



# U.S. ARMY COMBAT CAPABILITIES DEVELOPMENT COMMAND – ARMAMENTS CENTER

## The AI Disruption: The Challenges for Specialty Engineering Posed by Artificial Intelligence

Jason Cook, SSTM, SE Research

Benjamin Werner, Technical Lead, Quality Engineering and Systems Assurance

Mustafa Rawat, Logistics Project Officer, Logistics Research Engineering Directorate



# Jason Cook

# The Motivation

Systems Engineer

- Integrated
- Trusted
- Augmented
- Collaborative
- Learning

Soldier

The Engineer and Warfighter must arrive in this future together, before our adversaries

# The Problems

- How are systems verified and trusted when they have emergent properties?
- What is Configuration Management for an AI enabled system and fleet?
- How do we capture operational usage data to best inform system learning?
- How do we verify and validate the accuracy of a digital twin over time?
- How is the operational benefit of intelligent agents and autonomous systems quantified?
- What is the ideal strategy for implementation of learning that balances needs and constraints?

# Some of the Problems


Integrated

Trusted

Augmented

Collaborative

Learning

- How are requirements still SMART if they are intended to encourage emergent vs. deterministic requirements?
- How is a AI enabled system modeled and depicted without replicating the full AI logic?
- How is AI enabled design trusted and verified?
- What is the balance between niche tool sets and standardization?
- How is access and curation of big data sources accomplished with cyber security still enabled?
- What are the skills required of the future SE's?

# Benjamin Werner

# HIGHLIGHTED CHALLENGES

- **Recent Reports, Commissions, Strategic Guidance and Directives all highlight the need for trusted and assured AI for the Department of Defense**

| NSCAI REPORT (2021) | DIB REPORT (2019) | DOD AI STRATEGY (2018) |
|---|---|---|
| *Human-AI Interaction & Teaming* | *Define Reliability Benchmarks* | *Decentralized Development and Experimentation* |
| *Testing & Evaluation / Verification & Validation* | *Strengthen AI Test and Evaluation Techniques* | *Engaging with Commercial, Academic, and International* |
| *Robust & Reliable AI* | *Develop Risk Management Methodology* | *Leading in Ethics and Safety - invest in the research and development of AI systems that are resilient, robust, reliable, and secure* |
| *Accountability and Governance* | | |

- **NSCAI: National Security Commission on Artificial Intelligence**
- **DIB: Defense Innovation Board**

# AI CHALLENGES & APPROACH SUMMARY

- **AI Presents Unique Challenges and Disruptions**
  - Shift from traditional software applications
  - Uncertainty in continuous learning, complex logic, & configuration management
  - Novel methods needed for analysis and certification of AI training data sets
  - Critical assessments required of essential enabling sensors/systems
  - Unknown user buy-in, trust, and confidence of full system capabilities
  - New methods for T&E/V&V to ensure AI is reliable, ethical, safe, and robust
  - Impacts development methodologies and Materiel Release (MR) process
- **Assurance and Trust Critical to Ensure Successful Fielding**
  - A robust process to qualify AI enabled armaments systems is necessary
  - Collaborate with stakeholders regarding components of MR impacted by AI
  - Develop framework and roadmap to achieve assured AI
  - Achieve user trust in AI systems

# DESIGN FOR ASSURANCE CONSIDERATIONS

- **Assurance must be built in from early lifecycle**
- **How do we design for assurance?**
  - Consider the training data early for applications
  - What are the safety implications?
  - Are there risks to Soldiers? Equipment? Civilians?
    - How are these mitigated?
    - Have off nominal conditions been considered?
  - How will the system be sustained?
  - What are the requirements of host system?
  - Is the system suitable for the intended operations?
    - Will the system perform as intended under expected conditions?
    - Reliable, robust, resilient?
- **Integration early on can develop the framework for artifacts to mitigate risk & ensure a successful path to transition and fielding**

https://www.hurix.com/differences-between-quality-assurance-and-quality-control/

# PATH TO ASSURED AI

**Policy**
- Review of existing policy
- Identify gaps to better form requirements

**Data Science**
- Acknowledge criticality of data to AI
- Identify way and means to evaluate data sets for risk and readiness for AI application

**Verification and Validation**
- Develop framework for V&V of AI
- Establish procedures and measures for AI performance and reliability

**Safety**
- Identify unique hazards presented by AI
- Define appropriate design criteria and mitigations to ensure safety

**Materiel Release**
- Review current requirements
- Adapt and develop necessary deliverables to ensure safe/suitable/supportable

**Trust**
- Deliver product that the warfighter has trust in to deliver desired capability
- Deliver product that the evaluation community trusts to deliver desired capability


**Assured AI**: Product can be released and fielded with confidence that is it robust and resilient after rigorous application of best practices and risk mitigation

# AI ETHICAL PRINCIPLES

**The five AI ethical principles, based on recommendations from the Defense Innovation Board, are:**

1. **Responsible**: DOD personnel will exercise appropriate levels of judgment and care while remaining responsible for the development, deployment and use of AI capabilities.
2. **Equitable**: The department will take deliberate steps to minimize unintended bias in AI capabilities.
3. **Traceable**: The department's AI capabilities will be developed and deployed such that relevant personnel possess an appropriate understanding of the technology, development processes and operational methods applicable to AI capabilities, including with transparent and auditable methodologies, data sources and design procedures and documentation.
4. **Reliable**: The department's AI capabilities will have explicit, well-defined uses, and the safety, security and effectiveness of such capabilities will be subject to testing and assurance within those defined uses across their entire life cycles.
5. **Governable**: The department will design and engineer AI capabilities to fulfill their intended functions while possessing the ability to detect and avoid unintended consequences, and the ability to disengage or deactivate deployed systems that demonstrate unintended behavior.

Ethical Principles will be achieved through Engineering



# Mustafa Rawat

# AI IMPACT TO MAINTENANCE AND SUPPORTABILITY

## Evolution of Maintenance and Maintenance Concept Development

Corrective Maintenance -> Preventative Maintenance -> Condition Based Maintenance -> Predictive Maintenance

## Impact on Maintenance Concept Development

- Optimize concepts during development – making sure systems can be maintained and supported

## PPMx (Prognostic and Predictive Maintenance, Ammo, Spares)

- Army program to bring maintenance process into the 21st century
- Challenges focused on how to best implement based upon policies/tools/techniques developed over the years

## Why is it PPMx important?

- Higher Availability at a reduced cost
- Maintenance when you "can" do it instead of when you "have" to do it: fewer work hours, improved forecasting, better planning

## AI implications go far beyond maintenance of armament systems

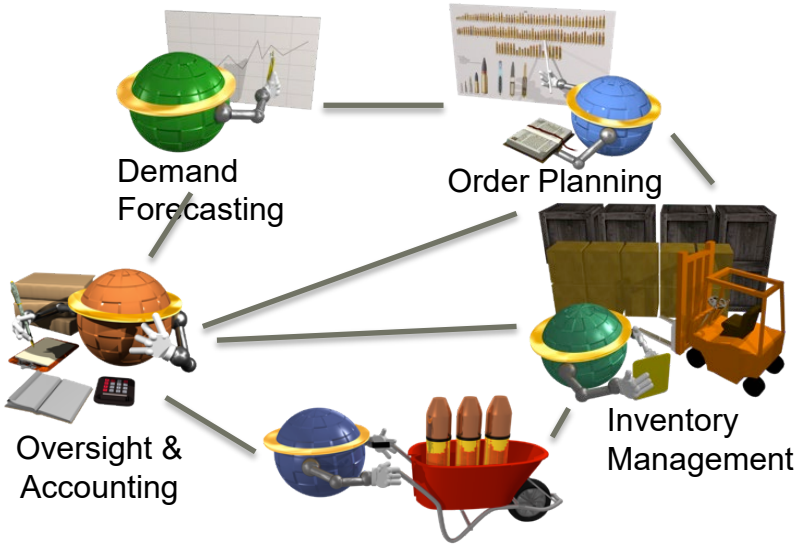
- Sustainment
- Readiness
- Operational

# FUNCTIONAL 'ELEMENTS' (AGENTS) WORK TOGETHER LIKE A TEAM…

Basketball Players and Their Roles


- Each player has same basic skills
- Each player has specialized skills
- Each player has a position & role
- They operate together executing plays
- They communicate explicitly & implicitly
- Each maintains situational awareness
- The coach oversees and directs as necessary

Theater Ammo Application
Agents Teams Solve Problems
[*we call them a Society of Agents*]




**GOAL:** Minimize inventory while ensuring customer demand met

| Data | Information | Knowledge |
|---|---|---|
| Consumption update (e.g. SAAS transactions) | Update future projections for demand | Demand projections updates propagate through the system to update recommendations to users for requirements and inventory levels to sustain theater operations |

# CLASS V ADAPTIVE DEMAND ESTIMATION SYSTEM (CADES) OVERVIEW

**What CADES is:** A Sense and Response/ Adaptive Planning human-collaborative decision support capability for Class V that demonstrates the application of intelligent agent technologies to enable adaptive demand estimation and optimize stockpile management.

To achieve the next generation ammunition system vision CADES incorporates the following elements

- Adaptive Demand Estimation and Planning Factors
- Time-Phased Situationally-Aware Demand Prediction
- Dynamic Stockage Objectives (SO)
- Continuous Inventory Monitoring and Recommendations
- Deep Analytical Support and for Data-Driven Decision Making
- Integrated Context-Aware Optimization

**What CADES is <u>NOT</u>:** A business system to execute transactions to manage the supply and distribution of ammunition.

## Benefits

- Reduces user cognitive load through autonomy
- Continuously optimizes supply chain operations
- Transformation of Data -> Information -> Knowledge
- Plan-based logistics planning and operations
- Knowledge-based decision making in context
- Continuous monitoring and reasoning in execution

CADES demonstrates how the future ammo enterprise could benefit from the insertion of smart decision aids based on a intelligent agent framework and advanced reasoning techniques.

# CADES FUNCTIONALITY

## External Systems

- Production Status
- Depot Stock Levels
- Allocations

- Daily Asset Status
- Daily Transactions

- Force Structure
- Unit Expenditures

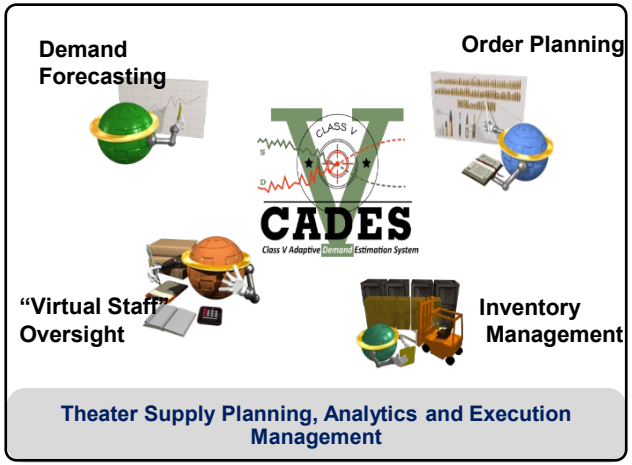
- S/I List
- Do Not Return List

OTHER
- Vessel Manifests
- LOGSTAT Reports

**Stockage Objective Planning**

Calculates projected theater on-hand and forecasted demand.
Recommends SO adjustments based on trend analysis
Ingests expenditure, force structure, weapon densities data from external data sources

Published plans help establish yearly requirements needed for sustaining theaters




**SO Planning:**
Delays in vessel helps with inventory impact analysis

**Vessel Planning:**
A published plan becomes the requirements which automatically calculates the quantities on the inbound vessel

**Allocation Planning**

Recommends DODIC quantity necessary to sustain current ops for upcoming FY
Accounts for a buffer stock
Factors in projected consumption on current inventory

Allocation:
Delays in vessel helps with inventory impact analysis

Vessel Planning:
Published allocations define the upper limit of the DODIC that can be ordered in vessel planning.
Provides notifications if future demand needs exceed this quantity

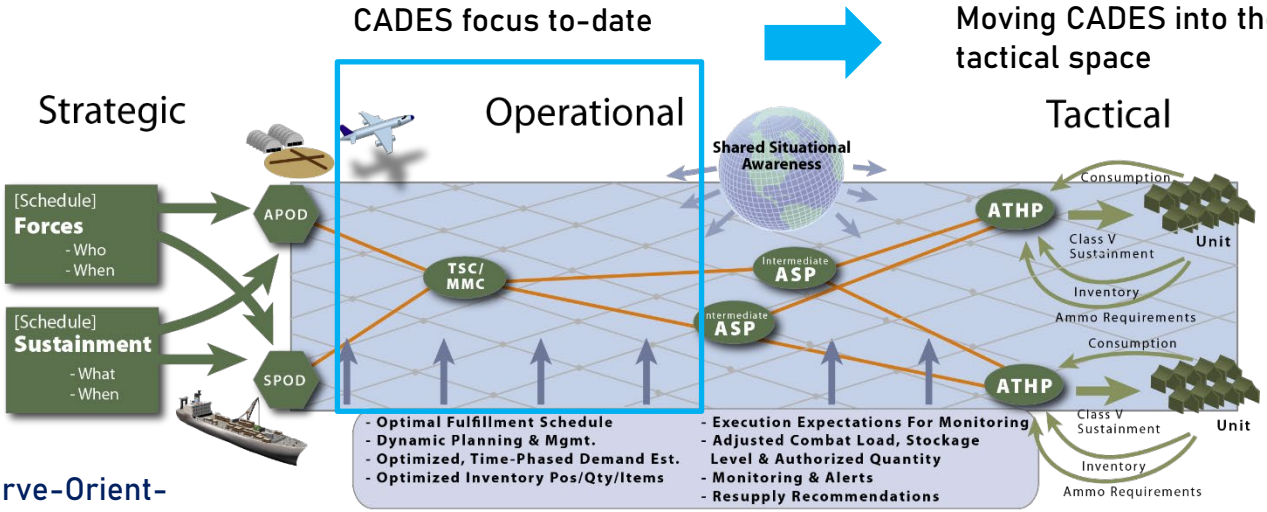
**Vessel Planning for Supply and Retrograde**

Uses historical data and demand prediction models to estimate the vessel call forward quantities Provides smart recommendations based on
- S/I lists
- Stocks across accounts and Condition Codes
- Depot stock levels
- Multi-vessel/Multi-location planning. Delays and/or adjustments on planned vessel automatically adjust quantities on future vessels

Recommends a DODIC retrograde plan based on quantities on-hand, due-ins and forecasted demand
Takes into account the Do Not Retrograde (DNR) list

- Every module implements a "plan"
- A plan can be private, shared, and published, allowing for multi-user collaboration and knowledge share across CADES
- CADES continuously revises recommendations based on data updates to improve accuracy
- Cuts down multi-week planning tasks to a few hours
- Common knowledge sharing across all stakeholders
- Automation of task functions to "virtual" staff agents thereby reducing cognitive workload

# NEXT STEPS




Three Level Observe-Orient-Decide-Act (OODA) Loop

An **"Network Node"** is server class node that provides Network services; shared situational knowledge, reasoning

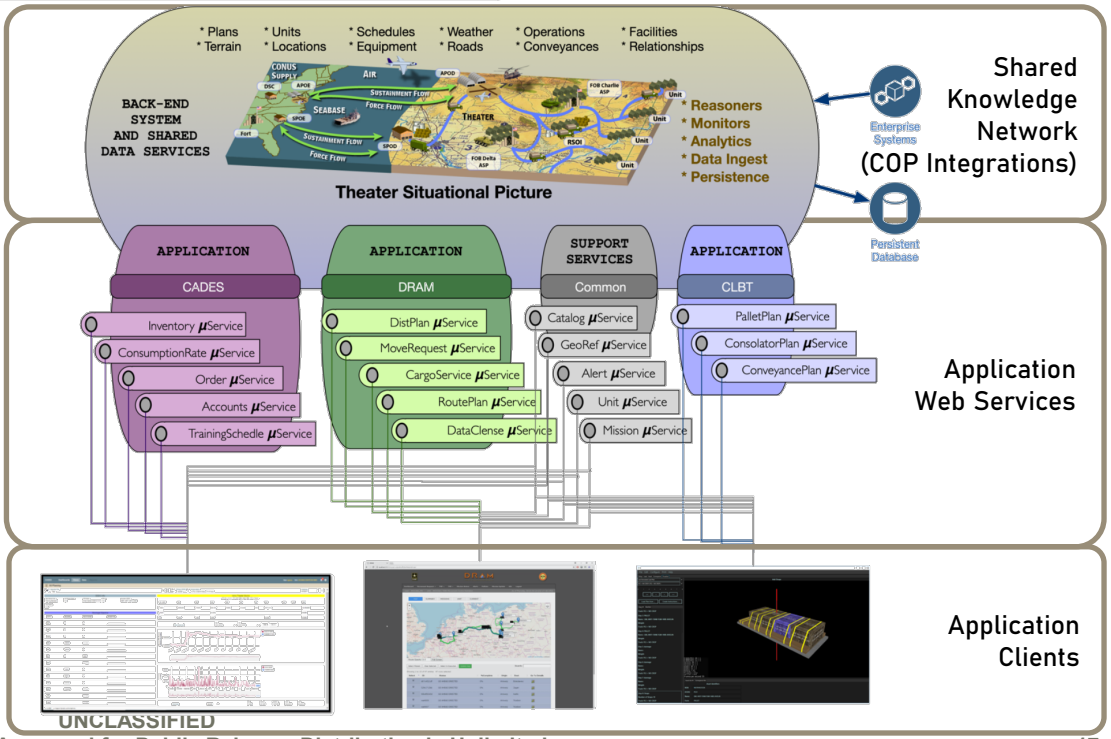
Execution and coordination of a replenishment mission

An **"Node"** is a container holding one or more agents, and provides essential services to the agents in its container

Planning a replenishment mission

An **"Agent"** is a container for behaviors, capabilities and domain specific knowledge – expert at performing one specific task

Replenishment order



# OPERATIONAL SUPPORT

**CADES** provides integration decision support for munitions materiel management in theater and is undergoing an extended user evaluation in 2 theaters

- CADES has automated the Stockage Objective (SO) Planning process. What used to be a multi-week preparation process is now reduced to a 2-3 days. Requirements entered by Units in CADES are used to calculate the theater SO
- CADES is being used to the automate the Vessel Call Forward process based on requirements and predicted demand. CADES recommends shipment quantities and can assess impacts due to delays. Impact analysis is available to decision maker in near real time
- Users depend on CADES dashboards for ammunition inventory levels (by accounts, condition codes), lot restriction management and demand reconciliation as part of their daily operations

Distribution & Retrograde APEX Management (DRAM) as a theater movement control software capability, provides integrated, distributed, collaborative planning and execution management support for distribution and retrograde in order to:

- Support multiple unit deployments including ABCT rotations, CAB deployments, as well as supporting exercise movements
- Optimize and streamline the complexity of deployment planning specifically during receipt, staging, and onward movement (RSOM) reducing planning time by up to 50%
- Automatically build detailed movement plans by mode of transport
- Provide high level dashboards for tracking the execution of theater transportation
- Specifically track closure of high visibility items such as combat power and pacing items
- Provide alerts in the case of designated plan violations and deviations
- Export plan and location data to designated external stakeholder and allied partner systems
- Simulate the transportation required to support the deployment of planned operations to provide Command updates or multiple theoretical BCTs for wargaming