Research Article

Sustaining Resilient Military Training in the Multi-Domain Era: Challenges and Opportunities

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Abstract: The rapid evolution of warfare in the modern multi-domain battlespace necessitates a corresponding transformation in military training and education. The 21st-century battlefield is increasingly complex, with technology and the operational environment changing at an unprecedented pace across all domains—land, air, sea, cyber, and space—while major opponents of Western alliances continue to strengthen and coordinate their economic and military power to challenge the international order. The ongoing Russian war in Ukraine starkly illustrates the dynamic challenges of the modern battlespace and underscores the need for military instruction systems that are both resilient and adaptable. This article explores the "train *while* we fight" concept as a paradigm for addressing the challenges and opportunities in military education and training, emphasizing that learning must be continuous, adaptive, and integrated into operational activities. We analyze the growing role of Advanced Distributed Learning in education and training, highlight the need for multinational cooperation to build and sustain training resilience, and examine innovative instructional approaches inspired by fields such as lean manufacturing, mass customization, personalized learning, and on-demand content production.

Keywords: ADL, training, train while we fight, resilience, training design, on-demand content, mass customization, personalized learning.

Introduction

As conflicts evolve and new threats emerge, the ability to sustain effective military training and education during wartime becomes essential for military suc-

cess and national security. This requires updating training content and adapting training methodologies and platforms to effectively leverage new technologies. The challenge lies in creating training systems that are flexible enough to quickly incorporate new technologies while ensuring that the fundamental skills and knowledge required for military operations are not lost in the rush to embrace the latest innovations.

In this context, the concept of "train *while* we fight" has emerged as a critical paradigm for modern military forces.[1] This approach recognizes that in the fast-paced, ever-changing environment of modern warfare, training cannot be confined to dedicated periods separate from combat deployments. Instead, training must be continuous, adaptive, and seamlessly integrated into operational activities. The technology underlying the "train *while* we fight" concept must be as resilient as possible. This article examines the obstacles in the current military training environment and highlights the cutting-edge solutions being developed and implemented to address them. It also analyzes the role of Advanced Distributed Learning (ADL) in education and training, explores innovative approaches inspired by lean manufacturing principles, and considers the necessity of multinational cooperation to build and sustain training resilience.

"Train *While* We Fight"

Russia's war in Ukraine and other international conflicts demonstrate that modern warfare is global, heavily dependent on information technology, and fought across all operational domains – air, land, sea, cyber, and space. Military forces must be flexible, mobile, interoperable, decentralized, yet networked. Anything that utilizes information technology—nearly everything in the modern battlespace—is vulnerable to cyberattacks and must be defended from adversaries' constant, evolving cyber operations. That is how we fight, and it informs a new paradigm for military education and training. The "train *while* we fight" approach emphasizes the need for resilient, interoperable learning infrastructure that can withstand physical and cyber attacks and then quickly recover from disruptions while providing personnel with responsive, up-to-date instruction when, where, and how they need it.

In the modern battlespace, deployed forces require continuous education and training to fight effectively, adapt to new situations, and manage battlefield losses.[2] Resilience is crucial for the "train *while* we fight" learning systems that provide this essential instruction. Training and education infrastructure and facilities are military targets and will be damaged or destroyed during wartime.

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[1] Partnership for Peace Consortium ADL Working Group, "Training While We Fight: Lessons from Ukraine's Use of Distributed Learning in War," *Information Paper*, April 20, 2023, https://www.pfp-consortium.org/media/471/download.

[2] Partnership for Peace Consortium ADL Working Group, "Training & Education in War: Ukrainian MILMED Requirements: Information Paper on Ukraine Military Medical Training and Education Requirements," December 14, 2023, https://www.pfp-consortium.org/media/488/download.

Therefore, education and training systems must be robust enough to withstand physical and cyber attacks, redundant to ensure continued access to instruction when parts of the system are inoperable or restricted, resourceful in creating and distributing content, and rapidly recoverable from inevitable successful attacks. Networking learning systems among allies, particularly those located far from the likely battlespace, can also enhance resilience and ensure continuity of instruction.

The responsive integration of real-world experiences into training programs is a key element of the "train *while* we fight" approach, ensuring that personnel are always prepared for the most current operational challenges. Content delivery must be readily adaptable, with instructional materials designed for rapid updates and dissemination to reflect evolving operational realities. Training content should incorporate lessons learned from ongoing operations, creating a feedback loop between operations and training that allows each to inform and improve the other. Warfighters with battlefield expertise should also play a more active role in learning content creation. Artificial intelligence and machine learning can be utilized to analyze battlefield data, create learning content, and automatically update training scenarios, further accelerating the distribution of the most current and relevant information to personnel accessing learning materials.

Decentralized instruction plays a crucial role in the "train *while* we fight" paradigm, with learning content delivered through a mix of in-person, digital, and hybrid tools. Centralized education and training facilities are vulnerable to incapacitating cyber and physical attacks. By leveraging technology to provide training across geographically dispersed locations, reliance on easily targetable and hard-to-rebuild sites is reduced. Additionally, digital learning tools are uniquely suited for supporting frontline performance and optimizing training, offering flexible, on-demand content accessible by personnel in the field through secure, encrypted networks.

E-learning interoperability standards[3] have matured and spread in recent years. Yet, allies and partners are not effectively leveraging this interoperability with a systematic approach to sharing, collaborating, or capitalizing on economies of scale. As a result, individual nations inefficiently expend finite resources, creating similar digital learning content instead of developing the capability for the effective joint use of common e-learning materials.

Process and policy barriers currently complicate the sharing of digital learning content, presenting four notable challenges: the lack of clarity and markings for classification; the lack of clarity and markings for copyright information and version control; language barriers stemming from training designs that have historically been nationally centralized; and the absence of systematic national and multilateral mechanisms to support the discovery and sharing of available mate-

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[3] Such as the Sharable Content Object Reference Model (SCORM), Experience Application Programming Interface (xAPI), and Learning Tools Interoperability (LTI).

rials.[4] Placing shareability at the core of digital content production—"designed to share"—will help allies and partners maximize the cost and quality advantages of distributed learning.[5]

Benefits and Challenges of Multinational Cooperation

In this era of interconnected global security challenges, multinational cooperation in military education and training is critical to enhancing and sustaining the resilience of learning systems and strengthening the interoperability of allied forces – a cornerstone of modern coalition warfare. In the context of training, interoperability goes beyond compatible equipment or shared doctrines. It encompasses a shared understanding of tactics, techniques, and procedures and integrates the cultural awareness and communication skills necessary for effective coalition operations. The key benefits of multinational cooperation in education and training include:

- *Sharing of resources, expertise, and costs*. Not every country has the capacity to develop comprehensive training programs for every possible scenario or technology. By pooling resources, allied nations can create more robust and diverse training opportunities than they could individually. Likewise, as training technologies become more sophisticated and expensive, sharing the financial burden across multiple nations makes cutting-edge training capabilities accessible to a broader range of allies.

- *Development of common standards and protocols*. When allied forces train together regularly, they naturally develop shared approaches to common challenges. This standardization enhances interoperability in both training and real-world operations, enabling multinational forces to come together more seamlessly when needed.

- *Cross-cultural understanding and communication.* The soft skills developed through working with personnel from different national and cultural backgrounds are invaluable in coalition operations. Regular multinational training fosters personal relationships and mutual trust, which can be crucial in high-stress operational environments.

- *Innovation catalyst.* Different nations contribute their unique perspectives and expertise to shared education and training initiatives. This cross-pollination of ideas can lead to the development of novel training approaches that might not have emerged within a single national context.

- *Rethinking national classification of information.* Sharing a learning platform is only effective if content can also be shared on it. Every nation

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4   Aaron Presnall, *ADL Content Sharing: Report and Recommendations* (Washington, D.C.: Jefferson Institute, March 2020).

5   Partnership for Peace Consortium ADL Working Group, "Sharing Digital Learning Content Among Allies and Partners," *Information Paper*, February 2025, https://www.pfp-consortium.org/media/621/download.

involved in the "train *while* we fight" paradigm must review its national classification guidelines to maximize content sharing. This not only ensures the continuity of training in case of the destruction of national learning infrastructure but also allows nations to assist others by sharing already developed content.

While multinational cooperation in education and training offers significant benefits, it also presents unique challenges. Language and cultural barriers can complicate training efforts, requiring careful planning and additional resources for translation and cultural liaison. Additionally, national military cultures vary, with different approaches to training methodologies or leadership styles, which must be reconciled for effective joint training. Technological disparities can also hinder multinational cooperation. For example, some nations may have access to advanced simulation systems or virtual reality training platforms, while others may still rely more on traditional training methods. Furthermore, sharing training content and data across national boundaries raises concerns about operational security and national sovereignty. Balancing the need for openness and collaboration with the requirement to protect sensitive information is a delicate task that requires careful management and robust security protocols.

Creating shareable learning content is only half the battle; allies and partners also need a clear and easy way to identify and access available materials. Content owners and managers should compile catalogs of shareable content using tagging, collation, and curation. They should also adhere to a standard format for naming conventions and metadata schema detailed in documents like the *NATO ADL Handbook*.[6] Adhering to these standards would make individual repositories accessible for search by allied and partner nations, and it would facilitate the development of a "catalog of catalogs" managed by an appropriate central coordinating body.

NATO Leadership in Sustaining Resilient Multinational Training

For decades, NATO has been at the forefront of promoting multinational cooperation in military education and training.[7] However, NATO doctrine currently does not provide allies and partners with overall guidance for interoperable instruction, nor does it outline specific direction on standardized approaches for integrating traditionally national learning systems. Additionally, the Alliance lacks a dedicated organizational structure to coordinate the development and

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6   NATO Training Group, Task Group for Individual Training & Education Developments (IT&ED), *The NATO Advanced Distributed Learning Handbook: Guidelines for the Development, Implementation and Evaluation of Technology Enhanced Learning* (NATO, January 2023), https://adlnet.gov/publications/2023/02/The-NATO-Advanced-Distributed-Learning-Handbook/.

7   "NATO Education and Training," NATO Allied Command Transformation, accessed December 13, 2024, https://www.act.nato.int/activities/nato-education-and-training/.

implementation of resilient, responsive, and interoperable education and training capabilities.

The rising challenge of cognitive warfare is directed at allies and partners as a community, with potential implications for international stability.[8] An effective response requires a partnership-driven approach underpinned by an operational framework aligned with common interoperable technology and policy standards. These standards should support the sharing and localization of learning content for all personnel, increasing their awareness of cognitive warfare and their capacity to counter it.[9]

Change is on the horizon. The NATO Learning and Technology Interoperability Group, co-chaired by NATO ACT and national leadership, is charged with maintaining NATO's standards for distributed learning (STANAG 2591) and has recently initiated the development of standards to enhance the federation of national learning systems.

Any innovative effort to expand sustainable military education and training in wartime should pursue four main objectives: 1) enhance network resilience and accessibility by improving distribution and redundancy; 2) ensure that all personnel have the necessary tools and connectivity to access learning resources effectively; 3) update and optimize existing content and methods to improve accessibility and efficiency; and 4) create and adapt instructional materials to address both current needs and rapidly changing environments. New NATO guidelines on learning technology interoperability will further support allies and partners in developing sustainable, resilient education and training systems that enable them to train while they fight:

- Improve access to learning resources and optimize connection quality by linking national military training networks and replicating content across different locations.

- Increase access to instructional materials by making learning platforms available on personnel's official or personal mobile devices or laptops, ensuring reliable and secure internet access—particularly in crisis and war zones—and providing 24/7 technical support for hardware, software, and connectivity issues.

- Shift the focus of education and training to e-learning and blended learning to maximize adaptability and resource efficiency. Expand the availability of existing content by lowering classification levels to unclassified whenever possible.

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8   Jean-Marc Rickli, Federico Mantellassi, and Gwyn Glasser, "Peace of Mind: Cognitive Warfare and the Governance of Subversion in the 21st Century," *GCSP Policy Brief* 9, Geneva Center for Security Policy, August 25, 2023, https://www.gcsp.ch/publications/peace-mind-cognitive-warfare-and-governance-subversion-21st-century.

9   Partnership for Peace Consortium ADL Working Group, "Countering Cognitive Warfare with Advanced Distributed Learning," *Information Paper*, February 2025, https://www.pfp-consortium.org/media/622/download.

- Accelerate the development of new learning content by swiftly integrating lessons from war zones and adjusting doctrines for rapid response.

Advanced Distributed Learning (ADL)

ADL is revolutionizing how military forces conceive and deliver instruction. The mainstreaming of e-learning in military education and training mirrors the rapid technological advancements of the past few decades. Initially focused on converting traditional classroom-based courses into digital formats, ADL has since expanded to encompass a wide range of technologies and methodologies aimed at delivering effective, accessible, and adaptable training solutions. The integration of ADL into military training systems can significantly enhance their resilience in several ways:

- *Reduced reliance on physical infrastructure*. ADL systems enable remote and distributed learning, reducing the vulnerabilities associated with centralized training facilities.

- *Rapid content updates*. Digital learning content can be quickly updated and disseminated to reflect changes in tactics, equipment, or threat landscapes. AI tools can also facilitate extremely fast content creation and updates.

- *Continuous learning*. ADL allows personnel to engage in ongoing skill development and knowledge acquisition, even during deployment or in austere environments.

- *Enhanced interoperability*. Standardized ADL systems can facilitate training across multinational forces, improving interoperability and fostering shared understanding.

- *Data-driven insights*. ADL systems can collect and analyze learning data to continually enhance training effectiveness and identify areas needing attention.

ADL ecosystems are often built around platforms for delivering, tracking, and managing training content—Learning Management Systems (LMS)—and leverage mobile devices, such as smartphones and tablets, to deliver training content anytime, anywhere. Distributed learning can include simulation and virtual reality, creating immersive training environments that enable realistic scenario practice without requiring physical resources. It also incorporates microlearning: short, focused learning modules that can be easily consumed during operational downtime. Programs like the U.S. Army's STEEL-R demonstrate how ADL increasingly utilizes artificial intelligence and adaptive learning to tailor learning experiences to individual needs and provide intelligent tutoring.[10]

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[10] Aaron Presnall, Biljana Presnall, and Benjamin Goldberg, "STEEL-R in Multinational Joint Training Exercises (STEEL-Rx)," in *Proceedings of the Twelfth Annual GIFT Users*

Substantial evidence supports the effectiveness of distributed learning as an instructional tool. A meta-analysis [11] of studies on mobile learning conducted in 2020 found a significant positive impact on learning outcomes. Similarly, a 2010 meta-analysis conducted by the U.S. Department of Education [12] revealed that students learning online outperformed those receiving face-to-face instruction, particularly when online learning was combined with collaborative or instructor-led methods. Furthermore, a 2022 meta-meta-analysis by the U.S. Department of Education [13] demonstrated a consistent advantage for online learning across a broad range of research. Additional meta-analyses have identified positive effects from key e-learning components, including multimedia design principles,[14] simulation games used for instruction,[15] and self-regulated learning [16] facilitated by many ADL systems.

Novel Strategies for Improving Education and Training

As nations grapple with the challenges of military education and training for multi-domain operations in an increasingly complex and unpredictable environment, they turn to innovative approaches drawn from civilian fields. These novel strategies aim to enhance learning systems' resilience, efficiency, and effectiveness.

Lean Principles in Training Design

The concept of "lean" originated in the manufacturing sector, particularly with Toyota's production system, but its principles have since been applied across

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Symposium, May 2024, Orlando, Florida, ed. Anne M. Sinatra (U.S. Army Combat Capabilities Development Command – Soldier Center, 2024), 119-126, https://gifttuto ring.org/attachments/download/4842/GIFTSym12Proceedings_Final.pdf.

11 Tarik Talan, "The Effect of Mobile Learning on Learning Performance: A Meta-Analysis Study," *Educational Sciences: Theory & Practice* 20, no. 1 (2020): 79-103, https://jest p.com/article-detail/?id=771.

12 Barbara Means et al., *Evaluation of Evidence-Based Practices in Online Learning: A Meta-Analysis and Review of Online Learning Studies* (Washington, D.C.: U.S. Department of Education, September 2010), https://www.ed.gov/sites/ed/files/rschstat/ eval/tech/evidence-based-practices/finalreport.pdf.

13 Florence Martin et al., "Examining Research on the Impact of Distance and Online Learning: A Second-Order Meta-Analysis Study," *Educational Research Review* 36 (June 2022): e100438, https://doi.org/10.1016/j.edurev.2022.100438.

14 Michael Noetel et al., "Multimedia Design for Learning: An Overview of Reviews with Meta-Meta-Analysis," *Review of Educational Research* 92, no. 3 (2022): 413-454, https://doi.org/10.3102/00346543211052329.

15 Traci Sitzmann, "A Meta-analytic Examination of the Instructional Effectiveness of Computer-based Simulation Games," *Personnel Psychology* 64, no. 2 (Summer 2011): 489-528, https://doi.org/10.1111/j.1744-6570.2011.01190.x.

16 Traci Sitzmann and Katherine Ely, "A Meta-Analysis of Self-Regulated Learning in Work-Related Training and Educational Attainment: What We Know and Where We Need to Go," *Psychological Bulletin* 137, no. 3 (2011): 421-442, https://doi.org/10.103 7/a0022777.

various fields. At its core, lean thinking focuses on maximizing value while minimizing waste. In the context of military training, this translates to designing learning systems that deliver maximum combat readiness with minimum wasted time, resources, or effort. For example, the U.S. Navy's "Ready Relevant Learning" initiative aims to provide the right training at the right time during a sailor's career, eliminating the waste associated with front-loading all training at the beginning of their service. This approach ensures that skills remain fresh and relevant when needed rather than potentially becoming outdated or forgotten.[17]

Another lean principle is the concept of efficient workflow. In manufacturing, this involves streamlining production processes to reduce delays and bottlenecks. In training design, it refers to creating smooth, logical progressions of learning that minimize confusion and maximize retention. This might include carefully sequencing training modules to ensure prerequisite skills are mastered before advancing to more complex topics or designing training systems that facilitate seamless transitions between different types of learning activities.

The concept of a "pull" system, where actual demand—rather than forecasts—drives production, is also being adapted to military training. In this context, training content is developed based on actual operational needs rather than predefined schedules. This approach ensures that training remains relevant and responsive to the rapidly changing demands of modern warfare. For example, if a new threat emerges in a particular theater of operations, a pull-based training system would quickly generate and distribute relevant materials to personnel who may encounter that threat.

Just-in-time production, another lean principle, when applied to education and training, aims to deliver learning at the point of need. This approach reduces the cognitive load on learners and ensures that skills and knowledge are fresh when most required. Mobile learning platforms and micro-learning modules are key enablers, allowing personnel to access bite-sized pieces of relevant training content as needed, whether preparing for a mission or troubleshooting equipment in the field.

Mass Customization and Personalized Learning

The concept of mass customization, which combines the efficiency of mass production with the personalization of custom-made products, is making its way into military learning systems.[18] In the commercial world, this might be seen in products like Nike's customizable sneakers or Dell's build-to-order computers. When applied to military instruction, it aims to create flexible, adaptable training

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[17] Sierra T. Snapp, "A Comparative Analysis of Ready Relevant Learning in Navy 'A' School Ratings," PhD dissertation (Monterey, CA: Naval Postgraduate School, March 2024), https://dair.nps.edu/bitstream/123456789/5211/1/NPS-AM-24-211.pdf.

[18] "The Army Learning Concept 2030-2040," *TRADOC Pamphlet* 525-8-2 (Fort Eustis, VA: U.S. Army Training and Doctrine Command, Department of the Army, February 2024), https://adminpubs.tradoc.army.mil/pamphlets/TP525-8-2.pdf.

systems tailored to individual learner's needs while maintaining the scalability required for large-scale force preparation.

Adaptive learning systems are at the forefront of this approach. These systems use artificial intelligence and machine learning algorithms to analyze a learner's performance, preferences, and goals, tailoring the learning experience accordingly. For example, an adaptive marksmanship training system might adjust the difficulty of simulated targets based on a trainee's improving accuracy or recommend additional practice on specific skills that the system identifies as needing improvement.

The U.S. Army's Synthetic Training Environment (STE) is an example of how mass customization principles are being applied to military training. The STE aims to provide a comprehensive virtual training platform that can be rapidly reconfigured to simulate any operational environment, from dense urban areas to remote mountain terrain. This flexibility allows units to receive customized training tailored to their specific mission requirements, all within a standardized, scalable system.[19]

Modular content design is another key aspect of mass customization in military education and training. By creating reusable learning objects—small, self-contained units of learning content—developers can mix and match these modules to create customized training programs for different roles, units, or missions. This approach not only allows for greater personalization but also increases the efficiency of content development and updates.

On-Demand Production of Training Content

The principle of on-demand production, where products are created only when there is a specific need or order, is being adapted to military training content development. This approach enhances the responsiveness and relevance of training materials, ensuring that personnel have access to the most up-to-date information and skills training. NATO's ETEE Policy supports the concept of on-demand production, emphasizing the importance of "speed[ing] up learning loops" to "shorten the time to integrate lessons from war zones and adjust doctrines if needed for rapid response."[20]

Rapid authoring tools play a crucial role in enabling on-demand training content creation. These user-friendly platforms allow subject matter experts to quickly develop and update training materials without requiring extensive technical skills. For example, an experienced combat medic returning from deployment could use rapid authoring tools to create a training module on new field

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[19] Jeremiah Rozman, "The Synthetic Training Environment," Association of the United States Army, December 10, 2020, www.ausa.org/publications/synthetic-training-environment.

[20] Secretary General, North Atlantic Treaty Organization, "Final Decision on MC 0458/4; NATO Education, Training, Exercises and Evaluation (ETEE) Policy" (NATO, January 3, 2023), 8, www.coemed.org/files/Branches/DH/0458-4_20230103_NU_NATO_EDUCATION_TRAINING_EXERCISES_AND_EVALUATION_POLICY.pdf.

medicine techniques they encountered, making this valuable knowledge immediately available to other medics in training.

Crowd-sourced content is another innovative approach to on-demand training material production. By leveraging the collective knowledge and experience of the force, military content creators can develop a continuously evolving body of training materials. Secure, military-specific platforms, similar to Wikipedia or YouTube—such as those available on the U.S. platform milSuite—enable personnel to share insights, techniques, and lessons learned, creating a dynamic, peer-reviewed knowledge base that complements official training materials.

Real-time feedback loops are essential for the success of on-demand training content production. The content can be continuously refined and improved by incorporating mechanisms for immediate user feedback on training materials. This might involve simple rating systems, detailed surveys, or even AI-powered analysis of user engagement and performance data to identify areas where training content can be enhanced.[21]

Digital Learning Ecosystems

The concept of a comprehensive digital learning ecosystem is gaining traction in military training circles. This approach goes beyond individual training technologies or platforms to create an integrated, holistic environment that supports learning and performance across all aspects of military operations.

At the heart of a digital learning ecosystem is the concept of integrated platforms. Instead of relying on separate systems for classroom learning, field training, performance support, and knowledge management, a digital learning ecosystem brings all these elements together into a seamless interface. For example, a soldier accessing a maintenance manual through a performance support app might automatically be offered relevant training modules if the system detects they are struggling with a particular task.

Data interoperability is crucial for the success of a digital learning ecosystem. Ensuring that learning data can be easily shared and analyzed across different systems provides a comprehensive view of learner progress and training effectiveness. This may involve adopting common data standards across different training platforms or developing AI-powered analytical tools capable of synthesizing data from diverse sources to provide actionable insights on force readiness and training needs.

Cloud-based infrastructure often serves as the backbone of a digital learning ecosystem, enhancing the accessibility, scalability, and resilience of training systems. Cloud technologies enable the rapid deployment of new training content across a globally distributed force, ensure personnel can access their personalized learning environments from any location, and provide the computational

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[21] Partnership for Peace Consortium ADL Working Group, "How does AI Supports Military Education Training, Exercises and Evaluation," *Information Paper*, November 2023, https://www.pfp-consortium.org/media/489/download.

power required for advanced simulations and AI-driven adaptive learning systems.

The U.S. Air Force's Pilot Training Transformation program exemplifies many aspects of a digital learning ecosystem. This innovative program combines virtual reality flight simulators, AI-powered adaptive learning systems, and a cloud-based learning management system to create a holistic, data-driven training environment for aspiring pilots. The system tracks a student's progress across various learning activities, from virtual reality flight practice to academic study, providing instructors with a comprehensive view of each trainee's strengths and areas for improvement.[22]

This trend toward greater integration of training systems and operational platforms will likely increase as military training systems continue to develop and refine their digital learning ecosystems. For instance, data from actual mission performance could automatically feed into training systems, ensuring that training scenarios accurately reflect current operational realities. Similarly, performance support tools used in the field could seamlessly connect to training modules, allowing personnel to refresh their skills or access just-in-time learning as needed during operations.

Conclusion

The rapid evolution of warfare in the modern multi-domain battlespace necessitates a paradigm shift in military education and training. As the ongoing war in Ukraine starkly illustrates, having effective, resilient learning systems in the face of both physical and cyber threats is crucial for sustaining military success. "Train *while* we fight" is an emerging concept critical for addressing new training demands. It emphasizes continuous, adaptive learning integrated into operational activities and interwoven in a web of interoperable training and education systems across allied and partner nations.

ADL technologies play a central role in enabling this transformation. ADL offers flexible, accessible education and training solutions that reduce reliance on vulnerable physical infrastructure. The effectiveness of ADL is supported by multiple meta-analyses, demonstrating improved learning outcomes compared to traditional face-to-face instruction.

Lean principles can guide the design of efficient, demand-driven training pipelines. Mass customization and personalized learning, enabled by adaptive technologies and modular content design, allow instruction tailored to individual needs at scale. On-demand production of training content, facilitated by rapid authoring tools and crowd-sourced knowledge sharing, ensures the timeliness and relevance of learning materials in a rapidly changing operational environment.

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[22] Patrick Parrish and John R. Hoehn, "U.S. Air Force Pilot Training Transformation," *In Focus*, IF12257, U.S. Congressional Research Service, November 29, 2022, https://crsreports.congress.gov/product/pdf/IF/IF12257/2.

Ultimately, the resilience of military learning systems in the face of evolving threats will depend on a sustained commitment to innovation, collaboration, and adaptability. By embracing the "train *while* we fight" paradigm, harnessing the power of ADL, and leveraging the strength of unity among allied and partner nations, military forces can ensure their readiness to confront the challenges of the multi-domain battlespace. The research and initiatives discussed in this article represent important steps toward this goal, but ongoing investment and experimentation will be essential to sustain the resilience and effectiveness of military education and training in an uncertain future.

Disclaimer

The views expressed in this article are those of the authors and do not necessarily reflect the official policies of the Partnership for Peace Consortium or its governance stakeholders.

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