Army Officer Corps Science, Technology, Engineering and Mathematics (STEM) Foundation Gaps Place Countering Weapons of Mass Destruction (CWMD) Operations at Risk - Part 3

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Background:

This is the third and final article of the series where the authors have outlined potential risks the Army may face in future Joint operations due to the shortage of STEM competencies in the Army Officer Corps. To assess this risk, we utilized the Joint Operational model, Notional Phasing for Predominant Military Activities, from JP 3-0, Joint Operations as the framework. In parts 1 and 2 we described how the current efforts in Phase 0 (Shape) and Phase 1 (Deter) were insufficient to develop the STEM competencies in the Army Officer Corps at large. As the United States Army is not directly engaged in a direct or decisive action conflict, our assumption is that we are currently in Phases 0 and 1. During these phases, the focus is on the ability of military leaders to understand the operational environment and develop competencies in preparation for offensive operations. In this article, we shift to address the potential future conflicts and how the lack of STEM competencies could impact the Army's ability to win our Nation's wars. During Phase 2 (Seize the initiative) and Phase 3 (Dominate) the focus for military leaders is on executing offensive operations and the abilities of those leaders to develop an operational plan leading to mission accomplishment. In Phase 4 (Stabilize) and Phase 5 (Enable Civil Authority) the focus shifts to stability operations and the leaders' abilities to use information to enable local leaders to re-establish authority and control of the operational environment. With the continued introduction of innovative technology, it is critically important that military officers at echelon have foundational STEM competencies in order to effectively integrate the technology into operations.

Introduction:

In concluding Parts 1[1] and 2,[2] we recommended several courses of action to address the shortfalls in the STEM competencies across the Army Officer Corps. These included:

- implementing a requirement for greater than 50% of all ROTC scholarship awardees and service academy graduates to earn an undergraduate degree in STEM

- allowing additional opportunities for company and field grade leaders to earn a graduate-level degree (M.S. or Ph.D.) in STEM-related fields

- including CWMD operations as part of planning and operational objectives during every training center rotation

As seen over the last year of the Russo-Ukrainian War, the rapid advancement of technology over the past decade continues to play a critical component in modern combat operations. Ranging from personal-use unmanned aerial vehicles to conduct attacks on remote locations, to the ability to deny an adversary use of satellite systems such as GPS or even communication, it is unlikely the next major conflict for the United States will not have similar technology used by all sides.[3,4] In order to leverage the capabilities that this ever-advancing technology provides, leaders at all levels should have a familiarity with a broad range of STEM fields and concepts. Having this familiarity allows leaders to recognize and capitalize on opportunities and minimize significant risks to their operations and forces. While leaders may not be the subject matter expert on the technology or scientific challenge, the ability to process and distill the most important information from data in less time than their adversaries will be a critical component in future conflicts. Given the increased prevalence of technology within the military at all echelons it would follow that there would be a focus on developing the technical competencies and understanding of trending technology at echelon within the formalized military development and education system. Unfortunately, this assumption is not true under the current Army accessions mission and professional military education structures. On the contrary, there is a significant lack of development of STEM competencies at any level of the formalized military leadership education, with the exception of specialized roles such as Medical Service Officers or Functional Area officers. Furthermore, the lack of STEM competencies in the military leadership education domain places the burden of STEM competency development on the undergraduate education program. While this does fulfill some requirements for STEM competencies, there are several concerning trends that elevate the risk of this approach. First, the percentage of newly commissioned officers with undergraduate degrees in STEM has decreased over the past 20 years. Second, looking only at the graduation requirements for the United States Military Academy at West Point, the number of required STEM courses to earn a Bachelor's of Science degree has decreased by 10% over the past 40 years (See Table 2). While this does not necessarily indicate a decrease in understanding or competency, it does present a probability that graduates have less depth of understanding of STEM concepts and competencies. Due to the varied programs ROTC graduates can attend it is more difficult to quantify the prevalence of general STEM courses in this population. These trends indicate a potential major risk during future operations, especially during the offensive and stability phases where commanders will need to understand and implement US and allied science and technology (S&T) while countering adversarial S&T, in order to make timely and accurate decisions. This risk further elevates when considering CWMD operations, which historically is not a priority during combat training center (CTC) rotations, leading to further erosion of the Soldier-level skills that are critical during these engagements. Without a significant effort to introduce more STEM-related competencies into the military officer education system at echelon the US Army risks being woefully unprepared for the conflicts ahead.

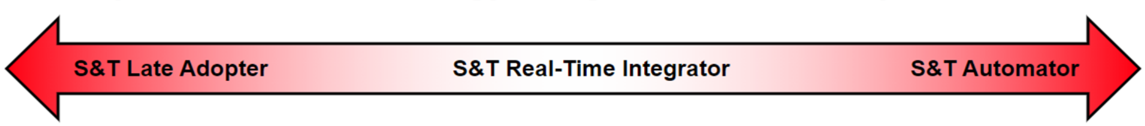
Assessing this risk requires an assessment of the technological complexity facing the Army and an acknowledgment of potential domains the Army faces in future conflicts. The recently published FM 3.0, Operations, details the ambiguity and complexity the Army faces in what it now calls Multi Domain Operations (MDO). Senior leaders recognize the complexity and ambiguity that future conflict can and likely will contain. Of note, Army leaders at every echelon must recognize the interdependency of domains within the operational environment, specifically recognizing that effects from the air, space, cyberspace, and maritime domains affect land operations, and vice versa.[5] Some prominent examples include the land domain's ability and/or responsibility to destroy physical nodes executing enemy cyber operations, and the ability of enemy cyber operations to disrupt communications and collect intelligence on ongoing land operations. How does an Army leader, at echelon, recognize the presence of a physical location for an enemy cyber node? A STEM-educated leader could potentially recognize the presence of additional power infrastructure, network equipment, and the difference between a multi-directional, line-of-sight or satellite communications array. While only a small example, many similar thought experiments exist between the interrelations of these four domains.

Spectrum of Science & Technology model

Understanding that S&T will continue to occupy an increasingly greater influence in our military necessitates that leaders understand, at least on a fundamental level, what various technologies can provide them on the battlefield. As a framework for analyzing the broad range of abilities for officers we propose the following spectrum of technology integration for military leaders as a tool to assess leaders at echelon. On the far ends of the spectrum are S&T Late Adopters and S&T Automators. These are defined as most sub-optimal for the conflicts of the future. Leaders who trend as a late adopter are at risk due to a tendency to not utilize the resources available or inability to integrate new systems into the decision-making process and, therefore, will be behind the decision-making cycle and likely achieve sub-optimal results. This is not to say those officers will be completely ineffective, but rather that they will fail to reach their full potential both as individuals and for the organizations they lead.

An emerging technology that is expected to have the greatest impact on future conflicts is the integration of artificial intelligence (AI) and machine learning (ML) systems. While these technologies are closely linked, there are some discrete differences in their application. Briefly, artificial intelligence leverages the abilities of computers to rapidly analyze data streams with pre-determined algorithms to provide specific information or to take a predetermined action. Machine learning is similar to AI in that it also uses algorithms to analyze data, but instead of taking action it recognizes patterns in the data stream and then adjusts the algorithms to make better assessments of future data.[6] With the development of artificial intelligence and machine learning system (AI/ML) it follows that these systems will eventually integrate into the myriad of sensors and battle tracking systems at the military's disposal. A late adopter will likely not take advantage of how these systems can rapidly analyze and synthesize this large pool of data to identify patterns and present potential courses of action. For example, through AI/ML it would be possible to quickly analyze a wide data set collected from a variety of forward positioned sensor systems. The AI/ML system could then analyze the information, detect patterns, and propose potential future operations or targets. Officers who are late adopters of this technology in favor of a more traditional analysis may still recognize this opportunity, but it would likely be well after the AI/ML system. This suggests these leaders could miss valuable opportunities against the enemy and delay the achievement of the overall mission. An important

Spectrum of Technology Integration for Military Leaders



Characteristics:
- Delays integrating new systems
- Late to recognize technology advancements
- Relies on personal experience in decision making, generally ignores "Big Data" or AI/ML
- Lacks understanding of STEM foundations and applications

Characteristics:
- Effectively integrates new systems into operations
- Distills useful information from large data streams to identify most important data
- Solid foundation in STEM foundations
- Able to rapidly assimilate new knowledge and technology

Characteristics:
- Integrates all new systems rapidly, but with limited efficiency due to ongoing development
- Recognizes value of "Big Data" and AI/ML systems; struggles to discern pertinent from noise
- Understands STEM foundations at surface level; lacks depth of knowledge

Figure 1. Spectrum of Technology integration for military leaders and associated characteristics of leaders along spectrum.

recognition is that these officers may see the value of this new technology, and may even praise it, but may be delayed integrating it due to their unfamiliarity with the technology or supporting infrastructure and lack the fundamental STEM competencies to understand it.

On the opposite end of the spectrum are S&T Automators, officers who rapidly integrate new technology into their operations without fully understanding how the technology operates. These officers implement new technology readily, but generally to suboptimal efficiency. One trait of officers on this end of the spectrum is they may not be able to discern the useful data from the large amount of information available to make effective decisions. They are also susceptible to information paralysis, or inability to decide due to the overwhelming amount of data at their disposal. Another risk of the S&T Automator is the potential to be ineffective at communicating their intent to subordinates due to reliance on digital systems. This disconnect could arise due to issues or flaws with the actual systems, or from the subordinates' lack of understanding of the system. While the physical act of running the system seems straight forward, to truly leverage these systems requires officers with an understanding of algorithms, probability, and computer systems. Without this ability, the officer could blindly trust the system, and its recommendations. If applied to the Army writ large, the Army officer corps could end up either abdicating its decision-making in combat to algorithm-based systems or miss the advantages and opportunities available due to an inability to implement and understand these new powerful tools. This is further exacerbated by the nature of the Army acquisition process which tends to trail behind the develop of new technologies as a necessity of determining how to properly integrate new technologies into the military operational structure and environment.

Another concern pertaining to officers who tend towards the S&T automators region of the spectrum is they may tend to engage passively with their units through the digital realm, versus actively with their subordinates. While these officers will incorporate many of the new systems, it will likely be desynchronized and create the potential that the leader and the subordinate are not able to share a common operating picture and assist in the decision-making process. This is a significant risk as most contemporary models of the innovation process include multiple iterative cycles requiring implementation, analysis, and re-evaluation before arriving at a final product.[7,8] By breaking the links between analysis and re-evaluation it lowers the potential that the organization will be able to develop an effective solution or to take advantage of opportunities on the battlefield. While innovation is necessary and will eventually lead to new possibilities, it requires STEM-competent leaders to reduce risk while implementing in combat. These risks set conditions for the S&T Automators to be generally ineffective and behind their adversaries in the decision-making cycle. While these officers may still achieve success, it will likely be at a greater cost both in terms of equipment and manpower.

The most optimal position on the spectrum for an officer to trend is the S&T Real-Time Integrator. These officers can both understand the benefits of the systems and technology, while also understanding the limitations or shortfalls. To truly weigh the benefit against the risk and implement effectively, the officer must understand the foundational concepts behind the system. With the ever-increasing complexity of the systems developed and the wide range of tasks they can perform, this means the officer must have a solid foundation in STEM competencies. An S&T integrator is able to absorb data from the various systems, identify the most pertinent for the decision, and then coalesce the information into actionable orders or recommendations. Unlike the officers who tend towards the ends of the spectrum, the technology integrator leverages the systems available for maximum efficiency and can seize advantages and opportunities in real-time. While all three types of leaders may ultimately be successful in a battle, campaign, or effort, only the technology integrator achieves these ends with the most efficient route. One of the defining skills an S&T integrator has compared to the other two types of officers is the solid foundation in STEM competencies which enable the officer to better integrate and understand the systems. Without these skills, the officer can only rely on others, which at best will only serve to further slow the decision-making process, and at worst leave the officer susceptible to misinformation or inability to recognize risks. Having a solid foundation in STEM will be critical in future conflicts to properly leverage the new and increasingly advanced systems that the Army fields. Currently, however, the Army's formalized educational system has a severe lack of STEM education for the Army officer corps and is overly reliant on the undergraduate STEM courses to provide officers the STEM competencies they will need throughout their career.

Argument 1: STEM Education is not significantly included in any echelon of professional military education (PME) (BOLC, CCC, ILE, War College)

Under the assumption that S&T will continue to progress and will play an increasingly important role in future conflicts, it follows that STEM competencies and proficiency would be included in the military officer education system. This system encompasses the required courses that all officers, regardless of branch, must complete to be eligible for promotion or leadership roles at the next rank. For the purposes of this article we define PME as the Basic Officer Leader Course (BOLC), Captain's Career Course (CCC), Intermediate Level Education (ILE), and the Army War College. Currently, there is almost no STEM competency education or evaluation in any echelon of the formalized military leadership education model. The formalized military education system lacks the content to effectively train current and future generations of senior leaders to make decisions in an MDO environment. The increase of S&T in Army systems will not be integrated effectively in the future because senior leaders will lack the foundational understanding of STEM concepts, forcing future leaders to trend as either S&T Late Adopters or Automators.

In a survey of the current programs of instruction for the military officer education systems at each echelon there were only two blocks of instruction dedicated to STEM-related fields. In both ILE and the War College, there is a block of instruction related to nuclear weapons and nuclear operational planning.[9,10] While understandably neither of these educational programs are designed to educate officers on the effects or an in-depth understanding of nuclear weapons or their effects, the concern arises from the lack of general STEM competency education for the senior leadership in the Army. Considering most officers have 10-12 years of service prior to attending ILE and more than 17 years prior to attending the War College, the conclusion is that the last formalized education most field grade leaders in the Army receive on STEM competencies was likely in their undergraduate education. At the lower echelon schools, BOLC and CCC, there is essentially no formalized education or assessment of STEM competencies. Some branches, such as Field Artillery and Engineers, have STEM-related points of instructions, but even in these fields these blocks of instruction account for less than 20% of the total hours of the course. While arguably both BOLC and CCC focus more on the development of tactical level skills for the positions their graduates will fill, this continues to widen the gap in STEM competencies for military officers upon graduation from their undergraduate commissioning source.

Further exacerbating the gap between STEM competencies and the development of other competencies is the formalized process for officers at both ILE and the War College to earn graduate degrees in various focus areas during their enrollment. All graduate degrees currently offered at both institutions, however, focus on history, politics, or international relations. The primary routes for an officer to obtain a graduate level degree in a STEM field currently is through selection for a functional area which requires a STEM degree, selection to be a rotating faculty member in a STEM department at the United States Military Academy, or through electing for a Graduate School Additional Duty Service Obligation (GRADSO) prior to commissioning as a second lieutenant. All three of these options are extremely selective, and in some cases potentially prohibitive towards an officer's career advancement. The end result is the vast majority of field grade officers have minimal formal STEM education or competency development throughout their military career.

With most military officers only having an undergraduate level education in STEM competencies the potential risks in future operations are most heavily prevalent during phases 2 (seize the initiative) and 3 (dominate) of the military operations model. During both phases, the focus is predominantly on offensive operations and leaders being able to exploit weaknesses and opportunities during the conflict. During these phases, however, there is also the greatest risk for the unknown as situations develop rapidly and there is a high degree of uncertainty in the developing conflict. FM 3-0 Chapter 1 highlights that the "proliferation of space and cyberspace capabilities further requires leadership who understand the advantages those capabilities create in their operational environment" and that leaders at echelon must be able to integrate and synchronize these capabilities to create and exploit advantages.5 The formal integration of these highly S&T related capabilities into the operations process underscores the need for officers with a solid foundation in STEM competencies in order to achieve the optimum results on the battlefield.

As a vignette, consider the threat the Army faced from improvised explosive devices (IEDs) during Operations Iraqi Freedom and Enduring Freedom throughout the early 2000s and 2010s. While conventional conflict was a major component of both of these conflicts, estimates of casualties from IEDs range from 40-50% across both of these campaigns.[11,12] When the US entered Phase 2 of these operations in the early 2000s, forces were generally not equipped or prepared for IED attacks and the number of casualties gradually increased over the first 10 years of conflict. This unexpected threat prompted a response from the military to continue to seize the initiative and enter Phase 3 of each operation. The enemy, however, did not remain static and continued to develop new methods of employment to evade US protection efforts. By comparison, the S&T employed to develop IEDs is considerably less complex than the technology being employed currently in the conflict in the Ukraine. In future conflicts, it will be increasingly important for military leaders at echelon to have a foundation in STEM competencies in order to attempt to stay ahead of the development of countermeasures or unknown threats.[13] This importance further amplifies by considering the employment of potential chemical or nuclear threats on the battlefield by combatants. Without a solid foundation in STEM competencies, officers at echelon will lose valuable time developing the skills, knowledge, and understanding to effectively analyze the environment and either make decisions on the battlefield or provide meaningful recommendations to senior leaders.

Argument 2: Officers with STEM degrees are pre-dominantly developed during undergraduate education; however, STEM courses have been decreasing in education.

Since graduates from ROTC programs have a wide range of requirements and variability between institutions it is difficult to assess the number of core STEM courses that ROTC graduates are required to complete in order to earn an undergraduate degree. While the core course requirements at the United States Military Academy (USMA) have changed over the years, the core courses have generally remained the same and serve as an effective control to assess the changes in STEM background for newly commissioned officers. Conducting a crosswalk of the core course requirements to earn a Bachelor of Science degree from the United States Military Academy revealed a trend that the number of required STEM courses for USMA graduates decreased over the past 40 years.

From 1985-1992 all cadets, including those in history, philosophy, or arts (HPA) focus areas, completed 16 core STEM courses out of the 32 required core courses (50.0% of the core course requirement). Cadets in a math, science, or engineering (MSE) focus were required to complete 18 core STEM courses out of the 32 required core courses (56.3% of the core course requirement).[14,15] Beginning in 1993-2007 the core course requirement decreased to 26 common courses for all cadets and the number of courses in a major ranged from 10-18 courses. Of the 26 core courses there were 14 core STEM courses required (54% of the core course requirement). It is important to note two of the core STEM courses were related to information technology/systems and both electrical and mechanical engineering were dropped from the core course sequence. Furthermore, the core engineering sequence reduced from five courses to three courses for all cadets regardless of major or focus area.[15,16]

Table 1: Cross-walk of Core STEM Courses Required to Graduate USMA[14–17]

1985-1992 Core Courses	1993-2014 Core Courses	2015-Present Core Courses
Chemistry x 2	Chemistry x 2	Chemistry x 1
Computer Science x 1	Computer Science x 2	Cyber/IT x 2
Math x 4	Math x 4	Chemistry/Physics/Biology x 1
Physics x 2	Environmental Science x 1	Math x 3
Electrical Engineering x 1	Physics x 2	Physics x 1
Mechanical Engineering x 2	Engineering Sequence x 3	Environmental Science x 1
Environmental Science x 1		
Engineering Sequence x 2 (HPA focus)		Engineering Sequence x 3
Engineering Sequence x 3 (MSE focus)		
HPA Required Electives: EV365		
MSE Required Electives: Math x1, Electrical Engineering x1, Physics x1		
Total STEM: 16 HPA / 18 MSE Focus	**Total STEM: 14 courses**	**Total STEM: 12 Courses**

In 2015 the United States Military Academy conducted a review of the academic program and restructured the core course sequence yet again. Under the new structure, cadets complete 26 core courses with 12 core STEM courses (46.2% of the core course requirement) and academic majors now have a standardized number of 13 courses including 3 electives which relate to the major field of study.[16,17] A summary of the core STEM courses cross-walk from the past 40 years is shown in Table 1.

While the average percentage of core STEM courses remained generally consistent across the years evaluated, the total number of STEM courses consistently decreased. Furthermore, West Point has gradually decreased the number of overall courses required to complete the academic program. From 1985-1992 cadets were required to complete 44 academic course to graduate.[14] In 1993 the number of required courses was decreased to 40 courses required to graduate.[15] It is important to note during this time period several majors, primarily in the STEM fields, required their cadets to complete more than 40 courses to earn their degrees. In order to normalize the values, the 40 course minimum was applied as the requirement to graduate and compared to the number of STEM courses required for all cadets. The requirement to complete 40 academic courses has remained constant through the present graduates, however the number of required STEM courses decreased to 12 courses in 2015.[17] The decrease in the number of overall courses compared to the number of STEM courses is shown in Table 2. While this data does not include an assessment of cadet performance across the last 40 years, nor their performance as officers upon graduation, it does reveal the general trend of the institution to focus less on STEM education for the officer corps, especially for officers who do not major in a STEM field.

In addition to requiring graduates to complete both less overall academic courses and less STEM courses there were several important changes to the STEM course requirements that are worth highlighting during this 40-year period. Beginning in 1993 the STEM course requirements focused on including more information technology courses to the curriculum decreasing the number of engineering courses from 5 courses to 3 courses.[14,15] Following the 2015 restructuring of the academic program cadets were only required to complete one semester of general chemistry and one semester of physics. The final physical science course was an option between general chemistry II, physics II, and a general biology course.[17] This is a significant change in the depth of knowledge for graduates that is not evident upon a review of the number of courses required, but is worth consideration when assessing the STEM competencies gap.

As the current model for officers to develop STEM competencies is almost solely reliant on undergraduate education, the officer corps is at significant risk to not possess the skills necessary to integrate or synchronize the technology of future conflicts. This leads to the potential that both current and future military officers will tend towards the extremes of the spectrum of S&T integration, rather than being S&T real-time integrators.

Table 2: Normalized Percentage of Academic Course Requirement at USMA 1985-Present[14–17]

	1985-1992	1993-2014	2015-Present
Academic Course Requirement	44	40	40
STEM Course Requirement	HPA Focus: 16 MSE Focus: 18	14	12
% STEM Courses Required	HPA Focus: 36.4% MSE Focus: 40.9%	35.0%	30.0%

Argument 3:
Future operations in MDO will require leaders to make decisions rapidly in ambiguous situations. These operations will require leaders to effectively integrate multiple systems and data streams simultaneously in order to make optimal decisions.

During Phases 2 and 3, when offensive operations are the primary focus, the understanding of the operational environment will develop rapidly and will likely contain large amounts of ambiguity. During these periods, the most effective officers can analyze ill-defined problems into actionable components to make recommendations and decisions to maintain momentum. With the increased prevalence of AI/ML systems and other technological breakthroughs, those who can integrate technology in real-time will have an advantage of leveraging these information streams to make more timely and effective decisions. One of the tenets of MDO is that these conflicts will contain "ambiguous or uncertain operational environments" and that leaders will need to execute judgement to "distinguish between risk acceptance…[for] successful operations and potentially disastrous rashness."[5] Military leadership in MDO and the understanding that effective decision making in ambiguous situations will be a spectrum of a leader's ability to integrate the varied sources of information, to rapidly make decisions, and to achieve success on the battlefields of the future. Comparative research proposes that senior-level leaders with STEM education make better decisions in highly competitive and developing fields when facing ambiguity and in increasingly technological fields or environments.[18,19]

These periods of ambiguity can be correlated to the experiences that CEOs of companies have when guiding their companies through ambiguous business environments. Both senior leaders in the military and in corporations make decisions that impact a large number of individuals. Research suggests that STEM-educated business leaders are better able to navigate their businesses through these ambiguous situations and create new value for their organizations.[18,19] Research into businesses who were faced with ambiguous environments found that "STEM leaders are able to make better decisions when innovation is crucial and there is a high level of ambiguity."[18] This result was also shown to be more important for companies that specialized in technology or STEM-related industries. The study found CEOs with robust STEM competencies not only better understood the technology of their company, but also understood the broader impact of the technology across the industry and created significantly more value for their organizations and the shareholders.[18] These STEM educated leaders are able to make a preferred decision due to their ability to "recognize, evaluate, and execute real options crucial to innovation."[18] While the military does not have shareholders in monetary terms, the shareholders impacted by the decisions of the senior leaders are the Soldiers, civilian support staff, family members and the broader American people; all of whom expect our senior leaders to make decisions that will help win our Nation's wars and protect our Nation. With the increasing prevalence of technology in the military, it follows that senior leaders in the military would benefit by increased understanding of STEM competencies and the foundations behind the technology they are employing to win future conflicts.

Research confirms STEM educated CEOs are better able to navigate a company through ambiguous situations to achieve success. Compared to non-STEM educated business leaders, STEM educated leaders are able to break down ambiguous situations into actionable decisions and then determine a potential course of action.[18] It follows that the education these leaders receive during their formal education enables them to make better decisions. A significant competency of STEM education develops individuals who can think analytically and identify the variables that are controls versus variables that can be affected. While a detailed education in humanities allows leaders to understand the human and cultural dimensions of conflicts, the ability to think analytically is a characteristic of STEM fields. Since Phases 2 and 3 of the JP 3-0 operations model highlight the ambiguity of these phases, it follows that STEM-educated leaders can make more effective decisions compared to their humanities educated peers. Layering the increased emphasis on the necessity for STEM leaders in order to effectively integrate technology into the decision-making process, the need for STEM educated officers becomes increasingly important for resolving future conflicts with efficiency.

One important finding from the study of the differences between STEM and non-STEM educated leaders was that "complex technical information cannot be conveyed cheaply, quickly, or easily to a non-STEM educated leader."[18] When applied to the model of the US military and combat operations in a potential presence of either chemical or nuclear attacks, the ability of senior leaders to understand and process data and models is critical to making effective and timely decisions. As a vignette, consider if there was a threat of a detonation of a low-yield nuclear weapon during an engagement. As part of the planning for the operation the staff would consider the potential impacts of a detonation and the post-blast effects on the environment as part of the planning for future operations. This can be accomplished by the computer-based effects modeling software that is currently in development within the United States military. These models can predict both the immediate post-detonation effects, such as thermal, blast damage, and prompt radiation, as well as the residual radiation effects. These models allow the operations planners to both consider the casualty evacuation plan following a detonation as well as the follow-on operations for the unit. While the staff and subject matter expert, i.e., FA-52 officers, would be the proponents to make recommendations to the commander, if the commander cannot quickly process the provided information, then there will be a delay in the decision making process. Based on the findings in business, it follows that STEM educated leaders would be able to process and understand the information faster than non-STEM educated leaders and therefore arrive at a decision sooner.

Another aspect that FM 3-0 focused on with the introduction of MDO is that the battlefield is no longer three dimensional. Adding in the presence and capabilities of space and cyberspace and their impacts on the battlefield adds additional strain on the intelligence preparation of the battlefield (IPB) prior to and during operations. Leaders will be expected to utilize the various systems and capabilities in their organizations to develop "timely, accurate, relevant, and predictive intelligence" in forming courses of action and identifying mission objectives.[5] This suggests that AI/ML systems will likely play a significant role in future operations and leaders need to be able to rapidly discern which data streams and recommendations are most relevant to understanding the operational environment. Two of the tenets of MDO are agility and convergence. Agility describes the ability of an organization to act faster than the enemy especially in the offensive phases of conflict.[5] Convergence is the ability to create exploitable opportunities from the "employment of capabilities from multiple domains and echelons against combinations of decisive points" and enable mission accomplishment.[5] Both of these tenets rely heavily on the ability of leaders to integrate and synchronize a variety of systems and intelligence sources into actionable mission orders. While leaders who tend towards the ends of the S&T integration spectrum may be able to identify and achieve success, there is a greater probability that leaders who can integrate the systems in real-time will have a better understanding of the operational environment. This understanding of the complete operational environment across multiple domains is the key to successfully exploiting the opportunities on the battlefield and achieving the mission.

Recommendation Summary

- **STEM integrated with Professional Military Education (PME) at echelon.**
- **STEM/Data analysis assessment during Battalion Command Assessment Program.**
- **Programs to allow for MS/PhD focused studies for officers.**
- **Quota of commissioned officers with STEM degrees/focuses.**

The United States is currently in Phase 0 and 1 of the joint operations model: this means there is time to adjust the model in preparation for the next conflict. However, understanding that making a STEM-educated battalion commander takes over 20 years it is evident that the longer the Army waits to begin closing the gap the greater the risk becomes. The planning horizon demonstrates the need to evaluate our officer development models immediately as making STEM-competent battalion and brigade commanders takes even longer than weapons procurement timelines. We propose the following recommendations to begin closing the STEM education gap and to shift more leaders towards the Technology Real-Time Integration section of the spectrum.

1. STEM competencies should be taught and assessed at each echelon of PME. This should be tailored to the specific level of warfare the officer is expected to predominantly engage: i.e., officers attending the Army War College receive in-depth training on the effects of nuclear and chemical weapons, while officers in CCC receive training on the various communication systems and the theoretical framework behind how the communications work.

2. STEM competencies and data analysis included in the assessment portion of the Battalion Command Assessment Program (BCAP). As Battalion Commanders are likely the first level of command where the staff would be able to obtain "big data" using AI/ML systems, these future commanders should be familiar with how the data is consolidated and be assessed on their ability to discern useful information from the data set. This would help to determine the leaders who possess the pre-requisite skills to be successful in future conflicts with the high degree of technology integration.

3. Programs that allow officers in ILE and the Army War College to obtain certifications in STEM related fields. These could be provided in concert with the currently established humanities related graduate degrees that are currently offered. One major consideration is that these degrees would likely not include the experimental design portions of these types of degrees but would include the course work associated with these degrees to provide the theoretical STEM competencies the leaders would need to understand a broad range of fields. From a review of current graduate programs there is no current model for this to be adapted, but would be an Army initiative specific to help cover the STEM gap in the officer corps. While these programs are not equivalent to the knowledge gained through a traditional MS or PhD program due to the lack of individual novel thinking and synthesis of ideas, it could provide a mechanism to ensure officers at echelon continue to develop their competencies in STEM related fields.

3a. Implementation of a Naval Post Graduate School (NPGS) or Air Force Institute of Technology (AFIT) type of graduate school in the Army through USMA with research internships at Army research centers. Regular Army officers can obtain STEM degrees and conduct a year of Army research at either an Army Research Lab (ARL) or at one of the centers under U.S. Army Combat Capabilities Development Command (DEVCOM) structure. An alternative pathway in the short term is to utilize the current graduate level programs in place from sister services. Both the US Air Force and Navy already have post-graduate level educational systems built into their structure and officer development models. While on the surface there is inherently more technical aspects associated with both of these branches of the military, that gap is rapidly narrowing as the Army becomes more reliant on technology and the integration of systems. In the short term, the Army should seek to obtain allocations at both NPGS and AFIT for officers to obtain graduate level degrees, either following or while attending ILE. A model is already in place for some functional areas, such as FA-52, which has allocations for officers to attend AFIT graduate certificate courses of Nuclear Weapons Effects Policy and Proliferation (NWEPP) and Countering Weapons of Mass Destruction (CWMD).[20] These courses are generally completed remotely, and similar to distance learning ILE, officers could complete alongside their current assignments. This model should be expanded to include the other AFIT graduate certificate courses aligned with branch specific skill sets and more broadly for officers to seek self-development.

4. At least one writing assignment specifically tailored to current developments in STEM related fields integrated into each echelon of the military education system. This assignment would serve to introduce leaders to the STEM foundations behind the equipment and or resources available to them at their specific level of warfare.

5. A quota on the number of commissioned officers with STEM degrees for each year group. Increasing the percentage of newly commissioned officers with degrees in STEM related fields will help to contribute towards closing the STEM gap in the officer corps and will help set the conditions for the future leaders of the military to have the necessary skills and ability to succeed in future conflicts.

6. Provide a reward structure for officers who earn a graduate level degree in STEM related fields. As proposed in Part 2 of this sequence, at promotion boards consideration will be given to those officers who receive a graduate level STEM degree should be viewed as the equivalent of receiving a “Most Qualified” (MQ) officer evaluation report (OER) at their current rank.[21] This would help to both increase the interest in these programs, while also recognizing the contribution these officers are making towards preparing for the future conflict. It is important to note this should only be for graduate level STEM degrees which include a thesis based on experimentation, vice the broad overview at the graduate level outlined in recommendation 3 above.

Conclusion

In conclusion, the Army officer corps is currently at risk to successfully integrate the wide variety of systems in development to prepare for future conflicts. The current professional military education system relies, almost exclusively, on an officer’s undergraduate education to set the foundation for STEM competencies. As technology continues to rapidly develop and S&T capabilities are being introduced into all echelons of the military it is paramount that the current PME model is re-evaluated to include more development of STEM competencies. Just as the knowledge and skills gained from in-depth studies of military history and science are critical towards an officer’s professional growth, the abilities of officers to understand the STEM concepts that enable these new systems will be critical towards successfully integrating them into the operations process. While no one leader is going to be the subject matter expert in all systems, aligning STEM training against the various staff and war fighting functions will allow for leaders to gather a more in-depth understanding of the operational environment. Commanders who are then able to synthesize and determine courses of action that yield the highest probability of success will be able to seize and maintain the initiative in future conflicts. The successful integration of capabilities introduced by the emerging technology ensures that our Army is prepared for the next conflict. To achieve this end, officers at echelon need to consistently develop their understanding and depth of STEM competencies so we can continue to meet our mission and win our Nation’s wars. ■

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