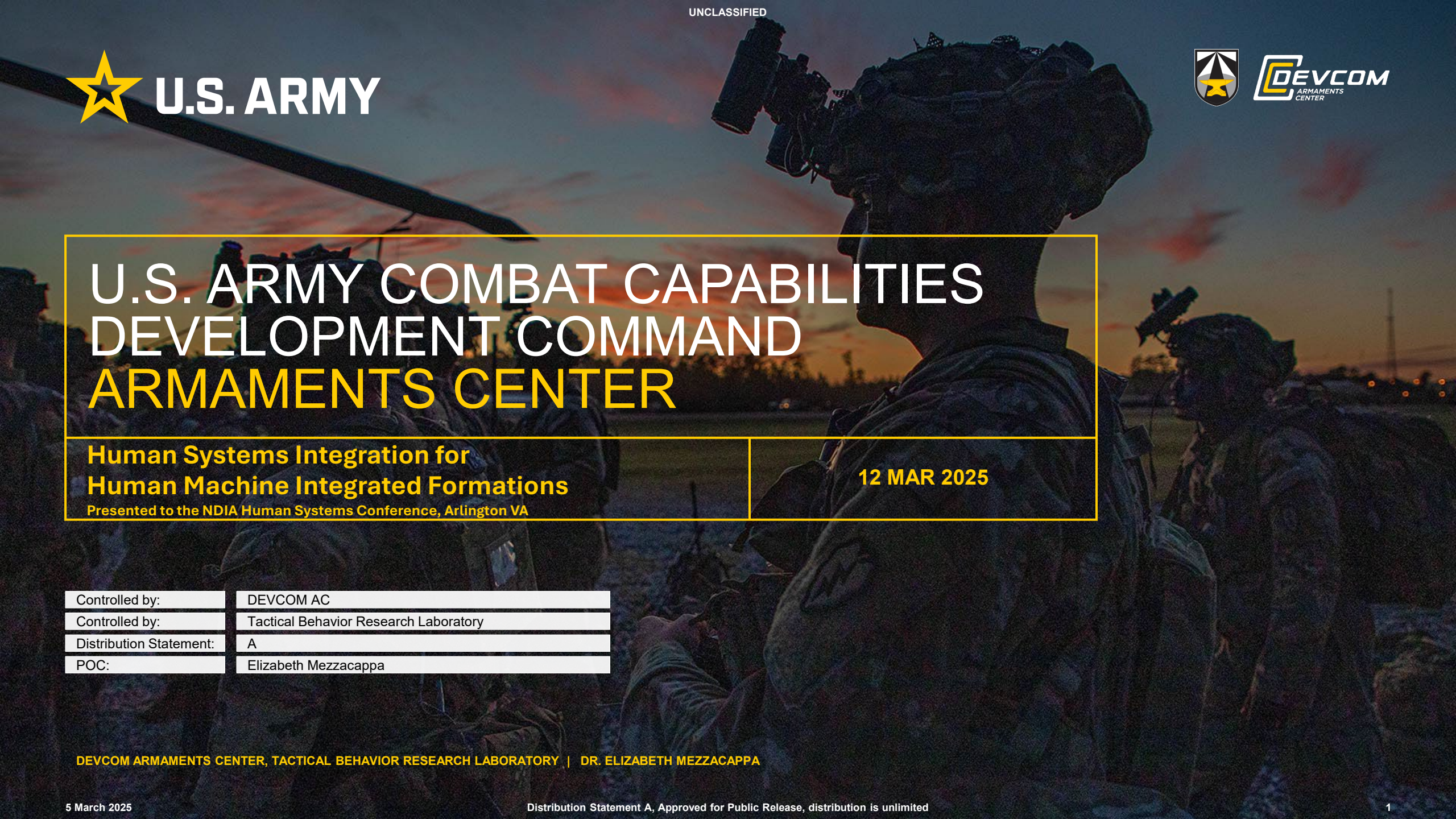

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Human Systems Integration for Human Machine Integrated Formations

Presented to the NDIA Human Systems Conference, Arlington VA

12 MAR 2025

Controlled by:	DEVCOM AC
Controlled by:	Tactical Behavior Research Laboratory
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POC:	Elizabeth Mezzacappa

DEVCOM ARMAMENTS CENTER, TACTICAL BEHAVIOR RESEARCH LABORATORY | DR. ELIZABETH MEZZACAPPA

US ARMY HUMAN MACHINE INTEGRATED FORMATIONS

Future of human-machine integration must bring right mix of robotic elements to formations

By Jerome Aliotta October 5, 2023

ARMY NEWS

AUSA NEWS: Army Gaining Ground on Human-Machine Integrated Formations

10/14/2024

By Josh Luckenbaugh

Share Tweet Email in

WASHINGTON, D.C. — The Army wants to integrate robots into its fighting formations, and the service will soon be hosting an industry day to provide companies a chance to offer solutions to this problem, the head of Army Futures Command said Oct. 14.

Initiated in 2023, the Army's human-machine integrated formations initiative is the service's effort to fight with a mix of human soldiers and unmanned systems on the battlefield, with the goal of having the robots make first contact with an adversary.

Gen. James Rainey, head of Army Futures Command, said the service has conducted testing with human-machine integrated formations this year at the National Training Center at Fort Irwin, California, adding that he feels "very good" about progress so far.

The service in November will be hosting an industry day during which it will be presenting companies five variants of human-machine integrated platoons it has developed, and "I fully expect industry is going to come back with some incredibly fascinating ideas," Rainey said during a media roundtable at the Association of the United States Army's annual meeting .

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Human Machine Integrated Formations (HMIF) Overview & Incremental Roadmap

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HMIF Overview

Mission Statement: Human Machine Integrated Formations (HMIF) accelerates the fielding of a robotic formation to leverage machines to offload risk and provide Soldiers with additional information for decision-making for Armored and Infantry Formations.

Description: Provide two HMIF formation sets (Armor and Infantry) for rapid prototyping and leave-behind capability at two U.S. Army Forces Command units for learning, iterative refinement, and operational deployment.

Capabilities:

1. One Infantry HMIF Platoon to an Infantry Brigade Combat Team (IBCT).
2. One Armored HMIF Platoon to an Armored Brigade Combat Team (ABCT).
3. Each formation will include ground and air systems and enablers to aid in the human decision-making process to find, fix, and engage enemy targets.
4. Prototype development supports existing and future robotic programs of record (PoR) by mitigating risk associated with enabling capabilities such as the common architecture, communications and network capabilities, and mitigation of safety risks hindering operational employment.
5. In addition to ground platforms, HMIF will be integrated with Unmanned Aircraft System (UAS), enablers, and a variety of payloads from existing PoR or developed and transitioned to PoRs.

"Think big, start small, and go fast!"

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HMIF OV-1

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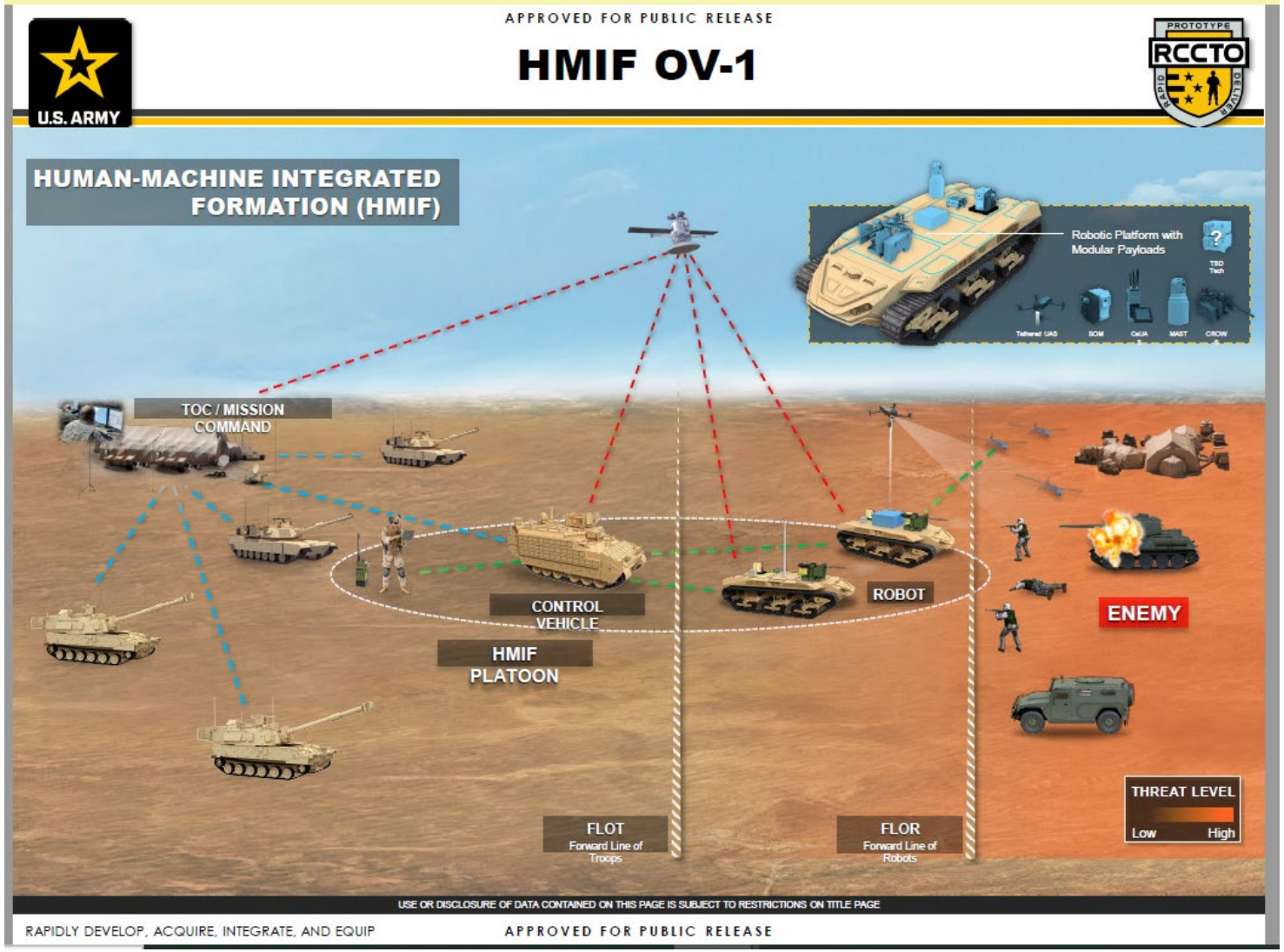
HUMAN-MACHINE INTEGRATED FORMATION (HMIF)



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HOW TO MEASURE TRUST AND GAIN SOLDIER INSIGHTS: RESEARCH PHASES 2023-2024

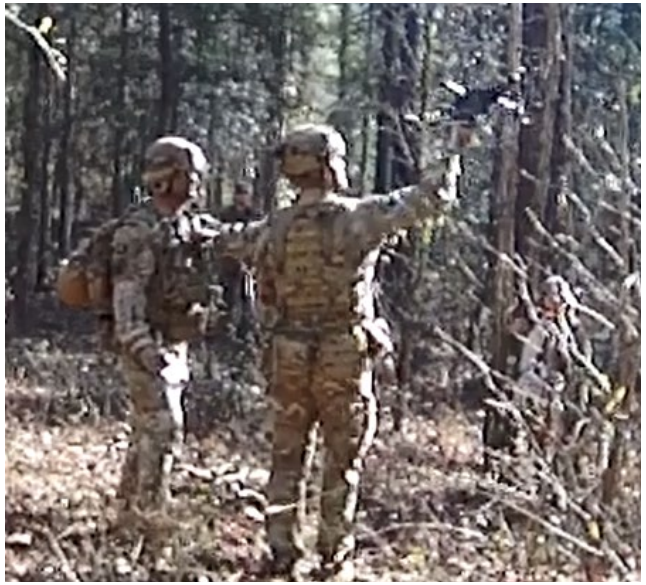
Table Top

METHOD

Data gathering based on qualitative approaches:

- Interviews
- Surveys
- Observation

UAS Live Fire



METHOD

Data gathering based on quantitative and qualitative approaches:

- Video and Audio recording
- Questionnaires

Live Force on Force

METHOD

Data gathering based on quantitative and qualitative approaches:

- Video and Audio recording
- Quantitative Performance Metrics
- Questionnaires

HOW TO MEASURE TRUST AND GAIN SOLDIER INSIGHTS: RESEARCH PHASES 2024

Virtual Environment

METHOD

Data gathering based on quantitative and qualitative approaches:

- Interactive virtual environment scenarios
- Motion capture
- Video recording
- Quantitative performance metrics
- Questionnaires

Engineering Integration Event

METHOD

Data gathering based on qualitative approaches:

- Interviews
- Surveys
- Observation

Live Fire

METHOD

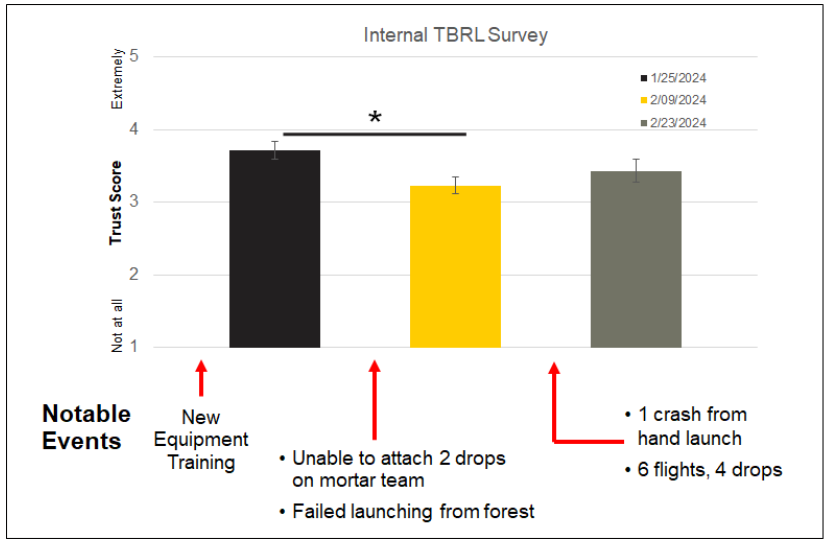
Data gathering based on quantitative and qualitative approaches:

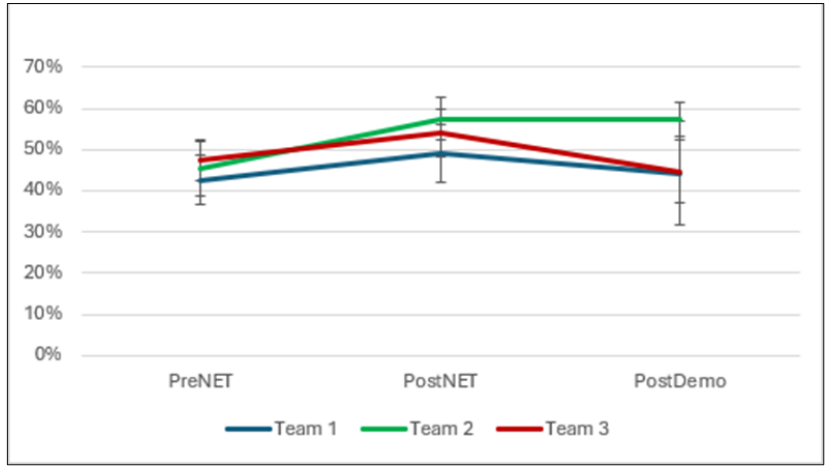
- Video and Audio recording
- Quantitative Performance Metrics
- Focus group discussion
- Interviews
- Questionnaires

TRUST IN AI AND AUTONOMOUS ARMAMENTS

Schaefer Item	Factor						
	1	2	3	4	5	6	7
Act as part of the team	0.801					0.304	
Work best with a team	0.789						
Considered part of the team	0.787						
Supportive	0.701						-0.335
Friendly	0.688						
Clearly communicate	0.68						
A good teammate	0.663						
Pleasant	0.631						
Responsible	0.582			0.305			
Work in close proximity with people	0.563					0.374	
Openly communicate	0.488		0.413				
Lifelike	0.418			0.609			
Communicate the people	0.417					0.502	
Provide feedback	0.374					0.531	
Reliable	0.368						-0.462
Follow directions	0.33						-0.529
Have errors		0.849					
Malfunction		0.841					
Require frequent maintenance		0.772					
Function successfully		0.571					-0.382
Act consistently		0.319					-0.544
Perform exactly as instructed		0.304					-0.609
Autonomous			0.586				
Perform a task better than a novice human user			0.429	0.316			
Protect soldiers			0.397				-0.452
Know the difference between friend and foe				0.868			
Keep classified information secure				0.769			
Conscious				0.767			
Possess adequate decision-making capability				0.756			
Make sensible decisions				0.679			-0.306
Tell the truth			-0.523	0.358		0.345	
Predictable				0.333			-0.738
Unresponsive					0.815		
Incompetent					0.785		
Led astray by unexpected changes in the environment					-0.493		0.317
Perform many functions at one time						0.519	
Warn Soldiers of potential risks in the environment						0.582	
Provide appropriate information						0.5	-0.497
Dependable							-0.579
Meet the needs of the mission task							-0.697

What % of the time will this robot…
Provide accurate fire
Be able to pull security
Betray me*
Follow rules of engagement (ROE)
Improve lethality of my unit
Get in my way*
Harm me or my unit*
Provide my unit with an advantage
Keep up with the demands of the mission
Improve mobility of my unit
Require oversight*
Improve survivability of my unit
Require an Emergency Stop (E-Stop)*
Commit Friendly Fire*
Need to be overridden*
Maintain the fight
Detect possible targets successfully
Identify targets successfully
Adhere to fire command (e.g., shift fire)
What % of the time will this robot be…
Broken*
Essential to the mission





- Factor 1: Following mission plan and functionality
- Factor 2: Negligence and danger of the device

SOLDIER INSIGHTS FOR ENGINEERS AND DEVELOPERS OF AUTONOMOUS LETHAL WEAPON SYSTEMS

- **Lethal Autonomous Weapon Systems Questionnaire (N=88).** 15-item free-text questionnaire asking for opinions and insights and recommendations to give guidance to engineers developing fully autonomous lethal armament systems.

- **Robotic Assets Questionnaire (N=140).** This 10-item Likert scale questionnaire asked Soldiers their level of agreement with statements on the use of robots on the battlefield (not necessarily as weapons).

- **AI Confidence Questionnaire (N=22).** This 18-item questionnaire asked Soldiers to indicate the percentage level of confidence that an artificial intelligence would need to report for the Soldier to take action. This question was repeated for three different targets (Human, Robotic Quadruped, Vehicle) at different phases across the kill chain.

- **AI Reported Confidence Levels Questionnaire (Weapons Tight / Weapons Free) (N=10).** This 16-item pilot questionnaire asked Soldiers to indicate the percentage level of confidence that an artificial intelligence would need to report for the Soldier to take action in several scenarios, under Weapons Tight and Weapons Free rules of engagement.

Data collected from several Soldier events from Dec 2023-Sept 2024
(demonstration, force-on-force, engineering integration events, live-fire)

Envisioned Use Cases

Key Findings:

1. Company-Level Deployment:

- AWS are primarily envisioned for deployment at the Company Level or higher.
- Allows for experienced oversight and strategic allocation to platoons or weapon squads as needed.

2. Operational Roles:

- Reconnaissance: Early identification of enemy positions.
- Support-by-Fire: Providing cover during operations.
- Load-Carrying: Assisting with logistics, resupply, and casualty evacuation.
- Route Clearance: Leading through dangerous areas to mitigate risk to soldiers.
- Lethal Deployment: Serving as forward elements to make initial enemy contact.

• Insights:

- AWS are seen as force multipliers that enhance unit flexibility and survivability.
- Participants emphasize using AWS in supportive roles rather than replacing human soldiers.

Interaction Methods

Key Findings:

1. **Centralized Control Systems:**
   - Single platform for flying, targeting, and firing (e.g., ATAK compatibility).
2. **Visual Displays:**
   - Full-screen HUDs and integrated visual feedback systems.
3. **Manual Controls:**
   - Preference for joysticks and console-style controllers.
   - Voice commands are viewed skeptically due to battlefield chaos.
4. **Reliability:**
   - Durable and weather-resistant control interfaces.
   - Avoiding sensory overload for operators.

- **Insights:**
  - Participants favor manual control and visual interfaces over fully automated or voice-controlled systems. Integrated control platforms reduce complexity and improve situational awareness.

Soldier Guidance

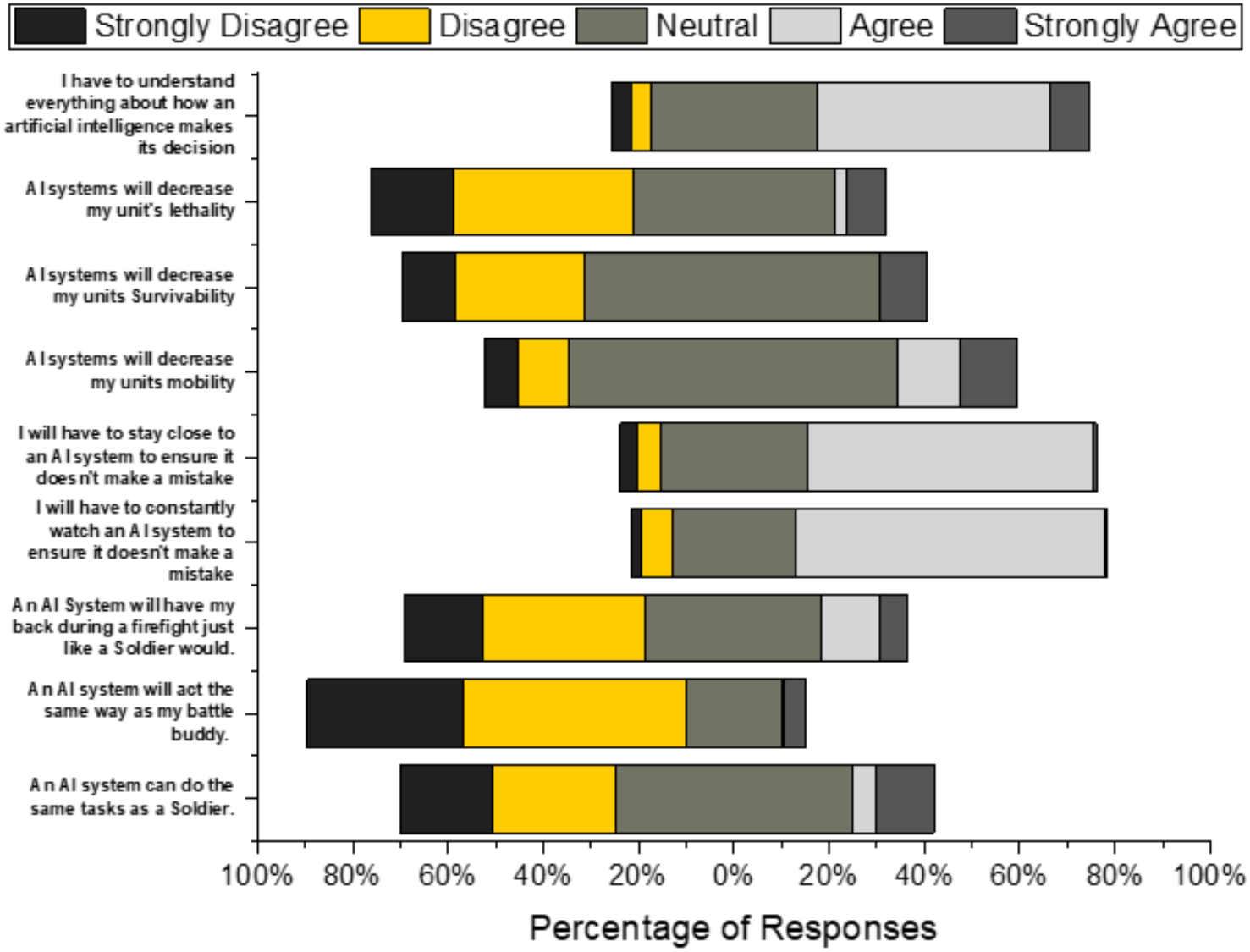
Key Findings:

1. **Simple to Use, Not Slow Unit Down, Reliability**
   - Most frequent responses
2. **Controllability**
   - Kill switch, self-destructs, E-Stops
   - Show system status
3. **Lethality Control**
   - Expressed wanting to control lethality
   - But control should not be burdensome

Insights:

- “Make sure the thing doesn't kill me”
- “The more the user experience is considered during the design, the better the chances are that Soldiers will like the weapon system”

ROBOTIC ASSET QUESTIONNAIRE RESULTS



AUTONOMOUS LETHAL WEAPON SYSTEMS

G.2. DEFINITIONS.

Unless otherwise noted, these terms and their definitions are for the purpose of this directive.

TERM	DEFINITION
autonomous weapon system	A weapon system that, once activated, can select and engage targets without further intervention by an operator. This includes, but is not limited to, operator-supervised autonomous weapon systems that are designed to allow operators to override operation of the weapon system, but can select and engage targets without further operator input after activation.

What level of risk are US Commanders willing to accept in deploying autonomous systems?

What is the acceptable collateral damage risk for autonomous weapon systems?

Is it more or less acceptable than the risk for a human operator?

Who decides when, where, and how often autonomous weapon systems are deployed?

How are decisions evaluated “right of boom” (i.e., in the wake of an attack)?

What degree of AI explainability should be required?

DoD DIRECTIVE 3000.09

AUTONOMY IN WEAPON SYSTEMS

Originating Component:	Office of the Under Secretary of Defense for Policy
Effective:	January 25, 2023
Releasability:	Cleared for public release. Available on the Directives Division Website at https://www.esd.whs.mil/DD/.
Reissues and Cancels:	DoD Directive 3000.09, “Autonomy in Weapon Systems,” November 21, 2012
Approved by:	Kathleen H. Hicks, Deputy Secretary of Defense

Trotti, C., Wetzel, T., Nurkin, T., & Hu, E. (2022). What does the future of autonomous warfare look like? Four critical questions, answered. https://www.atlanticcouncil.org/content-series/automating-the-fight/what-does-the-future-of-autonomous-warfare-look-like-four-critical-questions-answered/

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HUMAN SYSTEM INTEGRATION FACTORS RELEVANT TO WARFIGHTER INTERACTIONS WITH AUTONOMOUS LETHAL WEAPON SYSTEMS: REVIEW OF THE LITERATURE FOR TEST AND EVALUATION

FEBRUARY 2025

PREPARED FOR:
Mr. Chris DeLuca OUSD(R&E)

PREPARED BY:
Elizabeth S. Mezzacappa, PhD
AFC DEVCOM AC QE&SA Tactical Behavior Research Lab (TBRL)

Table 4. Link Between Operator and System: Controller

LINK BETWEEN OPERATOR AND SYSTEM: CONTROLLER	TESTING ACTIVITIES
Form Factor	Interview, ratings, performance time during simulation testing
Physical Layout	Interview, ratings, performance time during simulation testing, ergonomic testing, SUS, TAM
Effectors (e.g., buttons, joystick, etc.)	Interview, ratings, performance time during simulation testing, ergonomic testing, SUS, TAM
Screen Layout	Interview, ratings, performance time during simulation testing, SUS, TAM
Menu Configuration	Interview, ratings, performance time during simulation testing, SUS, TAM
Psychomotor Limitations	Performance time during simulation testing
Task Guidance	
What Operator Does	Interview, ratings, performance time during simulation testing
What System Does	Interview, ratings, performance time during simulation testing
Activation	Time to activation in simulation testing
Deactivation	Time to deactivation in simulation testing
Emergency Stops	Time from warning to stop in simulation testing

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Table 1. Requirements relevant to human systems integration with corresponding human systems topic area

3000.09 REQUIREMENT	HUMAN FACTORS CONSIDERATIONS
Describe how the system supports appropriate levels of human judgement.	Explain Soldier-Centered design history, incorporation of subject matter expert guidance and Soldier testing that demonstrates system support for appropriate levels of human judgment. Identify the human factors principles and Soldier testing data incorporated into design.
Describe how the system and Commander and Operator communicate back and forth 1) information 2) source of information 3) how it is conveyed.	Link between Operator and System: Displays, Controller
Describe procedures by which the Commander or Operator can alter the behavior of the system during execution of a mission.	Link between Operator and System: Displays, Controller
Describe how system status is monitored.	Link between Operator and System: Displays
Describe how identification, prioritization, nomination, and engagement information will be provided to the Commander or Operator (either from the system itself or other sources.)	Link between Operator and System: Displays
Describe what and how information related to the possibility of collateral damage.	Link between Operator and System: Displays
Identify the parameters that are pre-set or inputted ahead of time.	Link between Operator and System: Controllers
Identify the parameters that are modifiable or updated during the operation of the armament	Link between Operator and System: Controllers
Identify the timepoint in which decisions by the Commanders and Operators must be made.	Cognitive Alignment
Identify the timeframe in which decisions by the Commanders and Operators must be made.	Cognitive Alignment
Describe human factors considered for configuration of the user interface.	Link between Operator and System: Displays, Controller. Identify the human factors principles and Soldier testing data incorporated into design.
Describe the human factors considered for the overall system design.	CDAO 3, Link between Operator and System: Displays, Controller; Cognitive Alignments; Responses. Identify the human factors principles and Soldier testing data incorporated into design.

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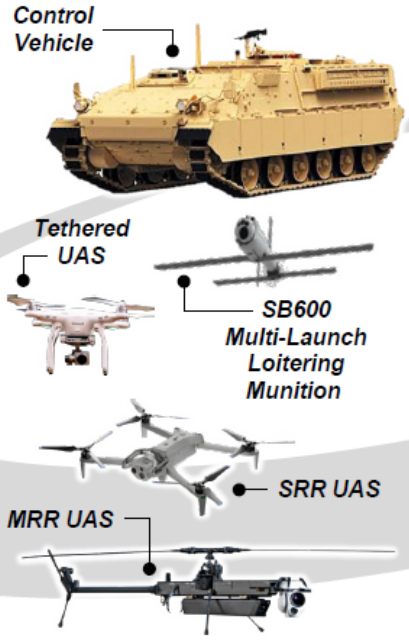
HMIF Increment 1 Baseline Armored and Infantry

HMIF-Armored (HMIF-A)

Baseline Configuration

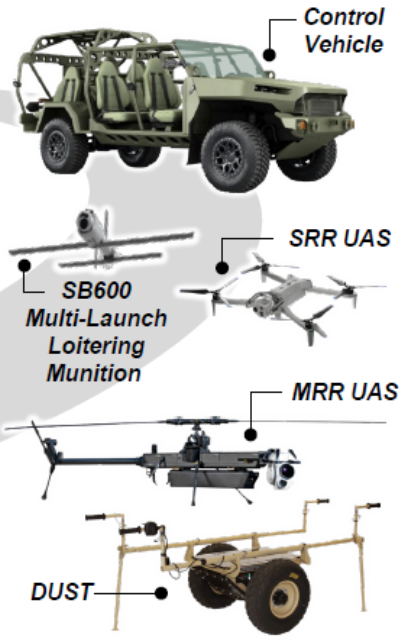
Soldier Operated Command and Control Vehicle (CV)



HMIF-Infantry (HMIF-I)

Baseline Configuration

Soldier Operated Command and Control Vehicle (CV)



NOTE: Full spare set to be available for each configuration

- Aligns Science and Technology from three AFC DEVCOM centers (GVSC, AC, C5ISR) to integrate and harden prototypes.
- Expands defined architecture and common compute across platforms enabling Modular Open System Approach (MOSA).
- Enhances communications between HMIF platforms and payloads to Command-and-Control (C2) nodes.
- Further develops teleoperation of unmanned ground vehicles to enable autonomous behaviors.
- Upgrades to platforms and payloads are tested for safety release to Soldiers.
- Development of common software defined mounted and dismounted controllers to reduce the number of devices and complexity.

AC - Armaments Center
AFC – U.S. Army Futures Command
C5ISR - Command, Control, Communication, Computers, Cyber, Intelligence, Surveillance and Reconnaissance Center
CROWS - Common Remotely Operated Weapon Station
DEVCOM - U.S. Army Combat Capabilities Development Command
DUST - Deployable Utility Support Trailer
EW - Electronic Warfare
GVSC - Ground Vehicle System Center
HMIF - Human Machine Integrated Formations
MRR - Mid-Range Reconnaissance
RCV-L - Robotic Combat Vehicle-Light
SOM - Screening Obscuration Module
SMET - Small Multipurpose Equipment Transport
SRR - Short Range Reconnaissance
UAS - Unmanned Aircraft System

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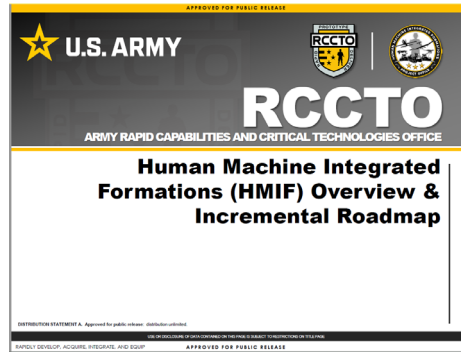

HSI FOR HMIF AT DEVCOM ARMAMENTS CENTER

- Present
  - Controller Study
  - Crew Configuration
    - Gathered crew evaluation of 3 different configurations
      - Demographics
      - Assignments/Roles, Access to Monitors
      - Crew-System Performance in scenarios
      - NASA-TLX (Workload)
  - Menu Book
    - Critique of planned display and controls for controllers, display
- Planned
  - Soldier Touch Points Planned coinciding with integration events, milestones
  - Cross training issues (gunnery and mobility)
  - Override Functions
  - Display requirements for targeting (communications delay)
  - Compliance with NDAA Human Readiness Levels

2025 NDAA Directs DOD to Report HRL Levels for All Major Programs

Posted January 03, 2025

The 2025 National Defense Authorization Act requires the Department of Defense to review the HFES/ANSI 400 Standard on Human Readiness Levels (HRL) to determine if it can be incorporated into DOD procedures "in order to enhance safety in relation to human factors". In addition, the DOD is to report on the HRL of all major development and acquisition programs. This accomplishment represents the successful culmination of a multi-year effort by HFES and Lewis-Burke Associates to improve the consideration of human factors in defense programs. It is a major win for improved safety and human performance.

THANK YOU.

Elizabeth Mezzacappa, PhD
DEVCOM Armaments Center
Tactical Behavior Research Laboratory
elizabeth.s.mezzacappa.civ@army.mil
(520) 684-2830


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