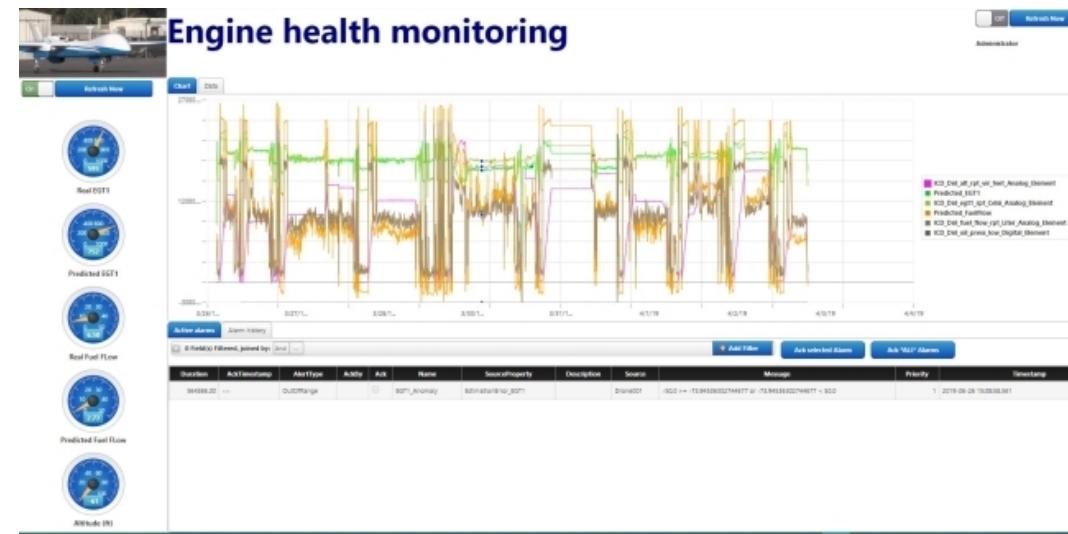


Kiewit



AR AND IOT DEMONSTRATIONS

Todd Stecker
Senior IoT Engineering, PTC





Connecting and Securing Decision Support Tools: Case Study in Leveraging PTC ThingWorx and ThingWorx Analytics

Presented by Jon Mitchell, ILW CEO/CTO



The views expressed in this presentation are those of the author and do not necessarily reflect the official policy or position of the Air Force, the Department of Defense, or the U.S. Government.



- **Why is Cyber Resiliency Important?**
- **Case Study: Analysis for Cyber Hygiene**
- **Decision Support Capabilities for Cyber Hygiene**
- **Case Study: Linking Decision Support Tools**
- **Evolution of Analysis and Prediction**
- **Thinking Differently About Cyber Resiliency**



Why is Cyber Resiliency Important?





CASE STUDY



Analysis for Cyber Hygiene

Identifying cyber hygiene events that may affect Air Force weapon systems by leveraging maintenance data and ThingWorx/ThingWorx Analytics



REMIS F16MLV On-Equipment & Off-Equipment Mx Records

CHALLENGE: Maintenance actions are required on the MLV and associated removable hard drives (RHD); very few geolocs are entering virus software updates and scanning information into IMDS (sent to REMIS)

SOLUTION: Dashboard to detail geolocs and whether maintenance action information exists for a given MLV



- **PROBLEM:** Identifying additional sources of data through analysis and human factors research that will help the Air Force construct a 360 view of cyber hygiene
- **ANALYSIS IDENTIFIED:**
 - Serial numbers not flowing from IMDS to REMIS
 - TAS/TCMax as additional source
 - Additional end items subject to virus scanning





Decision Support Capabilities for Cyber Hygiene

- TCTO/TO compliance
- Currency of virus definitions
- Bad actors
- Identified events
- MLV asset lifecycle





Decision Support Dashboard Demonstration

DEMO

[ThingWorx Cyber Hygiene Insights Dashboard](#)

CASE STUDY



Linking Decision Support Tools

Performing information fusion across disparate platforms leveraging the ThingWorx IoT platform



Data Linkage for TAS/TCMax/REMIS

CHALLENGE:

Maintainers are required to run RHD virus scans every 30 days and enter the scan and definition information into TAS/TCMax

SOLUTION: Dashboard to merge simulated data from TAS/TCMax and scrubbed data from REMIS to fuse the data sets into a much more detailed picture of cyber hygiene compliance



Linking Decision Support Tools Demonstration

DEMO

[ThingWorx Linking Decision Support Tools](#)



Evolution of Analysis & Linking...Prediction

- **Analytics maturation**
- **Cyber attack surface analysis**
- **Forensics**
- **Enterprise scan repository**
- **Prediction based on trends, indicators, external events**

CYBER RESILIENCE



Time to Think
Differently

- Identify and secure the cyber attack surface
- Treat every attack surface as a network that needs to be secured
- Capture every event for every surface
- Enter cyber IoT