ARL-TN-1292 ● DEC 2025

Scalable Cross-Echelon Command and Control (SC3) Lower Echelon FY25 Achievements

by Andrea Krausman, Eric Holder, Ralph Brewer, Shan Lakhmani, Cheryl Giammanco, Catherine Neubauer, David Chhan, Kimberly Pollard, Jonroy Canady, Jeffrey Hansberger, and Samantha Berg

NOTICES

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REPORT DOCUMENTATION PAGE

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED START DATE	END DATE
December 2025	Technical Note	10/1/2024	9/31/2025

4. TITLE AND SUBTITLE
Scalable Cross-Echelon Command and Control (SC3) Lower Echelon FY25 Achievements

5a. CONTRACT NUMBER	5b. GRANT NUMBER	5c. PROGRAM ELEMENT NUMBER
5d. PROJECT NUMBER	**5e. TASK NUMBER**	**5f. WORK UNIT NUMBER**

6. AUTHOR(S)
Andrea Krausman, Eric Holder, Ralph Brewer, Shan Lakhmani, Cheryl Giammanco, Catherine Neubauer, David Chhan, Kimberly Pollard, Jonroy Canady, Jeffrey Hansberger, and Samantha Berg

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	8. PERFORMING ORGANIZATION REPORT NUMBER
DEVCOM Army Research Laboratory ATTN: FCDD-RLA-FD Aberdeen Proving Ground, MD 21005	ARL-TN-1292

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
DISTRIBUTION STATEMENT A. Approved for public release: distribution unlimited.

13. SUPPLEMENTARY NOTES
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14. ABSTRACT
As part of the U.S. Army's modernization priorities and in response to the increasing speed and complexity of future warfare, the Army is pursuing efforts aimed at fundamentally transforming command and control (C2) systems. Adversaries are actively developing capabilities to disrupt the ability of the Army and Joint Force to identify and react to threats and the realities of the operational environment, rendering current C2 processes too slow and ineffective to keep pace and maintain a technological advantage. Future warfare demands faster more adaptable decision-making in complex, fast-paced, and ill-structured environments. To meet this demand, the Scalable Cross-Echelon Command and Control (SC3) program was established. SC3 aims to re-envision the C2 operations process by streamlining operations and enabling distributed decision-making through the integration of robust and resilient artificial intelligence and machine learning to enable faster more informed decision-making and enhanced operational effectiveness. This technical note provides an overview of the program's FY25 achievements in efforts focused on lower echelon (company and below) procedures.

15. SUBJECT TERMS
Humans in Complex Systems, command and control, C2, planning, decision-making, troop leading procedures, company, platoon, squad, lower echelon

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	C. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UU	19

19a. NAME OF RESPONSIBLE PERSON	19b. PHONE NUMBER *(Include area code)*
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STANDARD FORM 298 (REV. 5/2020)
Prescribed by ANSI Std. Z39.18

Contents

Acknowledgments

The Lower Echelon (LE) team acknowledges the following individuals who contributed to the efforts described in this technical note:

- Artificial Intelligence Integration Center (AI2C): LTC Sean Fraser
- Arizona State University (ASU): Matthew Peel, Jayci Landfair, Ryan Renwick, Dr. Nancy Cooke, and Dr. Nia Amazeen
- D-PRIME, LLC: Dr. Murat Kucukosmanoglu and Dr. Justin Brooks
- DCS Corporation: Matthew Jaswa, Bret Kellihan, Peter Bialek, Justin Jagielski, and Paul Groves
- U.S. Army Maneuver Battle Lab (MBL): MAJ Jeremy Hillyard, MAJ Jacob Kelly, and Justin Strayer
- U.S. Army Mission Command Battle Lab (MCBL): Chris Kenney, David Blackburn, Darryl Schroeder, Chris Kelshaw, and Jennifer McQueen

1. Introduction

As part of the U.S. Army's modernization priorities and in response to the increasing speed and complexity of future warfare, the Army is pursuing efforts aimed at fundamentally transforming command and control (C2) systems. Adversaries are actively developing capabilities to disrupt the ability of the Army and Joint Force to identify and react to threats and the realities of the operational environment, rendering current C2 processes too slow and ineffective to keep pace and maintain a technological advantage. Future warfare demands faster more adaptable decision-making in complex, fast-paced, and ill-structured environments. To meet this demand, the Scalable Cross-Echelon Command and Control (SC3) program was established. SC3 aims to re-envision the C2 operations process by streamlining operations and enabling distributed decision-making through the integration of robust and resilient artificial intelligence (AI) and machine learning (ML) to enable faster more informed decision-making and enhanced operational effectiveness.

To realize the full potential of AI in C2, the Army *must* prioritize a Soldier-centric approach, acknowledging that technology alone is insufficient. The goal of integrating AI is not intended to replace Soldiers, but to leverage the strengths of both humans and AI to create effective human–machine partnerships, such that the Soldier–AI team can accomplish more together than either entity acting alone. A key consideration of this integration is preserving the inherent benefits of traditional planning processes—specifically, ensuring shared situational awareness and unity of effort are not sacrificed in the pursuit of speed and efficiency.

The effective integration of AI into military operations—specifically, *teaming* Soldiers with AI systems—presents significant opportunities to enhance capabilities but also introduces challenges. Successful integration requires a comprehensive approach addressing issues across technological, human, and operational domains. As such, the SC3 program adopted a holistic doctrine, organization, training, material, leadership and education, personnel, facilities, and policy (DOTMLPF-P) approach that addresses several of these domains and aims to develop both materiel and nonmateriel solutions that enable more effective Soldier–AI teams. Each DOTMLPF-P area is a key aspect of the SC3 program and are included as lines of effort in the SC3 research portfolio. A unique characteristic of the SC3 program is recognizing the need to address the impacts of AI integration at both higher (Division-level and above) and lower echelons (Company [CO]-level and below), since AI will change the workflow processes at all echelons. This will ensure unity of effort across echelons and a better return on investment. This technical note focuses on the research efforts conducted in FY25 at the Lower Echelon (LE).

2. SC3 LE Approach

This note documents the FY25 research efforts aimed at enhancing the planning process at the CO echelons and below, to include how those plans are executed and how lessons learned are integrated back into planning. At the LEs there is a lack of a formal planning staff, which results in the CO Commander bearing the primary responsibility for planning. This suggests an opportunity for AI as limited time and lack of staff make it difficult for commanders to be proactive. Integrating AI tools and capabilities can enable commanders to consider alternatives and create and exploit windows of opportunity.

Our approach at the LE was to develop capabilities that support Soldier AI-enabled teams to conduct rapid adaptive tactical C2 in distributed environments, without losing the benefits of planning (e.g., situational awareness, unity of effort). We investigated novel metrics, algorithms, and approaches to assess team performance and coordination between human and AI team members across multiple echelons, including trust in AI, transparency of AI processes, and methods for assessing unity of effort. We also developed a conceptual plan for a next-generation After-Action Review (AAR) tool to facilitate evaluations across echelons in future C2, and explored the concept of adaptation at LEs to understand the workflows, information, and events that trigger adaptations during LE mission execution in the current force and identify aspects of AI and other technologies to enable rapid adaptation in the future operational environment.

Recognizing the need for SME input to ensure our research plans were targeting Soldier needs, we engaged in regular discussions with a military SME formerly at the U.S. Army Maneuver Battle Lab (MBL) to understand the difficulties Soldiers encounter in the LE planning environment. These touchpoints provided a solid foundation for our research plans and informed the support concepts to enable better mission planning and adaptation in future C2. We also had regular discussions with SMEs at the U.S. Army Mission Command Battle Lab (MCBL) to understand the military decision-making process (MDMP) at higher echelons. MCBL also conducted a week-long MDMP course for SC3 researchers to introduce them to the fundamentals of MDMP and begin discussions regarding areas where AI would be most beneficial in the planning process.

3. FY25 Research Areas and Outcomes

Here, we document the main research areas addressed by the LE team in FY25. In each subsection there is a brief description of each effort, followed by a summary of outcomes and associated products. Each product contains more details specific to each area.

3.1 Soldier–AI Teaming Assessment Metrics

3.1.1 Soldier–AI Metrics Literature Review

Description: This work examined the challenges and considerations for assessing team-level constructs—such as trust, cohesion, shared mental models, and situation awareness—within the context of Soldier–AI teams. It sought to expand on previous work developing a multimodal approach for continuous assessment of human-autonomy teams. In this effort, the team conducted a nonexhaustive literature review to uncover which metrics are successfully being used to measure team processes and user states in AI-enabled teams. They were documented in a technical report with summary table (Berg et al. 2025; Pollard et al. 2026) to serve as a guide for researchers interested in using the metrics.

Outcome: This research effort addressed the need for metrics suitable for continuous assessment of Soldier–AI teams. Several different metrics were explored in the literature review—including subjective metrics of trust; as well as more continuous metrics of trust derived from physiological, behavioral, and communication data; in addition to metrics for assessing team processes such as AI adoption, team adaptation, and situational awareness. These findings expand our understanding of how to assess Soldier–AI interactions, which is essential for ensuring the Army can effectively integrate AI-enabled systems into its operational forces. A thorough understanding of team dynamics and user states is critical for maximizing the benefits of these technologies while mitigating potential risks.

Products: Berg S, Waytowich N, Goecks VG, Krausman A. Evaluating user trust in large language models. Proceedings of the Human-Systems Conference; 2025 Mar. National Defense Industrial Association (NDIA).

Pollard K et al. Soldier-AI integration: AI trust and teaming metrics. DEVCOM Army Research Laboratory (US); Forthcoming 2026.

3.1.2 Soldier–AI Trust, Cohesion, and Workload ML Models

Description: In addition to the literature review and identification of suitable metrics for Soldier–AI teams, the LE team analyzed data from a human-autonomy teaming platoon-level experiment to better understand the relationship between continuous data modalities and their associated self-report survey, as well as to broaden understanding of which data modalities are robust indicators of trust, cohesion, and workload in Soldier–AI teams. Furthermore, the team used these same data to develop ML models for predicting trust, cohesion, and workload.

Outcome: Key findings indicated that predictive relationships are significantly strengthened when data are aggregated at the team level, as individual-level correlations are weak due to inherent variability. Future work will focus on expanding data collection, refining predictive models with advanced algorithms, and transitioning to real-time monitoring capabilities to enable adaptive human-autonomy teaming and improved operational performance. The ML models were integrated into the Human-Autonomy Teaming Trust Toolkit (HAT^3), described below.

Products: Chhan D, Kucukosmanoglu M, Neubauer C, Krausman A. Multimodal predictors of trust and cohesion measured during an experiment examining dynamic task allocation technologies in a next generation combat vehicle simulator. DEVCOM Army Research Laboratory (US); 2025 Nov. Report No.: ARL-TR-10229.

3.1.3 HAT^3 Toolkit Addendum Report

Description: The addendum expands on the initial HAT^3 report, which introduced the toolkit to assess team trust using subjective and communication modules (Neubauer et al. 2023). This addendum describes new capabilities added to the toolkit, including newly developed models for assessing trust, cohesion, workload, and sentiment analysis; thus, leveraging multimodal data such as physiological sensing and eye-tracking. These enhancements aim to provide a more comprehensive and real-time assessment of team dynamics in human-autonomy teams.

Outcome: One key addition is the sentiment analysis model, which extends the communication module to quantify the emotional tone of team communication—specifically, for the military domain. Using a fine-tuned DistilBERT natural language processing model, the system classifies sentiments (positive, negative, neutral) based on transcribed audio from simulated human-autonomy teaming platoon-level missions. The model outputs probabilities for each sentiment class, which are integrated with other modalities, such as eye-tracking to support trust monitoring. This work is an important advancement in obtaining sentiment specifically in the military domain.

The new physiological module in the HAT^3 toolkit offers real-time visualizations and predictive models for trust, cohesion, and workload. It includes features such as raw electrocardiography data visualization for monitoring data quality and sensor status, as well as raw eye-gaze data displayed as heat maps to identify gaps in recorded data. The module also provides interactive graphs for exploring predictions from the trust, workload, and cohesion models. Additionally, the sentiment analysis module has been enhanced to visualize probabilities of positive and negative sentiment across various communication channels. These visualizations allow users to explore sentiment probabilities and transcribed utterances for specific data points through interactive graphs.

In sum, the addendum describes significant enhancements to the HAT^3 toolkit, including the integration of advanced ML models and multimodal data streams to assess trust, cohesion, workload, and sentiment in human-autonomy teams. These new capabilities enable real-time monitoring and adaptive interventions, making the toolkit more comprehensive and effective for military and experimental applications.

Products: Chhan D, Kucukosmanoglu M, Neubauer C, Krausman A. Multimodal predictors of team trust and task cohesion measured during an experiment examining dynamic task allocation technologies in a next generation combat vehicle simulator. DEVCOM Army Research Laboratory (US); 2025 Nov. Report No.: ARL-TR-10229.

Kucukosmanoglu M et al. Exploring trust in AI-supported military teams using sentiment analysis. Interaction Studies. 2025;26:2.

Neubauer C et al. Addendum to ARL-TR-9623, Human-Autonomy Teaming Trust Toolkit (HAT^3) software development documentation and user guide. DEVCOM Army Research Laboratory (US); Forthcoming 2026.

3.1.4 Dynamical Systems Analysis (DSA)

Description: Another effort addressing the need for novel methods to assess Soldier–AI teams was performed in collaboration with Arizona State University (ASU). This effort focused specifically on quantifying adaptation in human-autonomy teams based on continuous time-series data collected as part of a larger human-autonomy teaming platoon-level simulation experiment. Time-series data is increasingly becoming a priority data source to overcome the limits of static/aggregated data and enabling opportunistic sensing. ASU developed and applied a novel DSA method called Collective Systems Adaptation (CSA) across multiple complex datasets from this experiment to understand and assess patterns suggestive of team adaptation across multiple data modalities (e.g., communication, combat and weapon sensors, control inputs, geospatial coordination, and physiological synchrony), providing enhanced insight into the team's process and performance. The ASU researchers focused on the Soldier-relevant themes of "move, shoot, and communicate," along with integrating physiological data.

Outcome: This analysis applied CSA, an innovative approach to identifying concurrent anomalies from baseline performance across disparate data streams, highlighting significant adaptation events and providing patterns for further analyses. Initial analyses highlight that successful team adaptation is characterized by "controlled flexibility"—i.e., strategic meaningful shifts in behavior rather than constant unfocused adjustments. Overall, the output from these analyses can lead to actionable insights that will improve team performance and overall combat effectiveness. The underlying DSA techniques have great potential to add value to any DoD applications that collect and learn from time-series data.

Products: Landfair JT, Peel MA, Amazeen PG, Cooke NJ. Investigating team adaptation through Warfighter communications. Proceedings of the Human Factors and Ergonomics Society Annual Meeting. 2025;69(1):69–75. https://doi.org/10.1177/10711813251367728

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Landfair JT, Peel MA, Renwick RM, Amazeen PG, Cooke NJ. The dynamic team process of mounted infantry platoons. End of year (2025) project report. DEVCOM Army Research Laboratory (US); Forthcoming 2026.

Peel MA, Landfair JT, Amazeen PG, Cooke NJ. Collective systems adaptation analysis: a method for measuring team adaptation in dynamic environments. DEVCOM Army Research Laboratory (US); Forthcoming 2026.

Peel MA, Landfair JT, Amazeen PG, Cooke NJ. Measuring multidimensional team adaptation. Proceedings of the Human Factors and Ergonomics Society Annual Meeting. 2025;69(1):534–540. https://doi.org/10.1177/10711813251374207

Peel MA, Landfair JT, Johnson CJ, Amazeen PG, Cooke NJ. An analysis of team adaptation using geospatial coordination measures of combat teams. Proceedings of the Human Factors and Ergonomics Society Annual Meeting. 2025;69(1):907–913. https://doi.org/10.1177/10711813251374132

4. AAR for Next-Generation C2

Description: AARs have long been a cornerstone of military doctrine, serving as a disciplined and structured process for analyzing experiences—both successes and failures—to identify lessons learned and enhance future performance across all echelons of command. However, the increasingly rapid operational tempo of modern warfare often relegates AARs to brief informal "hot washes," resulting in a significant loss of valuable insights and a failure to fully capitalize on collected mission data. This is particularly concerning as the character of combat undergoes a fundamental shift with the integration of AI/ML and increasingly advanced systems. Future battlefields will demand rapid responses to a more capable adversary, necessitating a capacity for Soldiers and systems to learn and adapt from mission to mission at an unprecedented pace. Initial examples of the continuous adaptation required can be seen in the current Eastern European conflict. To meet this challenge, there is an emerging need to streamline the current AAR process, transforming it into a proactive tool that provides leaders and commanders with rapid, actionable data to facilitate lessons learned and enable rapid adaptation to a constantly changing threat landscape. Based on lessons learned with AARs in human–machine integrated formation simulation experiments and Soldier touchpoints, we established requirements for the conceptual next-generation AAR capability and documented them in a technical note (Giammanco et al. 2026a, 2026b).

Outcome: The envisioned next-generation AAR capability will leverage AI/ML to overcome the limitations of traditional methods. Beyond simply identifying issues, the system will also proactively track and visualize key performance indicators for both human and AI elements, detect anomalies that warrant further investigation, and assist with identifying potential lessons learned. Importantly, the insights gleaned from these AARs will not just be documented but actively fed back into the AI/ML algorithms themselves, allowing them to continuously refine their behavior, correct deviations, and better align with human intent. This creates a closed-loop learning system that fosters continuous improvement. Transparency is also a key aspect of the next-generation AAR to address the need to get inside the "black box" of AI and understand its behaviors, actions, and status. This conceptual AAR technology represents a paradigm shift in military learning, empowering

Soldiers and commanders with the data-driven insights necessary to thrive in the complex and dynamic battlefields of the future.

Product: Giammanco C, Holder E, Krausman A. Scalable cross-echelon command and control (SC3) armor platoon after action review and plan adaptations with autonomous systems. DEVCOM Army Research Laboratory (US); Forthcoming 2026a.

Giammanco C et al. Scalable cross-echelon command and control (SC3) lower echelon after action review requirements. DEVCOM Army Research Laboratory (US); Forthcoming 2026b.

5. Soldier–AI Adaptation

Description: Advanced intelligent technologies will continually change the nature of the battlefield and the very nature of the tasks that Soldiers are required to perform. As such, many discussions on the role of AI in the battlefield have specifically focused on aspects of the mission where AI is most beneficial, the capability that Soldier–AI teams must provide to perform the mission effectively, as well as the necessary adaptation of both the human and the machine during the evolution of this mission. Here, systems must address adaptive intelligent adversaries that attempt to take advantage of complex environments. Furthermore, approaches for measuring adaptation are needed. In this research area, we addressed several different aspects of adaptation.

First, the team performed analyses of a dataset from human-autonomy platoon-level simulation experiments that included mission planning and AAR data, which allowed us to understand what types of events occurred during a mission that required the team to adapt either during the mission or in the next mission (Giammanco et al. 2026a). Results of the analyses, as well as SME discussions about adaptation, helped the team formulate several technology support concepts needed to support plan adaptation and mission-to-mission adaptation in future C2.

These concepts were discussed with CO- and platoon-level Soldiers during the LE Soldier touchpoint at MBL in Fort Benning, Georgia. The touchpoint comprised demonstrations of the support concepts and discussions with Soldiers regarding their usefulness in supporting mission planning and adaptation. Results were documented in the LE touchpoint report (Holder et al. 2026).

Outcome: Soldier discussions and demonstrations of support concepts at the Soldier touchpoint focused on obtaining Soldier feedback regarding how best to integrate AI and emergent technologies to enhance capabilities at the LE—specifically, CO-level and below. Soldiers identified several aspects where AI could benefit mission planning and execution—for example, four of the five top ranked solutions involved ways to better understand the terrain and battlespace for the Mission, Enemy, Terrain, and weather; Troops and support available; Time available; and Civilians (i.e., METT-TC) analysis part of planning. These aspects were consistently where the Soldiers mentioned doing the most analysis and thinking. However, Soldiers also cautioned about overreliance on technology resulting in skill atrophy and stressed the importance of continuing to train Soldiers to do these tasks manually.

Products: Holder E, Pollard K, Krausman A. Integrating AI and emergent technology at the Lower Echelon Soldier Touchpoint: August 19–20, 2025. DEVCOM Army Research Laboratory (US); Forthcoming 2026.

Giammanco C, Holder E, Krausman A. Scalable cross-echelon command and control (SC3) armor platoon after action review and plan adaptations with autonomous systems. DEVCOM Army Research Laboratory (US); Forthcoming 2026a.

Analysis of Soldier Adaptation in the Center for Army Lessons Learned Documentation of the Current Eastern European Conflict

Description: The purpose of this analysis was twofold: 1) To harvest themes and lessons learned from the Ukraine conflict to help drive SC3 thinking; 2) To educate the project team on the realistic drivers of Soldier adaption, primarily Soldiers being killed and trying to avoid this while still accomplishing missions and adapting to emerging enemy tactics and opportunities in a cat-and-mouse way. The priority technology focus areas for operational advantages and adaptation were identified and discussed.

Outputs: The briefing report (Holder 2025) allowed the lessons learned in Ukraine to be accessible to the project team at the CUI level. The key enablers and their impacts are discussed in the report, as well as identifying contextual factors and variables to consider when proposing or designing additional solution concepts.

Product: Holder E. Key adaptation themes from Center for Army Lessons Learned (CALL) lessons from Ukraine. DEVCOM Army Research Laboratory (US); 2025 May. Unpublished report. (CUI)

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Kucukosmanoglu M et al. Exploring trust in AI-supported military teams using sentiment analysis. Interaction Studies. 2025;26:2.

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Pollard K et al. Soldier-AI integration: AI trust and teaming metrics. DEVCOM Army Research Laboratory (US); Forthcoming 2026.

List of Symbols, Abbreviations, and Acronyms

AAR	After-Action Review
AI	Artificial Intelligence
AI2C	Artificial Intelligence Integration Center
ASU	Arizona State University
C2	Command and Control
CO	Company
CSA	Collective Systems Adaptation
DoD	Department of Defense
DOTMLPF-P	Doctrine, Organization, Training, Material, Leadership and Education, Personnel, Facilities, and Policy
DSA	Dynamical Systems Analysis
FY25	Fiscal Year 2025
HAT^3	Human-Autonomy Teaming Trust Toolkit
LE	Lower Echelon
MBL	U.S. Army Maneuver Battle Lab
MCBL	U.S. Army Mission Command Battle Lab
MDMP	Military Decision-Making Process
METT-TC	Mission, Enemy, Terrain, and Weather; Troops and Support Available; Time Available; and Civilians
ML	Machine Learning
SC3	Scalable Cross-Echelon Command and Control
SME	Subject Matter Expert

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