Automotive Research Center

Call for White Papers

Funding Opportunity Announcement
for Calendar Year 2025

Issue Date	**July 22**
Information Webinar	**August 6**
Submission Deadline for White Papers	**August 16**
Expected Feedback on White Papers	**September 6**
Deadline for Full Proposals	**October 11**

Table of Contents

1. Automotive Research Center

The Automotive Research Center (ARC) aspires to be the preeminent research organization for the US Army in the areas of modeling, simulation, and digital engineering of ground systems, with an emphasis on fundamental and convergent research efforts in autonomy.

The **ARC mission** is to develop cutting-edge modeling and simulation knowledge and technology for discovering and assessing critical ground systems for military-relevant operations. These encompass technology, human factors, and social behaviors that work in harmony to realize ground systems able to operate in stochastic, harsh, uncontrolled environments, with high mobility over a variety of terrains, and with high adaptability and teaming capabilities in the face of adversaries and constrained fuel supplies.

The **ARC focus** is to advance off-road mobility and operations of heterogeneous teams of humans and adaptable autonomous vehicles. This requires ARC projects to address a set of complex, interdisciplinary, multiphysics, multiscale challenges, for which the ARC employs experimental facilities for verification and validation, as well as for supporting integrative efforts.

The ARC invites white papers from the community of researchers at all its current partner universities. Research ideas that seek to answer fundamental research questions and fit the ARC mission and focus are welcomed. This document outlines specific research topics of interest in five thrust areas (TAs):

TA1. Vehicle Dynamics, Control, and Autonomous Behavior
TA2. Human-Centered Design and Human-Autonomy Teaming
TA3. High Performance Structures and Materials
TA4. Intelligent Power Systems
TA5. Fleet Operations and Vehicle System of Systems Integration

2. Funding Opportunity Description

The ARC welcomes white papers focusing on fundamental research in autonomy that assists the urgent modernization needs of the US Army by enabling advanced digital engineering for a faster pace of prototyping and experimentation. The focus is on digital engineering that considers the conceptualization, design, and analysis of systems with integrative models comprising structures, dynamics, controls, power systems, terramechanics, autonomous behaviors, humans and human-machine integrated formations.

The research topics of interest relate to scenarios in which multiple teams of humans and vehicles operate in adversarial environments with partial or uncertain information and communication. From the perspective of the ARC and GVSC, human/autonomy teams assume the following characteristics. Teams can comprise human Soldiers, directly human-operated vehicles, teleoperated vehicles, and autonomous vehicles. Soldiers and autonomous vehicles self-organize hierarchically. They use digital engineering to dynamically adjust their behaviors with new orders and information. Teams adapt structurally with diverse capabilities exploiting the adaptive and advanced architectures of vehicles enabled by tools such as digital twins. Vehicles are designed using digital technologies such that they can be reconfigured or repaired when damaged by swapping components, with seamless integration. Vehicles learn to adapt their behavior and have decentralized, secure information coordinated with humans. Digital technologies enable adaptive learning algorithms and secure, decentralized information systems for human-autonomy integration. Vehicles use multiple modalities and advanced adaptive interfaces to communicate effectively with humans through advanced digital technologies. Vehicles deploy means of concealment and deception to better protect themselves and humans.

The goal of the white paper submission is to enable PIs to articulate their novel ideas that can be developed into full proposals in collaboration with GVSC researchers. Details are provided below for each ARC Thrust Area.

Key ARC resources are available to enable ARC researchers to evaluate methods and algorithms in synthetic environments and in the real world. These resources include:

- Two instrumented autonomous vehicles,
- A high-fidelity synthetic environment for off-road studies,
- Advanced integrated motion-based simulators for autonomous vehicles and teams.

<u>Proposed methods that are integrated into and/or demonstrated with these resources are highly encouraged. Proposed autonomy algorithm development efforts should include demonstrations using either full vehicle testing or simulations that use military-relevant autonomy stacks such as GVR/GVSC RTK/ARCS, NATO, or ARL Phoenix.</u>

TA1. <u>Vehicle Dynamics, Control, and Autonomous Behavior</u>: Consider a future where vehicles have adaptive, transferable vehicle-level behaviors and controllers, gaining experience from working with Soldiers and other vehicles. Their behaviors are not constrained to a specific physical embodiment and can be shared or moved between assets with similar system dynamics. Vehicles are flexible and adaptable to allow the exchange of attributes or capabilities among them through module exchange and digital technologies such as virtual models and digital twins. Assets make real-time, vehicle-level decisions in complex, uncertain, adversarial, and dynamic environments, while being informed of or reading environmental conditions in real time. Vehicles have diverse capabilities, which give them adaptability and resilience while benefiting from commonality for cost effectiveness. Vehicles have enhanced reliability beyond the 5-7 year expected lifespan of current commercial products. Autonomous systems have increased readiness despite not having a crew to conduct systematic maintenance procedures.

TA1 white papers should focus on digital engineering technologies, modeling and simulation methods, and algorithms for autonomous off-road mobility near vehicle performance limits. Proposed solutions should address the following technology gaps:

1. <u>Algorithms and methods to extend the spectrum of operational design domains</u> (ODDs) possible today through approaches scalable to complex off-road environments and dynamically changing mission requirements, tolerant to partial information, uncertainty, and failures, that can allow the vehicles to maintain operations and/or tempo without requiring physical human intervention for long durations, that can automatically learn either in an unsupervised way or given a limited amount of manually labeled training data, or can rely on synthetic environments

for training, and are designed for self-aware and adaptive vehicles with faster-than-real-time decentralized decision-making in unstructured environments with high uncertainty and intelligent adversarial actions. This includes digital engineering tools to develop and test these algorithms and methods in synthetic environments, providing scalable and adaptive solutions for complex off-road scenarios.

2. Digital engineering solutions such as predictive algorithms, data management and integration, and performance metrics that assist in the sustainment and reliability of both manned and autonomous systems, which can demonstrate system resiliency, adaptation with partial system observability, and recovery from failures caused by military operations and off-road environments that can adversely affect vehicle mobility, e.g., sensor degradation, internal system faults and errors, and false or incorrect information from teammates.

3. Advanced computational methods and digital platforms for onboard applications with low-energy consumption, offboard applications with high performance, and offboard analyses with scalability and efficiency for off-road mobility and operations of autonomous vehicles, such as fusion of various sensor modalities, neuromorphic or quantum computing, machine learning, foundational models, and generative AI-based design; proposed methods are expected to be superior to classical methods in 5-10 years, and their proof-of-concept demonstrations must be performed in the project in at most 2.5 years.

White papers that address the technology gaps above are of interest to the ARC. Particular example topics of high interest include:

(a) System architectures and digital engineering to create such system architectures designed and optimized for continued remote usage and utility without physical intervention from a human over long periods of time by being able to change their behavior and to adapt while operating in response to changes in their environment, capabilities, and goals.

(b) Algorithms for advanced decision making that enable vehicles to operate autonomously in larger ODDs for long durations without physical intervention from a human, e.g. with extreme autonomous mobility on challenging off-road terrains, as well as digital engineering methods to validate these algorithms.

(c) Physical and digital experimentation and robust validation of models of vehicles, environments, and algorithms, including digital engineering methods and platforms to measure, characterize, and validate autonomy performance using data types that include synthetic physics-based data.

TA2. Human-Centered Design and Human-Autonomy Teaming: Consider a future where Soldiers train with both autonomous vehicles and on-vehicle autonomous agents to experience and understand each other's capabilities and preferences. Vehicles and on-vehicle autonomous agents use digital engineering and advanced human-machine interfaces to customize and adapt their behaviors to match Soldiers' preferences as well as the mission needs. They collaborate with humans, providing feedback to them, thereby supporting human-machine integrated formations. In certain operational scenarios, Soldiers need to provide only high-level commands, and vehicles produce a traceable response plan of how to execute these commands. Digital engineering technologies are used to support the creation of systems that generate traceable response plans from high-level commands, ensuring transparency and reliability in autonomous operations. This enables systems with increased complexity to be operated by a smaller number of Soldiers although systems have increased multi-functional performance requirements and capabilities of multi-domain teaming of multiple autonomous systems and a few humans.

TA2 white papers should focus on human-autonomy interactions for teams and human-machine integrated formations operating in off-road, adversarial conditions. Proposed solutions should address the following technology gaps:

1. Human-autonomy communication: digital engineering methods, models and control techniques for physical and cognitive interactions of humans and autonomous systems that provide context-accurate, real-time communication and consider factors including: (i) cognitive load capability, (ii) active information gathering, (iii) management of potentially incorrect or error-prone information, (iv) approaches to address system anomalies and recovery, and (v) bi-directional transparency of state. These models and controls are supported by human-autonomy interaction methods such as augmented and virtual reality (AR/VR).

2. Human-autonomy collaboration and control: methods for estimation and management of collaborative feedback between vehicles and humans to support off-loading of traditional Soldier functions to autonomy, reduce overall crew member cognitive burden, and increase team situational awareness, including bi-directional trust between humans and autonomous vehicles, mode-switching and monitoring of collaborative interactions in teams of vehicles and humans. This includes digital engineering platforms to create and test collaborative feedback methods, enhancing human-autonomy interaction and increasing team situational awareness.

3. Advanced formations: methods for human-machine integrated formations, in which autonomous systems seamlessly augment and enhance the capabilities of Soldiers to multiply the number of assets that can be controlled, monitored and operated by a few humans.

White papers that address the technology gaps above are of interest to the ARC. Particular example topics of high interest include:

(a) Methods to identify human/autonomous system's intent to gain context-aware interpretation of both human and autonomous system behavior, including digital engineering methods that account for collaborative interactions during task completion, allocation, and hand-off.

(b) Advanced human-autonomous system interfaces and advanced modalities of interaction, and better understanding of the interface requirements for safe and effective operation off-road with a few humans controlling many heterogeneous autonomous systems (10+) across air and ground domains simultaneously while the human operators are on the move (within a command-and-control vehicle and/or dismounted).

(c) Synthetic environments and experiment design methods based on digital engineering to measure, characterize, validate, and improve human-autonomy teaming performance when employing AI/ML techniques.

TA3. High Performance Structures and Materials: Consider a future where autonomous military vehicles have a wide range of sizes and capabilities, where military ground vehicles start with a common platform, but uses digital engineering and a modular structure that enables adaptability to diverse missions. Consider that parts to meet mission requirements can be designed, produced and repaired at the point of need using digital engineering tools such as simulators, emulators, and digital twins to ensure performance. These future vehicles have advanced autonomy capabilities that give them awareness of their structural integrity, the ability to self-repair, and the ability to make decisions about configuration based on the proposed mission profile. The physical components that provide autonomy capabilities are robust and protected from physical threats, but still lightweight and easily integrated into the vehicle. The integration of advanced digital engineering validates sensor systems that provide real-time structural health monitoring and decision-making capabilities. The management of structural performance is done autonomously and is particularly important when humans are not closely managing the system. Thus, a key research question emerges: What materials and structures will support military ground vehicle autonomy and modularity?

TA3 white papers should focus on modeling, simulation, and discovery of new materials, processing methods, and advanced structures for autonomous vehicles with adaptability and multi- functional capabilities. Proposed solutions should address the following technology gaps:

1. Materials: design of material concepts, including smart materials, which enable lightweighting while retaining the ability to meet complex mission requirements or allow structures and vehicle components to perform additional functions, such as vehicle diagnostics, reconfigurability or field self-repair, while sustaining large dynamic loads, including developments based on advanced multiscale, AI/ML, big data methods, foundational models, or quantum computing.

2. Structures: methods for the design and sustainment of lightweight, resilient, and smart structures, and methods to leverage advanced manufacturing such as solid-state additive, for vehicles without occupants. This includes methods for co-optimization of autonomous mobility at high speed, high strain rate mechanics, perception-enabled configurability to enhance performance, as well as modeling and simulation of structures designed to propagate waves for applications such as 4D radar and frequency-modulated continuous wave radar.

3. Running gear-soil interactions: computationally efficient modeling approaches and algorithms for off-road mobility simulations (such as quantum computing and tensor network for simulating the interaction of elastomer running gear and terrain), extending terramechanics beyond the traditional weight ranges of current vehicles, and improving models for elastomers. This includes: methods that use digital soil mapping to enhance the fidelity of off-road mobility simulations, models of complex soil conditions (wet, vegetation, mixed phase), frameworks for large visco-elastic calculations, materials and methods for keeping exterior sensors and emitters free from fouling, and integration of multispectral LiDAR and hyperspectral sensors into terramechanics and other off-road mobility applications.

White papers that address the technology gaps above are of interest to the ARC. Particular example topics of high interest include:
(a) Damage tolerant and self-healing materials and structures for lightweight vehicle components for maximized functionality, structural adaptation, and repair after an incident to enable vehicle behavior adaptation and the safe retrieval of autonomous assets.
(b) Computationally efficient algorithms for off-road mobility (e.g., running gear-terrain interaction models) and for optimization of autonomous vehicles considering high strain rate mechanics and as-manufactured material performance.
(c) Digital twins of structures and materials that can predict performance to aid in the design of sustainable and resilient systems and materials capable of autonomously reconfiguring to operate in wide ranges of environmental conditions.
(d) Digital discovery and design of autonomously self-cleaning materials that resist sticking of environmental materials such as dust, mud, water, and oil, and shock-absorbing and vibration damping materials.

TA4. Intelligent Power Systems: Consider vehicle operations in contested logistics where asset-level decision-making algorithms are cognizant of real time power system capabilities and failures through digital twin technologies. Moreover, intelligent power systems use digital engineering methods to anticipate and forecast asset-level power requirements and capabilities and change their behavior and operation accordingly. Thus, power systems learn not only from their own past operational experiences but also from the experiences of other auxiliary or supported systems. Digital engineering is used to enhance autonomous power management, which is important for reliability when humans are not closely monitoring/managing the system.

TA4 white papers should focus on intelligent power systems with heterogeneous energy sources for adaptability, management of operational energy, and decision-making support, and they should highlight how the proposed digital engineering methods can improve these systems by integrating real-time data, predictive analytics, and advanced control algorithms to boost autonomy. Proposed solutions should address the following technology gaps:

1. Adaptability: enhancing power system adaptability for individual vehicles and teams of vehicles using new architectures and materials that allow optimal control and real-time transformations during each mission, including the incorporation of heterogeneous energy sources (including hydrogen) and carriers with robust autonomous reconfiguration functionality.

2. Intelligence: enhanced decision-making regarding operations by understanding and predicting the power system needs through real-time self-awareness, including self-diagnostics, self-calibration, self-identification of performance, and energy management strategies for fleets.

3. Digital engineering methods: AI/ML and quantum computing techniques for power systems to maximize mission effectiveness, and energy optimized solutions for autonomy, low signature, directed energy weapons and communications.

White papers that address the technology gaps above are of interest to the ARC. Particular example topics of high interest include:

(a) Sensing and perception modalities, diagnostics, architectural designs, algorithms for autonomous assets to ensure intelligent, resilient, efficient, and effective power systems, including advanced digital twin models, optimized system architectures, and AI-powered algorithms through digital engineering.

(b) Decentralized algorithms for real-time robust adaptation of power systems on teams of vehicles to new information and new demands, digital engineering for integrating real-time sensor data, enabling immediate adjustments in power distribution, and advanced AI techniques for predicting future power needs, allowing dynamic resource allocation.

(c) Power trade space analysis and analysis of sustainment and operational requirements without decreasing effectiveness, including methods for detection of capability degradation, and methods to leverage digital engineering for comprehensive simulations and evaluations, enabling informed decisions on system trade-offs and configurations.

TA5. Fleet Operations and Vehicle System of Systems Integration: Consider a future where multi-agent systems with various levels of autonomy work together develop distinct behaviors over time. Teams autonomously create a hierarchy of tasks and form dynamic team structures in real time, which are adaptable and capable of coordination, negotiation, sharing and balancing of objectives. The system has a hierarchical structure for decision-making by autonomous assets. All types of communication and interactions occur among vehicles in a military tactical network, which uses AI/ML and big data methods to monitor and assess the self-assignment of mission functions and roles to the various assets. Fleet operations consider all interactions and leverage battle management, command, control, computers, communications, cyber, intelligence, surveillance and reconnaissance (BM/C5ISR). Vehicle communications can be disrupted or limited due to operation in unstructured and adversarial environments. Vehicles are diverse, with a mix of small and large sizes; large in numbers, and highly mobile. Cooperation allows collective sensing and perception within the team, making use of agents cognizant of failure probabilities.

TA5 white papers should focus on modeling and simulation, digital engineering, and model-based system engineering for heterogeneous multi-vehicle operations and teaming including design, control and integration. Proposed solutions may consider any aspect of the system life cycle (design, development, manufacturing, deployment, and sustainment), but should address the following technology gaps:

1. Novel digital engineering methods for trade space analysis that enable more effective and/or efficient evaluation of the interaction and impact of setting vehicle performance requirements for multiple vehicles across multiple disciplines and capability areas in complex operations such as those involving human-machine integrated formations. Developing and using operational effectiveness analysis and wargaming for product design and development, and new ways of visualizing trade space analysis results are also of interest.

2. Strategies and integrated digital engineering methods for lifecycle and dynamic management, requirements development, and performance evaluations of multiple heterogeneous vehicles in teams/formations (units) to exploit their collective, evolving operational capabilities; while considering them subjected to uncertainty associated with the environment, the mission, and design changes.

3. Decision-making and autonomous hierarchical organization in systems of teams with decentralized communication and complex adversarial demands, including context-accurate dynamic task allocation, with strategies for the creation, maintenance, and modification of human-machine integrated formations according to adversarial factors, context, and purpose.

4. Digital engineering for system of systems integration and optimization accounting for modular open systems approach in design, development, manufacturing, deployment, and logistics that consider vehicle connectivity, power/energy logistics and coordination using advanced control, agile model-based system engineering, AI/ML and generative AI to allow adaptation, enhanced readiness and performance.

White papers that address the technology gaps above are of interest to the ARC. Particular example topics of high interest include:

(a) Real-time decentralized control, coordination, and teaming strategies for human-machine integrated formations and robust adaptation to new and potentially incorrect information, and to changes in team behavior and composition (e.g., agents removed or added) in uncertain, unstructured, adversarial environments.

(b) Digital engineering methods to enhance resilience in teaming and formations as well as methods to design communication architectures for unconfirmed information, communication failures, and asset damage, including methods to detect capability degradation or failures of other assets or an asset's own failure.

(c) Digital engineering methods for design, operation, logistics, and system of systems modeling to identify and manage expected energy needs from restricted or partially observable environments to meet mission and energy requirements.

Crosscutting Research: In addition to TA-specific topics, crosscutting fundamental research that integrates solutions across TAs is of interest to the ARC. Convergent digital engineering methods and algorithms integrated and demonstrated on ARC software or vehicle platforms are highly encouraged. This includes but is not limited to fundamental research focused on development of:
(a) Methods and metrics for high-fidelity verification, validation, and testing of algorithms.
(b) Tools to construct synthetic environments with adjustable fidelity and gaming methods.
(c) Digital engineering methods and trade space methods for managing the granularity of autonomous behavior that explore system architecture in addition to parameter sweeps.

3. Application and Submission Information

The ARC welcomes single PI proposals and collaborative proposals with multiple PIs and larger scope. White papers should closely follow the following format:

A. Cover page (**limit of one page**, containing A.1-4, no other information allowed on this page):
   - A.1. proposal title,
   - A.2. research team members: name, position, affiliation, email, phone for all PIs, Co-PIs, research investigators, students, as well as GVSC and industry quad members,
   - A.3. estimated budget and duration (2-3 lines only, typical/expected duration is 2–3 years),
   - A.4. brief budget justification (2-3 lines only).

B. Narrative (**limit of one page**, including graphics and tables):
   - B.1. problem statement (including the state-of-the-art) and uniqueness of proposed research,
   - B.2. fundamental research questions and their novelty,
   - B.3. approach, highlighting original contributions,
   - B.4. primary expected outcomes, and plans to make research results reproducible,
   - B.5. relevance of the proposed work to the ARC topics listed in this call.

C. List of references cited in the narrative (**no page limit** for the list of references).

Please use single spacing, Arial font of size 11 or higher, and margins of at least 1” on all sides.

Please address white papers to Prof. Bogdan Epureanu, ARC Director, and submit them by **August 16 at 5 PM Eastern** via e-mail in a **single PDF file** to Mr. William Lim, ARC Program Manager, at choonhun@umich.edu with **e-mail subject:** “**ARC FY25 call for white papers”**.

White papers will be evaluated by GVSC researchers and the ARC leadership. Following that, the PIs will be provided guidance regarding potential full proposals, namely:
1. Full Proposal Encouraged, or
2. Full Proposal Not Encouraged.

The outcome of the white paper evaluation will be communicated by September 6.

An **information webinar** held by Prof. Bogdan Epureanu, ARC Director, will **begin at 11 AM Eastern on August 6**. Connection details:
Web: https://umich.zoom.us/j/93386747704
Passcode: 019288
Call-in number: (669)-444-9171
Meeting ID: 9338 6747 704