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# **A Summary of the Effects of Technology Aids and Crew Size on a Next Generation Combat Vehicle Platoon Section**

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<b>14. ABSTRACT</b> The Next Generation Combat Vehicle (NGCV) will operate in the Future Operating Environment, providing Soldiers with advanced capabilities to team with autonomous systems and overmatch adversaries with a reduced crew-to-autonomy ratio. The Human–Autonomy Teaming Essential Research Program seeks to provide Soldiers with autonomous systems that function as teammates rather than tools, reducing workload, sharing tasking, and helping to improve survivability and lethality in the face of a dynamic environment and adversaries. Here, we examined how technology aids and crew size affected workload, situational awareness, and team performance. We found with the technology aids available, the crew was able to make faster decisions, reduce the number of communications needed, and reduce workload. In some of these analyses, we found that technology aids had a larger effect in a smaller crew (six Soldiers), leading their metrics to be more similar to those of a seven-person crew. These technologies thus enabled the NGCV crew to be more lethal and resilient in the face of varying mission types and a dynamic operational tempo.					
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## Executive Summary\*

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In the Future Operating Environment (FOE), the US Army and joint forces will employ teams of humans and intelligent agents (software and robotic) across all echelons to enable operations at speed and scale. The increasingly explosive evolution of technologies, such as artificial intelligence (AI), autonomy, and biosensing, will transform the battlefield and the role warfighters will play in mission success. Specifically, future Army teams facing an AI-enabled adversary will face increases in technological sophistication, expansion of operational scope, and narrowing time windows of opportunity, which will require decisions to be made at a rate greatly exceeding human capabilities. Additionally, dramatic decreases in time to field new technologies combined with in-field learning will create unforeseen emergent capabilities for friendlies and adversaries, thereby forcing Army teams to adapt at rates and in ways that will challenge future autonomy or AI-enabled systems. As such, the FOE will require future Soldiers to interact with a dramatically increasing variety of technologies (i.e., platforms, equipment, systems, and more), take on novel and emerging roles in teams and systems, and rely on technologies for nontraditional tasks and decisions, all under greater levels of operational uncertainty and complexity and increased temporal and coordination pressures. To address these future challenges, effective human–technology teams will need to exploit differences in the abilities of humans and machines to create ultra-capable military systems that exhibit the best properties of both humans and technology, as well as provide transformational overmatch well beyond approaches that focus on human or technological capabilities alone.

The Next Generation Combat Vehicle (NGCV) Army modernization priority provides one example of how the Army envisions employing these human–technology teams. NGCV seeks to improve vehicle and crew performance, crew awareness, rapid decision-making, and reduce crew workload through use of autonomous systems. The US Army’s NGCV concept consists of both optionally manned control vehicles (MCVs) and unmanned robotic combat vehicles (RCVs), making up Manned–Unmanned Teams. These vehicles will have some autonomy (e.g., AI to allow the vehicle to move in the environment), which will be at times manually controlled via teleoperation and at other times allow for autonomous behaviors with Soldiers providing supervisory control. This new operating concept

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\* This technical note summarizes the full version of the limited distribution report *Effects of Technology Aids and Crew Size on a Next Generation Combat Vehicle Platoon Section*, by Katherine R Cox, Joe T Rexwinkle, Gregory M Gremillion, Brandon S Perelman, Justin R Brooks, Philip Dyer, Kimberly A Pollard, Daniel E Forster, David Chhan, Evan C Carter, Sean M Fitzhugh, Shan G Lakhmani, Chou P Hung, Thomas L Rohaly, Jonroy D Canady, Andrea S Krausman, Steven M Gutstein, and Amar R Marathe (ARL-TR-9403, February 2022).

requires that the Army develop new tactics, techniques, and procedures to provide the direction and context for how these human–autonomous teams should function together to provide overmatch in the dynamic and rapid battles of the future.

A key factor in enabling these future NGCV capabilities is enhancing the capability for Soldier–autonomy teams to rapidly make accurate decisions. Air Force Colonel John Boyd described the military decision-making process as a cycle that included the stages of observe-orient-decide-act (OODA).<sup>1</sup> This approach highlights that decisions are derived from observations of a changing or dynamic environment, and which are then focused through a lens of implicit information, past experiences, and knowledge of larger objectives at hand. The observe and orient portions of the OODA loop are often synonymous with maintaining situational awareness (SA). The Army defines SA as “the ability to have accurate real-time information of friendly, enemy, neutral and non-combatant locations; a common, relevant picture of the battlefield scaled to specific levels of interest and special needs”.<sup>2</sup> Considering the OODA loop, and specifically the SA components of the OODA loop within the context of the NGCV within the FOE, brings up two major challenges.

First, the MCVs are intended to be operated as closed-hatch vehicles, meaning that all crew members are fully enclosed within the vehicle hull and all sensory awareness of the outside world is provided through various sensors. Operating under closed-hatch conditions creates significant challenges for developing and maintaining SA, as most of a Soldier’s natural senses are required to be replaced by information from artificial or man-made sensors. Additionally, closed-hatch operations dramatically increased crew workload and associated task completion times<sup>3</sup> due to the reduced field of view and multimodal (e.g., audio, visual, and vestibular) input afforded crew members.

The second major challenge is that the NGCV concept in the FOE creates a team of Soldiers and systems whose decisions and actions must be synchronized to maintain effective combat output. Thus, not only must the Soldiers be capable of maintaining SA, but they must also be capable of maintaining shared SA with their fellow NGCV crew members and autonomous systems. In fact, developing appropriate SA has been shown to be a mission-critical goal for human–autonomy

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<sup>1</sup> Boyd JR. Organic design for command and control. A discourse on winning and losing. 1987 May;14.

<sup>2</sup> Endsley MR, Garland DJ, Wampler RL, Matthews MD. Modeling and measuring situation awareness in the infantry operational environment. TRW Systems Integration Group, Fairfax, VA, Systems Division; 2000 Jan 1.

<sup>3</sup> Smyth CC, Gombash JW, Burcham PM. Indirect vision driving with fixed flat panel displays for near-unity, wide, and extended fields of camera view. Army Research Laboratory (US); 2001. Report No.: ARL-TR-2511.

teams,<sup>4</sup> and human-autonomy SA has been named a critical DoD research area for successful teaming and team performance in the FOE.<sup>5</sup>

The US Army Combat Capabilities Development Command (DEVCOM) Army Research Laboratory's (ARL's) Human–Autonomy Teaming Essential Research Program (HAT ERP) and its Ground Vehicle System Center's Crew Optimization and Augmentation Technologies program have developed and tested five technologies designed to enhance capabilities for future Soldier–autonomy teams operating within an NGCV platoon to develop, maintain, and share SA within operational settings. The technologies tested included the following:

- Adaptive aided target recognition system: Methodology to improve aided target recognition (AiTR) system accuracy by leveraging Soldier input through targeted after action reviews.
- Commander's Interface: Toolset embedded in the Warfighter–Machine Interface (WMI) that provides a consolidated view of information related to vehicle, crew, and autonomy state.
- Human–autonomy playbook capabilities: Toolset embedded in the WMI (optionally in the Commander's Interface) that provides command and control capabilities to coordinate the execution of team responses to evolving situational needs.
- Task Switching: Extension to the human–autonomy playbook that enables a commander to orchestrate dynamic tasking of individual operators or agents through the WMI.
- Voice-based commands: Capability to interact with the WMI through verbal commands.

These technologies specifically targeted the FY21 NGCV stagegate for **“Technology aids to efficiently process and share critical data for enhanced mutual crew-agent situational awareness”**. The collective goal of these technologies is to

- enhance the speed and accuracy with which information about the battlefield environment is sensed,

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<sup>4</sup> Evans III AW. Safe operations of unmanned systems for reconnaissance in complex environments–Army technology objective field experimentation observations and Soldier feedback. Army Research Laboratory (US); 2012 July. Report No.: ARL-TN-0488.

<sup>5</sup> National Academies of Sciences, Engineering, and Medicine. Human-AI teaming: state of the art and research needs. The National Academies Press; 2021.

- enhance the speed and accuracy with which information is shared across the Soldier–Autonomy team to allow for greater team coordination, and
- decrease the workload associated with operating the NGCV.

Our research team executed a series of studies designed to evaluate the efficacy of the DEVCOM Army Research Laboratory technologies in achieving the described goals. Our primary experiment took the form of a simulation experiment (SIMEX) involving a three-vehicle NGCV section completing simulated missions against a live opposition force (OpFor). In this study, the NGCV crew completed 14 simulated missions over a 2-week period. Each mission required the crew to meet intermediate objectives while maintaining SA across the team. We examined the impact of each of the technologies on the crew’s ability to maintain SA and achieve mission objectives. In addition to the impact of the technologies, we also examined the impact of crew size (six- vs. seven-person crew) on the utility of each of the technologies for maintaining SA and the impact on the overall mission performance. In addition to the SIMEX, we ran two more focused studies to fully characterize the utility of the task switching capabilities and the adaptive AiTR (aAiTR) system in ways that were not possible in the larger SIMEX. Results from the combination of these three studies led to several key outcomes regarding the utility of the DEVCOM ARL technologies:

- The aAiTR system demonstrated a 433% improvement in target recognition accuracy after adaptation through a Soldier–autonomy after-action review.
- The Commander’s Interface streamlined information exchange between crew and commander, leading to a 75% decrease in requests for information throughout missions. Logical extensions to the Commander’s Interface could remove the requirement for these reports by providing persistent information availability across the platoon and higher echelons.
- The Automated Detection System reduced time to first shot fired at OpFor by 25%.
- The combination of all technologies resulted in a 46% decrease in decision making time for Soldiers to hit OpFor after initial detection.
- The combination of all technologies resulted in a 27% decrease in workload for six-person crews.

These findings demonstrate that the combination of the five technologies tested will enable an NGCV crew to rapidly attain and maintain the SA necessary to effectively make decisions in operational settings. Specifically, the aAiTR system demonstrates a capability to enhance the quality of sensed information from the

battlefield, and the Commander's Interface provides platoon and section leaders with timely access to pertinent information about current mission, enemy, terrain, troop, time, and civilian factors that allows them to rapidly make informed decisions on the battlefield. The play-calling and task-switching features embedded within the Commander's Interface provide necessary tools to share information and coordinate actions across the unit. The verbal commands streamline the interactions between each crew member and the embedded technologies in the WMI, thereby contributing to the efficiency with which each operator can act. Collectively these technologies enhanced SA and decreased the overall workload of the crew, especially at lower crew-agent ratios.

The present set of studies support the HAT ERP's successful completion of the FY21 NGCV stagegate, "Technology aids to efficiently process and share critical data for enhanced mutual crew-agent situational awareness". In a section-level experiment, we examined the effects of multiple technologies on joining crew-autonomy SA. The results of the SIMEX will inform future technology development. Additionally, two stand-alone studies showed the effects of task-switching on crew performance in NGCV tasks and that an aAiTR pipeline reduces workload while maintaining performance. Overall, these capabilities will improve responsiveness, resiliency, and performance of human-autonomy teaming in the FOE. While these capabilities will be demonstrated in ground vehicle crews of the NGCV, the foundational work underpinning these capabilities can translate to other application spaces where teams composed of Soldiers and autonomous systems operate in complex, high-operational-tempo mission environments.

## List of Symbols, Abbreviations, and Acronyms

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aAiTR	adaptive AiTR
AI	artificial intelligence
AiTR	aided target recognition
ARL	Army Research Laboratory
DEVCOM	US Army Combat Capabilities Development Command
ERP	Essential Research Program
FOE	Future Operating Environment
FY	fiscal year
HAT	Human–Autonomy Team(ing)
MCV	manned control vehicle
NGCV	Next Generation Combat Vehicle
OODA	observe-orient-decide-act
OpFor	opposition force(s)
RCV	robotic combat vehicle
SA	situation awareness
SIMEX	simulation experiment
WMI	Warfighter–Machine Interface

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