Army Officer Corps Science, Technology, Engineering and Mathematics (STEM) Foundation Gaps Place Countering Weapons of Mass Destruction (CWMD) Operations at Risk – Part 2*

LTC Andrew R. Kick[1], MAJ Bryan Lagasse[1], MAJ Stephen Hummel[1,2], LTC Matthew Gettings[1], MAJ Patrick Bowers[1], and COL F. John Burpo[1]

1. Department of Chemistry & Life Science, United States Military Academy, West Point, NY 10996, USA
2. Biology Department, Boston College, Chestnut Hill, MA 02467, USA

Background:

This is the second of three articles from the authors describing the risk to Joint Operations incurred by an Army that is vulnerable to the STEM challenges faced in a great power competition involving CWMD operations. In Part 1, we described the problem: "The Army's failure to emphasize STEM competence in the Army officer corps outside of Functional Areas creates risk to mission accomplishment in CWMD multi-domain operations. The Army must prioritize STEM education in accessions and throughout PME to prepare commanders for effective science and technology (S&T) informed decision making within mission command in CWMD multi-domain operations".[1] For Parts 2 and 3, we utilize the Joint Operational Model, Notional Phasing for Predominant Mili-

Lieutenant Colonel Andrew R. Kick is an Academy Professor in Life Science in the Department of Chemistry and Life Science at the United States Military Academy at West Point and serves as the Director of the Center for Molecular Science. LTC Kick earned a B.S. in Biology from the University of Dayton and commissioned as a military intelligence officer. He received both his M.S. and Ph.D. from North Carolina State University with an Immunology concentration. His email address is andrew.kick@westpoint.edu.

Major Bryan Lagasse is an Assistant Professor in Chemistry at the Department of Chemistry and Life Science at the United States Military Academy at West Point and serves as the Course Director for General Chemistry I. He has a B.S. in Chemistry from the United States Military Academy at West Point, a M.S. in Chemistry from Clemson University. His email address is Bryan.Lagasse@westpoint.edu.

MAJ Stephen Hummel is a PhD candidate at Boston College, in Chestnut Hill, MA. He has a BA in political science from Boston College and two M.S. in Free Radical and Radiation Biology from the University of Iowa and Chemical and Physical Biology from Vanderbilt University. He was previously assigned as a Deputy, Commander's Initiatives Group at the 20th CBRNE Command. His email address is Stephen.g.hummel2.mil@army.mil.

LTC Matthew Gettings is an Assistant Professor at the U.S. Military Academy, in West Point, NY. He has a B.S. in Electrical Engineering from the U.S. Air Force Academy, a M.S. in Nuclear Engineering from the Air Force Institute of Technology, and a Ph.D. in Materials Engineering from Purdue University. He was previously assigned as a Test Operations Officer and Experiment Director at the Defense Threat Reduction Agency (DTRA) Kirtland AFB, NM. His email address is matthew.gettings@westpoint.edu.

MAJ Patrick Bowers is an instructor in the Department of Chemistry and Life Science at the United States Military Academy, at West Point, NY. He has a B.S. in Chemical Engineering from the United States Military Academy and an M.S. in Chemical Engineering from Purdue University. He was previously assigned as the battalion intelligence officer for the 2nd Chemical Battalion, the commander of Headquarters and Headquarters Company, 48th Chemical Brigade, and the brigade threat assessment officer for the 48th Chemical Brigade. His email address is patrick.bowers@westpoint.edu.

COL John Burpo is the Department Head of Chemistry and Life Science at the United States Military Academy at West Point. He has a B.S. in Mechanical-Aerospace Engineering from West Point, a M.S. in Chemical Engineering from Stanford University, and a Sc.D. in Bioengineering from the Massachusetts Institute of Technology. He was previously assigned as the Deputy Commander-Transformation at the 20th CBRNE Command. His email address is john.burpo@westpoint.edu.

tary Activities, from JP 3-0, Joint Operations[2], to describe the risk of an Army officer corps lacking STEM dominance for CWMD operations during a regional or great power competition involving CWMD operations. In this article, we address the risk of our current efforts as we operate in Phase 0 (Shape) and Phase 1 (Deter) while our final article (Part 3) will examine the transition to decisive action / unified action with Phase 2 (Seize the Initiative) through Phase 5 (Enable Civil Authority).

Joint / Army Strategy and Doctrine Highlights: Phase 0 (Shape) and Phase 1 (Deter)

Our approach in this article is to first emphasize the applicable tenets from Joint and Army CWMD strategy and doctrine to establish our thesis as relevant and consistent with these documents. We summarize these documents into four themes that describe the operational environment and the importance of human capital in ensuring our preparedness for those challenges. We, then, propose four principles necessary for successful CWMD operations and evaluate the inherent risk in Shape and Deter operations for an Army officer corps that overall lacks core STEM competence.

Shape and Deter operations: the United States Joint Force continuously maintains this posture in every Geographical Combatant Command (GCC) around the world. Unfortunately, daily events in Russia and Ukraine, the Taiwan strait, Korean peninsula, or even in southwest Asia amplify the necessity of our thesis: how soon before the Joint Force is committed to decisive operations in one or more of these areas? The 2018 National Defense Strategy describes the Joint Force in Shape / Deter Operations as the "Global Operating Model". Joint Force capabilities include nuclear; cyber; space; C4ISR; strategic mobility; and counter WMD proliferation as it completes its competition or wartime missions.[3] JP 3-0, Joint Operations, describes Phase 0 (Shape) operations as setting conditions for successful theater operations within a Geographical Combatant Command. "Shaping activities include long-term persistent and preventive military engagement, security cooperation, and deterrence actions to assure friends, build partner capacity and capability, and promote regional stability. They help identify, deter, counter, and/or mitigate competitor and adversary actions that challenge country and regional stability."[4] For Phase 1 (Deter), "Successful deterrence prevents an adversary's undesirable actions, because the adversary perceives an unacceptable risk or cost of acting. Deterrent actions are generally weighted toward protection and security activities that are characterized by preparatory actions to protect friendly forces, assets, and partners, and indicate the intent to execute subsequent phases of the planned operation."[5]

Furthermore, JP 3-40 characterizes the CWMD Activities and Tasks and, though not aligned to the Phasing of JP 3-0, the organizing principles of Prevent and Protect, along with the specialized activities of WMD Pathway Defeat and WMD Defeat, correspond with Shape and Deter Operations.[6] Of note, the "foundational activities and tasks include Maintain and expand technical expertise (recruit, develop, retain)" and the "crosscutting activities and tasks include Understand the environment, threats, and vulnerabilities."[7]

The Army Strategy (2018) assesses the strategic environment to include adversaries leveraging "advanced capabilities such as cyber, counter-space, electronic warfare, robotics, and artificial intelligence." While the U.S. does not seek war with China or Russia, "we are likely to face their systems and methods of warfare as they proliferate military capabilities to others."[8] These include Regional State Adversaries (North Korea and Iran) as well as terrorists and proxies. The Army Modernization Strategy (2021) provides updated vision to the Army Strategy and describes how the Army must modernize to be positioned in 2035 to conduct Multi-Domain Operations by modernizing "how we fight, what we fight with, and who we are."[9] An overarching theme across those domains is S&T dominance. Nested within both strategic documents is the Army Biological Defense Strategy (ABDS). Maintaining the importance of S&T, to correct the "years of atrophy" of our biological defense, the ABDS focuses on four Lines of Effort (LOEs): Knowledge, Biological Defense Situational Awareness, Readiness, and Modernization.[10]

As the Chief of Staff of the Army (CSA) Paper #1 Army Multi-Domain Transformation describes:

> *In the past, the Army has enjoyed a competitive advantage over any potential adversary in capital, technology, and people. As competitors reduce the technology gap, our people will provide us with an enduring advantage to remain the world's most ready, lethal, and capable land combat force.*[11]

> *The acceleration of innovation and change will increase the technical and cognitive demands on our personnel. This, in turn, will generate new personnel and training requirements. We are transforming how we fight, what we fight with, and how we organize, but we must also transform how we train. The development of our Soldiers' and leaders' technology skills to operate in this significantly more complex environment is at the forefront of the Army's strategy.*[12]

Finally, ADP 6-0 defines Mission Command and specifically articulates a commander's decision-making process: "Commanders make decisions using judgement acquired from experience, training, and study." Furthermore, foundational to leadership is a commander's understanding:

An operational environment encompasses physical areas of the air, land, maritime, space, and cyberspace domains as well as the information environment, the electromagnetic spectrum, and other factors. Understanding an operational environment and associated problems is fundamental to establishing a situation's context and visualizing operations. The interrelationship of the air, land, maritime, space, and cyberspace domains and the information environment requires a cross-domain understanding of an operational environment. While understanding the land domain is essential, commanders consider the influence of other domains and the information environment on land operations. They also consider how land power can influence operations in the other domains. For example, commanders consider how friendly and enemy air and missile defense capabilities influence operations in the air domain. Included within these areas are the enemy, friendly, and neutral actors who are relevant to a specific operation.[14]

ADP 6-0 elaborates on commanders making decisions in time: "Timely decisions and actions are essential for effective command and control. Commanders who demonstrate the agility to consistently make appropriate decisions faster than their opponents have a significant advantage. By the time the slower commander decides and acts, the faster one has already changed the situation, rendering the slower commander's actions irrelevant. With such an advantage, the faster commander can dictate the tempo and maintain the operational initiative."[15]

Finally, within control, commanders and staff utilize the "operational variables (political, military, economic, social, information, infrastructure, physical environment, and time—known as PMESII-PT) and mission variables (mission, enemy, terrain and weather, troops, and support available, time available and civil considerations—known as METT-TC)" to analyze and describe the operational environment.[16]

From these highlighted doctrinal and strategy passages, we derive the following four themes: 1) Shape and Deter CWMD operations are ongoing in every GCC to varying degrees; 2) Great power competition and regional state adversaries possess significant WMD capabilities / facilities; any movement beyond Deter will result in multi-domain operations where Joint Forces will conduct CWMD tasks / activities and likely CBRN response; 3) Human talent is the Army's priority capability and S&T skills will provide the advantage in CWMD operations; 4) Commanders make correct, timely decisions based upon understanding, intuition, staff recommendations, and critical analysis. Shape, Deter, and ultimately wars are won based upon the decisions of commanders. In summary, CWMD multi-domain operations present the convergence of complexity in command, control, risk to force, risk to civilian populations, risk to political / national will, and S&T informed decision making. Whether responding to the aggression of a near peer or regional state adversary, the Army officer (commander and staffs) as a component of the Joint Force must understand the capabilities and advancements that these aggressors pose in real-time, as our adversaries' ability to employ emerging technologies affects every phase of joint operations. The understanding of these emerging technologies by only specialized Army officers makes these threats ever more lethal as units of every echelon become more susceptible in linear or non-linear operations to their effects. As the Army recalibrates the skills re-

quired from a counterinsurgency concentration to great-power / near-peer competition, STEM competence in the officer corps is essential.

CWMD Phase 0 and Phase 1 Activities:

As outlined above, Joint and Army doctrine provides vision, direction, tasks, and activities for Phase 0 and Phase 1 operations. With respect to CWMD operations, Shape and Deter has largely characterized Joint conventional CWMD operations since possibly 2003 with the Iraq invasion and hunt for WMD. Phase 2 and beyond CWMD operations in a regional or near-peer competition have not occurred; our evaluation is based upon our experience observing Shape and Deter operations over the past 10-30 years in multiple GCCs. Accordingly, we constructed four organizational principles to guide our CWMD risk evaluation as it relates specifically to our thesis: CWMD deficiency in the Army officer corps presents great risk to successful conduct of CWMD operations in regional or great power competition. Our organizing principles to evaluate CWMD risk are as follows: 1) STEM Undergraduate / Graduate Education, Leader development, and Professional Military Education (PME); 2) Threat modeling and WMD Pathway defeat; 3) Doctrine / Training / WMD defeat; and 4) Acquisition / Science/ Technology development. To substantiate the premise of our argument, we will emphasize how our principles though postulated discreetly from the Army Modernization Strategy and ABDS four lines of effort are congruent with both Army Strategy documents.

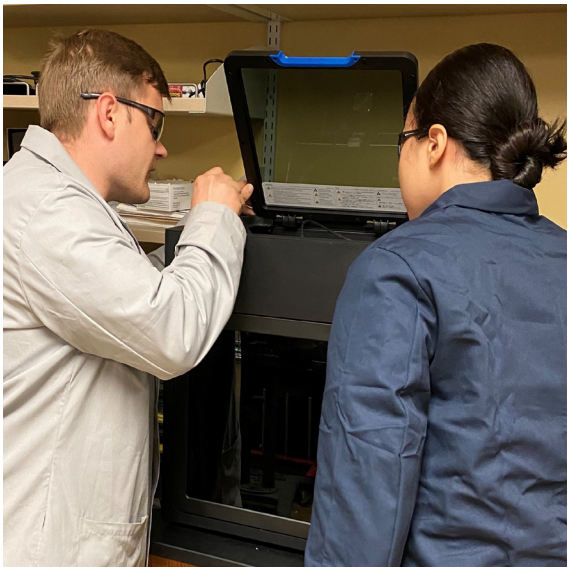

Figure 1. MAJ Patrick Bowers and CDT Valencia Ramirez observe a 3D printer during operation. The print was utilized in MAJ Bowers' soft robotics research

STEM Undergraduate / Graduate Education, Leader development, and Professional Military Education:

Every foreseeable theater of operations for the Joint Force for the next 20 years will involve integrating novel S&T applications to provide advantages and solutions to overcome CWMD challenges in decisive operations. STEM competence will be a necessity in Phase 2 (Seize the Initiative) CWMD operations; however, the competence gained through advanced degree programs is largely confined to functional areas and officers selected to teach at the United States Military Academy. STEM-competence cannot be achieved rapidly. A Masters in a STEM-discipline requires two years and considerable research; the PhD requires an additional three or more years of laboratory, design or computations research. This is not a 3 or 6-month ramp up to gain depth and breadth and the complex-problem solving required for multi-domain CWMD operations. This requires professional development in the same manner as the aviation officer, maneuver, or sustainment officer spends years gaining competence in those fields. Further, STEM competence builds on undergraduate STEM foundations that are not widely present in the Army officer corps.[17] We elevate "operational experience" in the officer corps through development experience and relegate advanced STEM-education to those who will not command. Are combined arms operations at the battalion, brigade, and division so fundamentally different that an officer must devote 20+ years within those organizations to gain and demonstrate competence? Can the talented commander not spend 75% of that time in those organizations and 25% gaining the STEM competence to truly be a forward-thinking tactical and operational leader? As the ADP 6-0 excerpts illustrated earlier, a commander's understanding and decision making is a direct result of his / her education and experience. The Army cannot expect its operational commanders to make the most STEM-informed decision when the Army has not continuously developed the leader in that capacity. Exclusive reliance on staff officers for STEM analysis and recommendations, places command decisions at risk of lacking the lens to crit-

ically evaluate information and decision space. Additionally, for tactical level / company grade commanders to possess STEM-disciplines they must obtain those through their commissioning sources. As discussed during Part 1, a minority of commissioned officers possess a bachelors in a STEM-discipline and this percentage decreases based upon years of active federal service. Further, undergraduate STEM foundations, if not reinforced and expanded through graduate education, obsolesce, and degrade over time.

The strategic environment requires the Army to "maintain established subject matter expertise while cultivating much-needed NEW expertise within the Force". This assessment underscores the need for officers with advanced technical degrees who will also play a vital role in engaging our allies and partners. Such officers meet the need for "agility in biological defense," and by extension CWMD operations, through creativity and innovative thinking.[18] Clearly, the Army has a need for more officers with science backgrounds who can reason quickly during compressed reaction times and shortened decision cycles.

The reality for many company and field grade officers in basic branches is they may experience risk of promotion and certainly command when they accept an advanced civil schooling opportunity. More senior officers may discourage this path because they perceive it will likely harm the junior officer's career. Senior officers often instead advocate one-year PME (CGSC / AWC) and masters-level education in non-STEM fields. Currently there is no focus related specifically to STEM concepts included in any level of formalized PME, including Basic Officer Leader Course, the Captain's Career Course, the Command and General Staff College, or the Army War College. Throughout these courses officers may be exposed to some applications or planning considerations for CWMD operations or emerging S&T capabilities, but there is limited formalized education regarding the STEM background of these situations. This presents a situation where officers are making decisions with minimal knowledge on how to mitigate the effects of a CBRN scenario.

As a whole, the Army PME aligns with non-STEM advanced degree (humanities-based education) opportunities which lack scientific and technical rigor. Advanced STEM degrees can only be obtained through other opportunities, often at technical institutions of the other services: Naval Post-graduate School (NPS) and Air Force Institute of Technology (AFIT). Both institutions routinely provide their officers with scientific and engineering graduate education. A comparable institution for the Army does not exist.

The Army Modernization Strategy recommends "to update its leader development and education processes to increase critical, creative, and systems thinking so that the next generations of Army leaders and warfighters are prepared for the complexities of MDO."[19] STEM education is a central component of critical, creative, and systems thinking.

ABDS promotes Knowledge as the first necessary LOE because "without a strong basis in scientific knowledge and understanding, biological defense situational awareness and readiness are not possible, and the modernization needed to defend against new but uncertain…threats and hazards cannot be attained." However, biological defense knowledge in the Army has deteriorated. Consequently, new development of talent management is required. ABDS depends on "scientific and medical expertise". The strategy takes this a step further by advocating that "knowledge must be embedded in professional military education at all levels… [in order to] enable knowledge-based decision making."[20]

In summary, because we postulate a STEM-trained commander (bachelors / advanced degree) will make a better decision when faced with a S&T challenge in multi-domain CWMD operations, then the Army is assuming great risk in not prioritizing officer STEM education and expertise. During Phase 2-3 CWMD operations if this postulate is validated, it will be too late to correct this deficiency due to duration and intensity of obtaining an advanced STEM degree.

Threat modeling and WMD Pathway defeat:

Who are the officers with tactical experience developing the computer, AI, and technical models to describe the CWMD threat? Such officers must understand the capabilities and limitations of nuclear and chemical weapons, pathogens, virus infectivity, detectors, sensors, environmental hazards, civilian population movements, and assumed parameters which feed the sophisticated models. Without STEM education, CWMD operational models simply exist as a "black box"

for most Army officers.

Who are the technical experts in the Army contributing to WMD Pathway defeat? Is this a technical skill possessed and coveted by maneuver, fires, and effects officers or is this important skill set compartmented to civilians, other services, Special Forces, and Operations Support officers? To contribute and develop innovative, effective solutions in WMD Pathway defeat, STEM-competence is a necessity. S&T critical thinking and understanding is paramount to WMD Pathway defeat.

Along these lines, the COVID-19 pandemic demonstrated to the world the power of a biological pathogen, expert opinions, medical treatment capacity / vulnerability, social media information dissemination and control, and the difference in decision-making by government authorities when presented with the same general facts. The Joint Force will undoubtedly rely heavily on the initial assessment and recommendations of leaders at the point of contact, and these leaders must understand STEM capabilities and concepts to depict an accurate understanding of the operational environment for supporting agencies to effectively assess the situation. What is the depth of CWMD expertise in any Army unit? In an Army Brigade Combat Team, the CWMD experts are the CBRN officer (with four to six years in the Army) and the brigade surgeon (a physician with probably limited knowledge on biological weapons transmission). Certainly, there are supporting headquarters and other agencies that can contribute to knowledge in these situations; however, the "expert" opinion in that organization often holds the greatest sway. A STEM-competent force provides depth and critical thinking to ensure the most appropriate staff recommendations and command decisions. Conventional forces need to be able to react to the full spectrum of WMD threats, and it cannot rely solely on the STEM expertise of supporting agencies, as they could be limited in their ability to rapidly respond to the force's immediate threats.

The Army Modernization Strategy describes this as "How We Fight". "The MDO capable force will combine tailorable formations of networked manned and unmanned platforms, fires, electronic warfare, cyber, intelligence, surveillance, reconnaissance, engineers, sustainment, communications, and protection capabilities at all echelons, from squad to theater."[21] And furthermore, "An MDO capable force will allow the Army, a part of an integrated Joint Force, to expand the options available to civilian authorities, to include effective deterrence and competition short of armed conflict, or timely response to an attack attempting to permanently change the status quo."[22] Integrating S&T across multi-domain operations into Shape and Deter CWMD requires commanders and staff competent and confident in STEM.

The second line of effort of ABDS is Biological Defense Situational Awareness to support decision-making. Army officers with STEM backgrounds are better able to "identify and analyze how the adversary may exploit biological threats and hazards in novel ways and recommend countermeasures."[23] Consider the possible threat posed by drone swarms and CBRN weapons. Such swarms are of great interest to our adversaries because they offer a dynamic capability to complement, challenge, and substitute. Swarms may enhance delivery of CBRN weapons, serve deterrent/detector roles, or simply achieve similar effects of CBRN weapons. Furthermore, non-state actors, such as ISIS have demonstrated their capacity to employ drones with devastating effects as well as their willingness to kill civilians via chemical attacks.[24]

The ABDS strategy justifiably assumes the biological attacks are neither deterred nor prevented by CWMD efforts alone. In many cases, early detection of biological attacks remains elusive due to long incubation periods and high transmissibility. The stealth-like nature of such bioweapons offers anonymity to our adversaries, who can evade attribution. Consequently, the use of deadly toxins and pathogens proves to be an attractive option for our enemies.[25]

In summary, constraining STEM and WMD expertise to particular branches and functional areas, holds risk in CWMD Shape and Deter operations. The Army officer corps gains strength through depth; CWMD is a whole of Service problem set. If only "experts" understand the S&T of CWMD operations and WMD effects, then commanders are dependent upon experts who as evidenced by this pandemic can differ widely in their advice and recommendations. Commanders must possess the CWMD situational awareness to be able to make right decisions.

Doctrine / Training / WMD defeat:

Army / Joint CWMD doctrine is conservative, conventional, and not predictive. To be predictive, doctrine writers must be able to envision how future technologies can be integrated into CWMD operations. Are the officers developing and writing CWMD doctrine reading and writing in current nuclear, chemical and biotechnology fields or are they trained through Army schools and operational experience? Innovation does not normally arise through new applications of approved ideas but through new ideas and new technologies. Applying new technologies requires a STEM-educated officer with continued STEM Professional Military Education (PME).

In one theater of operations, the Army is appropriately focused on CWMD operations: Korea. For example, the 2nd Infantry Division must remain prepared for possible CWMD operations on the Korean peninsula. Working closely together, US and ROK partners train for CWMD tactical operations.[26] Technical enablers such as the CBRN response teams and nuclear disablement teams from the 20th CBRNE Command provide valuable support.[27] Korea conducts multiple theater-level computer exercises, CWMD focused combined training exercises, Noncombatant Evacuation Operations (NEO) and many other training scenarios that incorporate CWMD into the main training threads. As discussed repeatedly, this scenario is not unique to Korea but is almost ubiquitous in any likely location for Army forces to be committed. The high-level of training serves the JP 3-40 WMD defeat task and activity. A trained and ready force is a significant deterrent to WMD employment because the adversary cannot assume the WMD will have the desired effect.

The Army Modernization Strategy identifies the Synthetic Training Environment (STE) in relation to Army Futures Command Cross Functional Teams (CFT) ensuring new requirements are being matched to capabilities.[28] CWMD operations must be integrated into this new training paradigm. STEM and CWMD competence in the Army officers building the STE is critical to ensuring realistic and anticipatory training is a component of future unit training plans.

Doctrine / Training and WMD Defeat directly support the third LOE of ABDS (Readiness), which hinges on subject matter expertise. Strengthening our biological defense requires "…commanders and staff at all levels have access to the biological subject matter expertise needed to support situational awareness and response decision making."[29] Army officers who have earned formal degrees in STEM are aptly suited to meet this need. Their education enables these officers to communicate and collaborate across DoD agencies as well as allies and partners.

Acquisition / Science/ Technology Development:

This is the most important area of emphasis for CWMD Shape operations. The Acquisition Corps and all Army Futures Command leaders must be STEM-educated and have advanced STEM degrees in their areas of expertise / responsibility. Acquisition and development are just not leadership, processes, and procurement regulations: it addresses the fundamental question of whether this weapons system or technology is applicable to today's available technology or tomorrow's required capability. S&T engineering questions embraced by Army officers with years of operational experience combined with advanced engineering degrees, and best business practices will significantly improve Army acquisition success. The result is a modernized fighting force, which supports the Army modernization priorities.

The risk to Shape and Deter operations is especially difficult to measure or quantify within this principle. How would the development and delivery of new CWMD technologies be different if STEM-educated, tactically competent officers were deeply-invested in the acquisition process? We believe the CWMD system would be more likely to meet the anticipated need and durability of the requirement due to the sustained involvement of the officer, and when the system is fielded, the Army officer would better understand its capabilities and limitations for employment based upon his / her S&T contribution to its development. This requires a fundamental shift in how the Army values officer experiences: Cross-Functional Teams should be a highly regarded and competitive assignment for advanced degree STEM-trained field grade officers. If the Army expects to achieve its Modernization Strategy, then officer assignments to CFTs with the requisite technical competence should be a key development assignment.

The Army Modernization Strategy devotes the largest portion to this concept, "What we fight

with." The six modernization priorities and 31 CFT efforts will be achieved through advanced S&T development and integration into the force.[30] STEM-competent officers are required for implementation of this effort. There is great risk we cannot achieve these objectives by 2035 without forwarding-thinking STEM-trained leaders to guide these programs.

The fourth LOE of the ABDS (Modernization) explicitly calls for "…the requisite manning (skill, rank, and distribution) of biological defense expertise…". Integration of "subject matter expertise into operational decision-making and response" is emphasized along with the modernization of equipment and facilities.[31]

Our Recommendations:

In this conclusion of Part 2, we propose our solutions to this identified risk. In Part 3, we will elaborate on our recommendations and provide actionable and measurable strategies and outcomes for fundamentally changing the Army's approach to STEM education and CWMD operations. In the meantime….

1. STEM degrees required in >50% of all ROTC scholarship awardees / service academy graduates.
2. Advanced STEM degree opportunities for company / field grade (MS) and senior field grade officers (PhD); successful completion of the degree achieving a required GPA / research completion (thesis / dissertation) will be viewed as equivalent to the commensurate above center of mass (ACOM) Officer Evaluation Reports for promotion board selection. The current Additional Service Obligation (ADSO) requirements remain for ACS-funded education.
3. Professional scholarship in the officer corps should be expected. New ideas will be generated with the free exchange of ideas, especially when officers are rewarded and selected for how they think, not just their results.
4. Army acquisition, Futures Command, and doctrine developers must be STEM-competent in the disciplines appropriate for their responsibilities.
5. CWMD operations should be included as a planning and operational objective during every training center rotation and into the STE. We have established that every theater of operations expects to encounter CBRN effects or conduct CWMD operations during Phase 2-5 Joint Force operations. This should be our routine and not restricted to a Korean peninsula training scenario.
6. Conduct a funded internal and external review to determine the applicability of adding a Master of Science degree capacity in STEM disciplines to the United States Military Academy (commensurate with AFIT or NPS) with partnered research throughout Army Futures Command in order to expand PME opportunities and develop STEM competent field-grade officers.

Figure 2. Cadet (now second lieutenant) Kirsten O'Keefe briefs Brigadier General Shane Reeves, the Dean of the Academic Board of the United States Military Academy at West Point, on her group's research poster, at West Point Projects Day 2022 (photo taken by Major William Horne, April 28, 2022).

Notes

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