U.S. ARMY

DEVCOM ARMAMENTS CENTER

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

**DEVCOM AC ARTIFICIAL INTELLIGENCE (AI) AND SYSTEMS ENGINEERING (SE) PERSPECTIVES**

**17 SEPTEMBER 2024**

# DEVCOM ARMAMENTS CENTER


## MISSION

Lead innovative research and lifecycle engineering of armaments solutions.

## VISION

To be the most trusted and responsive provider of pioneering armaments solutions for decisive victory.

**Forging the Future of Armaments**

# ARMAMENTS CENTER CORE COMPETENCIES

## Weapon Systems & Technologies

- Integrated Weapon Systems
- Gun Mounts & Recoil Mitigation
- Non-Lethal, Directed Energy Weapons & Target Effects
- Remote & Automated Weapon Systems
- Ammo autoloaders and magazines
- Large Caliber Cannon Design, Prototyping & Certification
- Weapons Manufacturing Technology

## Logistics

- Class V Ammunition Packaging, Handling, Storage, Planning Distribution, & Transportation
- Logistic Engineering & New Equipment Training

## Fire Control Systems

- Embedded/Real-Time Software
- Fire / Weapon Control Hardware & Integration
- Ballistic Data & Products
- Prognostic / Diagnostics
- Automated Test Sets
- Networked Lethality
- Weapon System Assurance
- Emergency Management & Anti-Terrorism Systems
- Embedded Training for Ground Combat & Soldier Platforms

## Munition Systems & Technologies

- Gun Launched Munition Systems
- Non-Lethal and Scalable Munitions
- Grenades, Demolitions, Signal Flares
- Countermeasure Flares / Decoys
- Guidance, Navigation, and Control
- Interior, Terminal & Aeroballistics
- Fuzing & Munition Power Systems
- Telemetry
- Munition Producibility & Manufacturing Sciences
- Explosive Ordnance Devices
- Maneuver Support Munitions
- Reactive Armor

## Enterprise Engineering & Business

- Systems Engineering & Analysis
- Quality & System Reliability Engineering
- Modeling & Simulation of Armaments
- Product and Technical Data Management
- Acquisition Support, Business Process Management
- Industrial Base Analysis/Obsolescence Management

## Energetics, Warheads & Materials

- Propellants & Propulsion Systems
- Explosives
- Pyrotechnics
- Warheads / Lethal Mechanisms
- Demil & Environmental
- Integrated Explosive Detection Systems
- Munition Production Engineering
- Stockpile Reliability

Armaments Life-Cycle Engineering: Research, Development, Production, Field Support & Demilitarization

# FUTURE ARMAMENTS TECHNOLOGIES OF INTEREST (SOME EXAMPLES…)

**WEAPON SYSTEMS**

- Attritable armament systems
- Optionally autonomous weapon systems
- Counter-UAS / swarm defense
- Remote, robotic & optionally manned systems Human Machine Integrated Formation (HMI-F)
- Signature reduction
- Non-Volume suppressive effects
- Adaptive terrain shaping systems

**MUNITIONS**

- Collaborative seeking munitions / submunitions
- Adaptive Countermeasures
- Agile warhead concepts
- Munition-delivered sensors / non-kinetic effects
- Multi-Domain Operations (MDO) / Multi-mode submunitions
- Dynamic re-targeting
- Assured Positioning, Navigation and Timing (PNT) for GPS denied environments
- Munition concepts for surge capacity

**FIRE CONTROL**

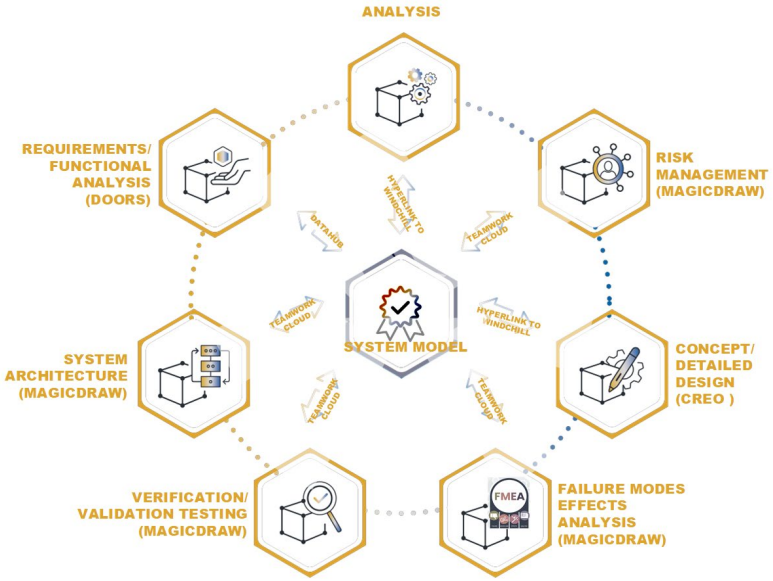
- AI-enabled / collaborative fire control
- Supervised autonomy
- Advanced ballistic algorithms
- Photonics solutions for fire control
- Soldier aim augmentation
- Tactical data collection and processing

**ENABLING**

- Tunable Effects
- Contested logistics & resupply
- Alternative materials / sources / manufacturing methods
- Advanced materials / point of need manufacturing
- Modular Open Systems Approach (MOSA), digital engineering & predictive analytics
- Design for demilitarization / reduced lifecycle environmental impact

# AC SYSTEMS ENGINEERING FOCUS

- Acknowledgement of the Challenge
  - How do we leverage AI-enabled capabilities to improve SE execution? (AI4SE)
  - How do we execute SE activities on AI-enabled systems? (SE4AI)
- Better Definition and Management of the “System”
  - System Model Advancements & Ontology
- Data-driven Decisions (technical and operations)
  - Statistical and Analytical Approach
  - Reinforcement Learning & Machine Learning
  - Automation
- Development of Major Strategies
  - Digital Engineering (DE)
  - Artificial Intelligence (AI)
  - Data

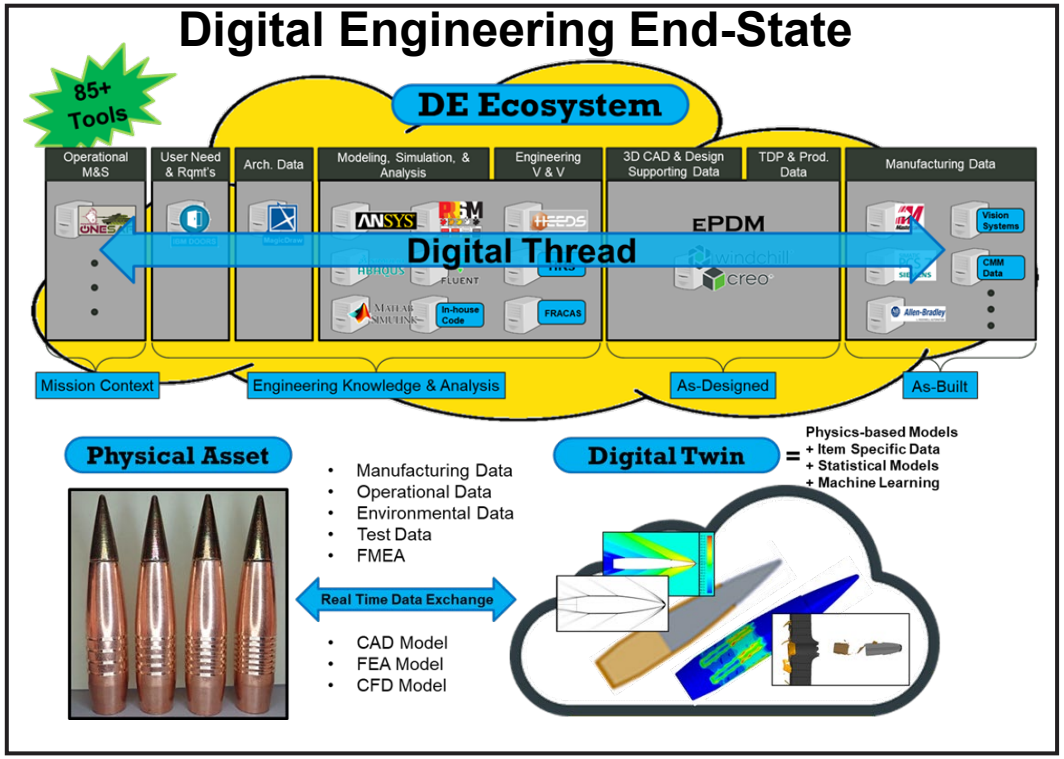



**AC is committed to evolving with AI-enabled capabilities to improve Systems Engineering Execution**
**Achieving Army Future Command’s Goal: “…faster innovation, experimentation and demonstration”**

# DEVCOM AC DIGITAL ENGINEERING (DE) STRATEGY

**Purpose:** Transform the culture and workforce to adopt digital engineering across the lifecycle by using models to inform the enterprise and provide the authoritative source of truth.

- **LOE 1: Build the Digital Foundation:**
  - *Continue transformation from documents to models & digital data.*
- **LOE 2: Establish the Data Architecture:**
  - *Build the data infrastructure & development of Armaments ontology*
- **LOE 3: Deploy Digital Engineering Ecosystem (DEE):**
  - *Deployment of an ecosystem to realize Digital Twin/Thread*
  - *Enabling catalyst for use of AI to support the synthesis of data across the enterprise*
- **LOE 4: Grow Workforce Digital Literacy and Adoption:**
  - *Workforce development will be key to success of digital transformation.*




**The SERC is a key partner to help realize our DE Infrastructure**

# DEVCOM AC ARTIFICIAL INTELLIGENCE (AI) STRATEGY

**Purpose:** Transform DEVCOM AC into a data-centric organization that can operationalize Artificial Intelligence

- **LOE 1: AI-Enabled Armament Systems**
- **LOE 2: AI-Enabled Competencies & Operations:**
  - *Establish requisite competencies, tools, ecosystem platform and processes*
  - *Implementation of data strategy requirements*
- **LOE 3: Capabilities & Workforce Development:**
  - *Recruit and develop workforce with required skills*
- **LOE 4: Strategic Partnership:**
  - *Establish and maintain collaborative partnership with Government, Industry, and Academia*


*NSCAI Final Report (2021)* *RAI Memorandum (2021)* *RAI Strategy & Implementation (2022)* *DoDD 3000.09 (2023)*



# Holistic Effects Modeling Environment (HEME) Tool

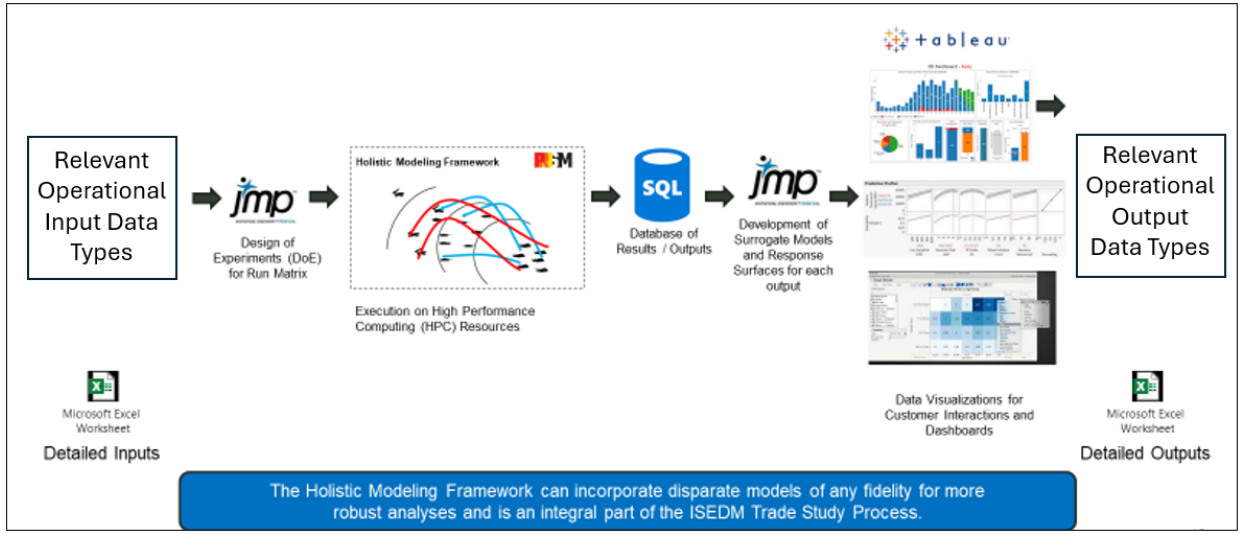
## Summary


- HEME is a holistic, probabilistic analytical tool with a modular framework developed to explore trade spaces within Army system portfolios

- HEME combines a modular, adaptable framework with modern data science approaches to result in a robust and fast tool for system engineering applications.
  - Built on the **PRISM Framework**, an in-house framework of **high-fidelity physics-based models** and an engine to drive them. PRISM is composed of high-fidelity models both internal and external to Systems Analysis Division
  - Utilizes **Design-of-Experiments and Machine Learning** approaches to produce highly effective **assessments of system performance**

- HEME enables rapid exploration of system trade spaces to help **inform system requirements, down-select alternatives, and inform evolving decision maker needs**


## Adaptable Modelling Framework




## Design of Experiments Approach

- HEME utilizes **Design of Experiments** to efficiently sample **broad design spaces** for System Engineering.

- Efficient sampling practices such as the **Latin Hypercube** approach enables analysis of **2-5x more variables** than traditional analyses, with greatly reduced runtimes.

- DOE approaches are also highly supportive of **surrogate modeling and sensitivity analysis**

- Through Machine Learning approaches, HEME helps determine **what factors drive system performance**

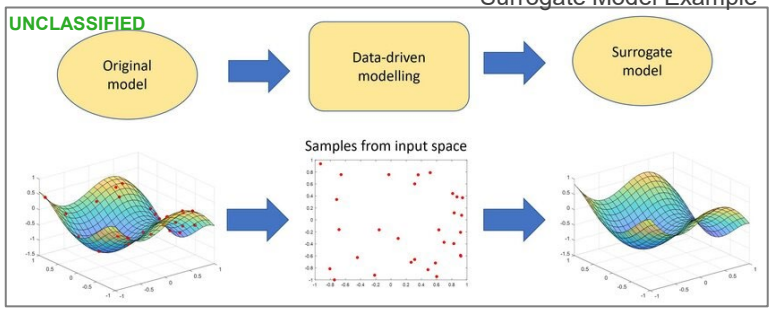
## Surrogate Modeling

- Results from HEME are used to generate **surrogate models** of the data within measured confidence. Historically we have used both **general regression models**, and **neural networks** depending on the complexity of the data.

- In addition to **sensitivity analysis** and **variance measurement**, strong predictive models can be used to supplement ongoing analyses, and inform future projects.

- Strong models can determine the performance of a **newly-identified system or** inform the impacts of an **update to a system** with , with **measurable confidence**.

Surrogate Model Example



# REINFORCEMENT LEARNING WITH ONESAF

## Summary

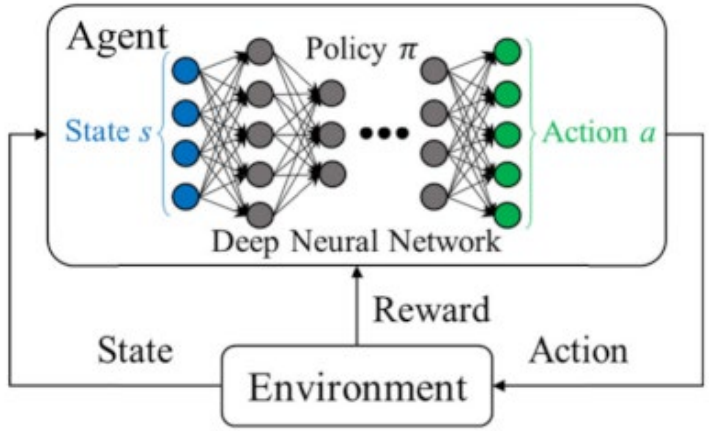

- Current Operational Analyses with OneSAF are completed with multiple human-in-the-loop roles or statically planned activities.
- Applying a reinforcement learning (RL) algorithm to OneSAF will enable decreased workload on the analyst and innovative operational strategies.


## Progress/Future Work

- RLSAF currently has the capability to train and employ a BLUFOR RL Agent vs an OPFOR non-RL Agent.
- Future development of RLSAF will lead to not only RL vs RL simulations, as well as multi-agent RL vs multi-agent RL simulations.

## Reinforcement Learning (RL) Overview

- RL is a machine learning method in which an agent is trained within an environment and learns to interact with the environment to maximize a reward function.
- The RL agent takes the environment state variables as the input to the training policy.
- The policy is a deep neural network that tries to create a black box function to map the environment state variables (input) to the agent action variables (output) while trying to gain the most reward.
- The agent then takes an action based on the trained policy, and if those actions lead to desirable results the agent will be given a certain level of reward. The goal of the policy is to maximize the reward.



# APPLYING AI/ML TO PROTOTYPING

**Desired End State:** Maximize machine output and minimize human tending of manufacturing cells

**Enabling Technology:**
1. Robotics
2. Automation
3. Statistical Process Control (SPC)
4. Artificial Intelligence & Machine Learning

**Phase 1 (current):**
- Develop competency in robotics and automation integration into existing manufacturing processes

**Phase 2 (future):**
- Augment staff by deploying automated solutions for manufacturing processes
- Integrate in-process inspection to feed data collection for SPC

**Phase 3 (future):**
- Utilize SPC data to teach AI/ML how a skilled operator responds to data trends
- Enable AI to make real time offsets based on SPC data

***Pilot run of 2,550 clamps made with robotic machine tending***

***Validation of automated process simulations***

**AI/ML will enable extension of prototyping capacity, ensuring accuracy and minimizing downtime**

# PATH TO TRUSTED & ASSURED AI/ML-ENABLED PRODUCTS

**Armaments Human System Integration (HSI)**
- Development of appropriate mental models and trust metrics
- Interfaces optimized to convey the right information

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

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

**T&E/V&V**
- Develop framework for T&E/V&V of AI/ML
- Establish procedures and measures for AI/ML performance and reliability

**Reliability**
- Identify potential failure modes of AI/ML
- Ensure enabling systems and sensors can meet needs

**Materiel Release**
- Coordinate across stakeholders to reduce risk
- Adapt and develop necessary deliverables to ensure safe/suitable/supportable


**Trusted AI**: Product that the warfighter trusts to deliver desired capability

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

# SE FOR TRUSTED AI

**Background:**
Armament systems are becoming increasingly complex through the integration of AI methods for automation and autonomy and will impact the way users interact with AI-enabled systems requiring:

- Systems engineering methods
- A robust analytic framework with supporting resources and tools
- Required domain expertise of Systems Engineers to provide solutions

**Current Focus:**

- DEVCOM AC established a “Challenge” with the SERC to look at ways to improve Trust in AI-enabled Armament Systems. Teams are engaged in answering the three (3) major questions:

What SE activities and artifacts are best suited to build trust in AI-enabled systems?

What infrastructure is needed to train & validate trusted AI-enabled systems?

What are workforce KSAs required to be successful in the development and management of AI-enabled systems?

**Future:**

- Improved SE Tools, Methods and Best Practices (TMBPs) to build Trust in AI-enabled systems
  - Appropriate level of SE based on changing Requirements/Environment as the systems learn/adopt AI/ML principles

**Ongoing Joint Effort with the SERC: Trusted AI for Armaments Systems Challenge**

# PARTNERING THROUGH TECHNOLOGY TRANSFER

- Our most common tools:
  - Cooperative R&D Agreements (CRADAs)
  - Educational Partnerships
  - Service Agreements
  - Consortia
  - Patent Licensing
  - IR&D
  - SBIR/STTR
  - International Agreements


***DEVCOM Armaments Center Transfers Technology to the Industrial Base to Speed Transition to the Warfighter***

**Visit our Technology Transfer Website**
**https://ac.DEVCOM.army.mil/collaborate/**

**Let's continue to work together!**

# THANK YOU.


U.S. ARMY