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A CROSS-DISCIPLINE FRAMEWORK TO ENABLE MILITARY MODERNIZATION RESEARCH

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ABSTRACT

The field of military development touches upon disciplines from basic science to international policy. The complexity of modern military development creates additional layers of categorization in an environment of increasingly multidisciplinary research. Hierarchy in complex systems can improve communication and outcomes. In addition to hierarchy, coordination amongst diverse research disciplines requires frameworks of standardized communication. By expanding existing military hierarchies and combining them with existing frameworks of cross-discipline coordination, practitioners of military modernization can improve knowledge management, sense-making, experiment design, and build improved campaigns of learning. To create methods of improved communication which accelerates military development, this paper proposes a sixteen-level hierarchy of military modernization with levels from basic science to global international policy, which are described in terms of research, theory, method, tools, applications, datasets, and administrative information.

1 INTRODUCTION

In 2017, General Mark Milley provided testimony to the United States Senate Committee on Armed Services, outlining that both state competitors and non-state actors were integrating technologies to outmatch U.S. forces (2017). As a consequence, the U.S. Army took a number of measures to speed the development of future military concepts and capabilities. Efforts to increase developmental tempo included “a realignment of modernization responsibilities under a new organization” (Judson 2017).

Less than a year later, the Army established U.S. Army Futures Command (AFC), in Austin, Texas. As Secretary Ryan McCarthy mentioned, this organization’s goals included establishing unity of command and effort by consolidating modernization, streamlining work, and overcoming the bureaucratic inertia and stovepipes in previous organizations (Judson). In other words, “putting all of those participants under one roof, the process should ‘theoretically’ become easier, faster and more collaborative” (Judson).

In fact, AFC achieved many of its initial objectives in a short period of time. For the Army’s highest priority systems, Cross-Functional Teams combine the experience of “warfighters” with the technical expertise of capability developers, program managers, testers, logisticians, and scientists (Freedberg 2017). In a similar effort, Task Force Ignite seeks to integrate “warfighting” concept writers with science and technology (S&T) developers of two subordinate AFC commands - the Futures and Concepts Center and the Combat Capabilities Development Command (Hitchens 2020).

AFC reorganization puts practitioners of various disciplines, from basic science to military strategy, in closer and frequent contact. Collaboration between disciplines can create innovation, if properly enabled by cooperative processes and tools. Designing an enduring, flexible enterprise for modernization requires integrating principles of complex adaptive systems and cross-discipline cooperation.

This paper proposes that combining multiple disciplines requires new tools for coordinated, rapid, development. Acknowledging the complex nature of the modernization system requires holism and new forms of knowledge. Because modernization requires the transformation of abstract ideas (concepts) to physical realities (capabilities and materiel solutions), frameworks from the modeling discipline can act as a “Rosetta stone” that enables cross-discipline communication. Hierarchical frameworks provide structure and place to otherwise disparate components. Since modeling requires abstraction of real objects and topics by its very nature, it is a good integrator of disciplines. To this end, this paper will describe a matrix framework that combines a hierarchy of military models with a hybrid modeling framework to create a *Cross-Discipline Framework for Military Modernization*.

When this framework is populated with information, it can provide cross-referencing between the syntax and context of different disciplines to aide common understanding. This understanding can then be employed for a variety of situations including knowledge management, sense-making, consequence forecasting, application of S&T to capabilities, experiment design, the design of campaigns of learning, and other relevant activities. The following section provides a review of related work to help understand why this approach is both possible and necessary.

2 RELATED WORK

2.1 Complexity in the Army Modernization Enterprise

A basic understanding of complex systems helps to establish why frameworks for collaboration are necessary. Mitchell (2009) defines a complex system as a large network of components with no central control and whose simple rules give rise to collective behavior, sophisticated processing, and adaptation via learning or evolution. It is helpful to think of how the Army modernization enterprise and AFC might be considered a system operating in a complex environment. The Army modernization enterprise consists of a combination of loose and tightly connected organizational nodes that contribute to future force development. AFC is the most formally defined component of this network. AFC, like many other military organizations, is made up of a series of progressively smaller subordinate organizations. AFC contains major components including the Futures and Concepts Center, Combat Capabilities Development Command (DEVCOM), and eight Cross-Functional Teams. Alongside these components are a number of other organizations such as the Artificial Intelligence & Integration Center, Army Applications Lab, University Technology Development Division, Army Testing & Evaluation Command, 75th Innovation Command, The Research and Analysis Center (TRAC), and others. These organizations combine military and civilians from a number of fields like engineering, basic and applied science, modeling and simulation professionals, officers and soldiers from all military branches, and many other professions. Even inside the formal organization, ad hoc networks emerge to respond to emergent issues.

2.2 Modernization through Top-Down Guidance and Bottom-Up Solutions

AFC does impose some centralized control by ensuring laws, regulations, and senior leaders’ intent are carried out. However, the daily relationships between subordinate and external organizational agents are generally loosely coupled and dynamic. This flexibility allows for bespoke organizations to develop around emergent issues. This requires a balance between directed outcomes and organizational flexibility. From an engineering perspective; top-down approaches are associated with decomposition from a known goal, which may not be an appropriate response when final formulations are uncertain. However, when top-down *guidance* is employed to influence the system’s direction, as opposed to centrally controlling it, it can act as a contributor to a “bottom up” process of creation. Senior leader guidance, external feedback, and internal learning do change the conditions of the problems to be solved. The “top down” guidance that AFC employs about modernization can create environmental imperatives for subordinate organizations and their members who act as agents in the modernization enterprise. This leads to adaption and additional learning, to progressively evolve the material and conceptual solutions for future military problems. Creating adaptive systems that improve learning and communication can improve the quality of outcomes and ensure that top-down guidance supports the creative processes critical to development. Hierarchy of knowledge provides a starting point for adaptive cross-discipline communication for the emergent teams that create solutions.

2.3 Hierarchy as a Means of Efficient Communication in Complex Systems

The study of communication and network science highlights this relationship between hierarchy and communication. Guimerà et al. (2001) posit that organizations are "a system of information processors." The authors identify that although "flat" organizations are the most efficient to solve problems when there are no costs, the introduction of even small costs creates conditions for hierarchical organization. In other words, hierarchy can make communication more efficient. This comes to no surprise to simulations professionals who long dealt with costs of processing and memory and employed hierarchy of modeling fidelity as a solution (Battilega and Grange 1984). Even in management and business studies, where flat organizations experienced great praise, there is acknowledgement that "loosely coupled" hierarchies play an important role in enabling efficient operation (Kane 2013). This research supports the idea of employing an expanded military hierarchy to improve communication in modernization efforts.

In cross-discipline studies, the researcher must deal with the fact that each discipline develops its own syntax appropriate for the needs of its own context. Interpretation between fields is helped by common reference points. Because *modeling* is "the purposeful abstraction and simplification of the perception of a real or imagined system with the intention to solve [a problem]" (Tolk 2012), it can act as that common reference. Specifically, military modernization seeks to solve the problem of choosing what materiel and non-materiel solutions to acquire. Because these solutions have not yet been realized they are, like models, abstract. Modeling can act as a stand-in for physical realities in modernization problems. If each discipline can explain their proposals in the form of models at the appropriate military activity level, they can facilitate communication. Tying coordination through a hierarchy of modeling is a way to "string together" a series of aggregated abstractions amongst disparate fields. By using an expanded military hierarchy as the reference point, each discipline can add their specific research at each level.

2.4 Hierarchy in Military Modeling and Experimentation

The field of military experimentation also employs a variety of hierarchies, as Hartley (2020) highlights in great detail. For example, most wargamers are familiar with tactical, operational, strategic, or even policy games. Elsewhere, Joint Publication-1 defines that unit/crew actions, engagements, and battles reside at the tactical level; major operations and campaigns at the operational level; theater strategy and national policy at the strategic level. Tolk (2012) highlights the connection of this understanding in the field of military modeling and simulation. At the base of the hierarchy is a technical (engineering) level composed of physics-based engineering models that represent components and systems. Above this is a tactical (engagement) level that focuses on system-on-system engagements. The next level represents series of engagements in battles or missions, known as the operational level (theater/campaign). Finally, the top of the hierarchy is concerned with designs of forces at the strategic level. Moving up the hierarchy represents higher levels of aggregation and moving down, increasing levels of resolution (Tolk, 2012). As Gallagher et al. (2014) point out, similar depictions are in references from the United States Air Force, National Research Council, Center for Army Analysis, and the Department of Defense. The recent expansion in modernization experimentation may require additional levels of hierarchy to finely scope events, due to increasing internal complexity.

The Army Modernization Enterprise Analytic Community describes six focus areas in their expanded hierarchy (Figure 1). The depiction aligns responsible agencies with different levels of realization, with the exception being the activities of Capability Development Integration Directorates (CDIDs), which are defined by a method - experimentation. Meanwhile, DEVCOM, the Data Analysis Center (DAC), TRAC, the Center for Army Analysis (CAA), and Federally Funded Research and Development

Commands (FFRDC) such as RAND are categorized by their military modernization hierarchical level, which generally align to the JP-1 levels of warfare. This depiction serves a useful role in highlighting the Army's alignment of tasks to purposes. However, its focus on analysis does not provide clear alignment with agencies who conduct synthetic or creative activities, which is the other side of the developmental coin. Synthetic or creative entities include engineers designing components and capabilities, concept designers, select force developers, writers, and many others. Additionally, while this depiction is explanatory at macro level, it does not necessarily coordinate between disciplines.

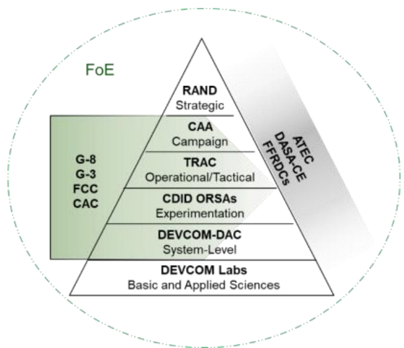

Figure 1: The Army Modernization Enterprise Analytic Community focus areas (U.S. Army 2020).

For better or for worse, the scale and diversity of modern U.S. military operations increased the complexity of military terminology, knowledge, and operations. For example, where campaigns were once the purview of the strategic level, U.S. military doctrine has since made them the province of the operational level (United States Army 1982). Those interested in the particulars of the strategy-versus-operations debate should refer to Kelly and Brennan (2009) and Brucino (2020). Additionally, ideas such as the so called "strategic corporal" led to the belief of a military "butterfly effect" where low-level activities could cascade through systems generating catastrophic effects. While this particular anecdote has been called into question (Feltey 2015), the military crispness of categories continues to break down. The U.S. Army's newest Field Manual 3.0 for Operations is likely to add a "Theater Strategic" level between Strategic and Operational Levels of War.

Recognizing these and other issues, Gallagher et al. (2014) expanded the traditional military modeling hierarchy, adding levels of "defense enterprise" and "government, non-government, and coalition instruments of power" above the campaign/theater level. Levels below the system engineering level were not added. Gallagher would later work with Hackman and Lad to extend this hierarchy into multiple dimensions "to provide a framework to assess the tools, data, people, processes, and partnerships" (2018). This paper will attempt a similar goal, but through the incorporation of a transdiscipline framework.

2.5 Cross-Discipline Coordination: A Familiar Task in Military Planning

While establishing appropriate hierarchy is important to facilitating communication, it is not sufficient to complete a framework for improved coordination. Leveraging cross-discipline tools are equally important, especially when dealing with complicated or complex systems. The U.S. military already relies on forms of cross-discipline coordination, including combined operations of multinational forces, interagency operations across the Whole of Government, Joint operations across each of the services, and combined arms operations between each branch or specialty of the Army. To enable these cross-discipline operations, the Army employs frameworks of understanding, such as the six Warfighting Functions (mission command/command and control, movement and maneuver, fires, intelligence, protection, and sustainment). These frameworks provide military practitioners the ability to deal with complexity of daily operations and future plans. To better coordinate activities, the Army could employ a expanded version of the Warfighting Functions to integrate the various disciplines involved in modernization.

2.6 Complexity and Cross-Discipline Frameworks

As Snowden and Boone (2007) point out in their Cynefin framework, complicated problems require leaders to sense, analyze, and respond while balancing viewpoints of diverse experts to allow for novel solutions. When problems are sensitive to change, are interdependent, wicked, or based on incomplete data, they are likely complex. To solve complex problems, groups of experts are put in close proximity and use experimental approaches to probe, sense, and then respond. Approaches that attempt to employ best practices or other command and control practices are likely to fail to solve their problem. Organizing information to solve complex problems is essential. Frameworks that help organize thought across disciplines without undue constraints are especially useful.

Complexity applies not only to the system being studied, but also the number of disciplines involved in the study. Tolk, Harper, and Mustafee (2019) outline three categories of cross-discipline frameworks; multidisciplinary, interdisciplinary, and transdisciplinary. In multidisciplinary approaches, individual disciplines remain separate but increase their scope, methods, and information based on interactions with other disciplines. Interdisciplinary approaches create integration of concepts, methods, procedures and terms through blending and cooperation. Interdisciplinary teams may need to deconstruct practices of individual disciplines and restructure them into new forms. Transdisciplinary approaches seek systematic integration, with an overarching integration of disciplines that requires new methodological frameworks and coproduction of knowledge with stakeholders. While each cross-discipline approach is appropriate at different times, the "real-world" problem-orientation of the transdisciplinary approach makes it particularly well suited to managing large military studies and campaigns of learning.

Tolk et al. (2019) sought to develop a framework for transdisciplinary simulation studies. Simulation's dependency on modeling as a way of abstracting real-world ideas makes it a good candidate for aligning analytic and creative activities. Advantages of the transdisciplinary framework for hybrid modeling included a structured approach to collaboration, common data exchange, a holistic body of knowledge, common research questions, and aligned methods. To achieve the hybrid modeling framework, the authors combined the scientific focus areas of research, theory, and method alongside application focus areas of methods, tools, and application (Section 3.3 defines these terms in greater detail). In doing so, they created a single continuum that flowed from the referential aspect of modeling through the methodological aspects of simulation. This paper proposes a similar aggregation, but with slightly broader definitions, to allow application to the disciplines most applicable to AFC.

2.7 Combining Hierarchy and Cross-Discipline Techniques

This review reveals that hierarchies are a method of efficient organization that emerges in networks and systems where costs are experienced. Military studies have long employed systems of hierarchy for organization. The increasing complexity of military operations implies the need for complex problem solving approaches. This includes frameworks that not only organize by hierarchy, but organize experts from across multiple disciplines and facilitate communication for experimental learning. The combination of hierarchies across disciplines is visualized in the following section.

3 PROPOSED FRAMEWORK DESIGN

3.1 Overview

To address the organizational issues of AFC and others, a cross-discipline framework for military modernization is proposed. This matrix combines an adapted hierarchy of military models along the vertical axis, while employing a modified version of Tolk et al. (2017) Transdisciplinary-Enabling Framework for Hybrid Models on the horizontal axis. By combining the two frameworks into a single tool, the goal is to relate the components of research from a variety of disciplines to each other, as well as a hierarchy of military activities. With this visualization realized, risk of misunderstanding between disciplines is mitigated, resources can be more easily tracked, and plans of learning more rapidly developed. Figure 1 shows how existing military modernization hierarchies intersect with the proposed matrix.

Table 1: Comparison of Hierarchies. This shows the partially overlapping nature of the expanded hierarchy of military modernization with existing hierarchies such as Technology Readiness Levels, JP-1 Level of Warfare, AME Analytical Community Focus Areas (Figure 1) and an extrapolation of creative agencies. Beside these hierarchies is the original Transdisciplinary Framework for Hybrid Modeling, to be filled by researchers.

					Transdisciplinary-Enabling Framework				
					Scientific Focus Areas			Application Focus Areas	
Level of Hierarchy	TRL	JP-1 Level	AME Analytic Community	AME Creative Community	Research	Theory	Method	Tool	Application
Global International Policy		Strategic	Rand	Army/Joint Staffs					
Global Integrated Operations		Strategic	Rand	Army/Joint Staffs					
Regional Policy / Strategy		Strategic	Rand	Army/Joint Staffs					
National Policy / Strategy		Strategic	Rand	Army/Joint Staffs					
Total Force Analysis		Strategic	CAA	TRADOC Army Staff					
DoD Policy/ Service Policy		Strategic	Rand	Army/Joint Staffs					
Theater Strategies		Strategic	Rand/ CCMDs	CCMDs					
Theater Operations / Campaigns	7-9	Operations	CAA	FCC					
JOA Operations / Campaigns	7-9	Operations	TRAC	FCC					
Battles (Tactical Unit on Unit)	7-9	Tactical	TRAC/ CDIDs	CDIDs/ FCC					
Organizational Design		Tactical	CDIDs	CDIDs/ FCC					
Engagements (System on System)	7-9	Tactical	CDIDs	CDIDs / CFT					
Single Systems or Soldiers	6-9	Tactical	CDIDs/ DEVCOM	CDID Concepts/ CFT					
Components of Single Systems / Physiological Systems	3-5		DEVCOM	CDIDs/ CFT					
Applied Science	1-2		DEVCOM	DEVCOM					
Basic Science			DEVCOM	DEVCOM					

3.2 Adapted Hierarchy of Military Models (Vertical Axis)

Sixteen separate levels of military hierarchy are initially proposed for the vertical axis. The advent of AFC brings together diverse workgroups with differing goals. This means that human, material systems, and organizations are all considered and sorted. The hierarchy is sorted with micro-level systems at the bottom and increase to macro-level systems towards the top. Below, each level is outlined:

1. *Basic (Pure) Science* – This is "science that aims to create knowledge per se rather than knowledge for practical use" (Hansson 2007). While basic science is being funded by the military, there is no guarantee or necessary plan on if or how it will be used, which therefore separates it from applied science. Agencies such as the Army Research Laboratory conduct this type of research for AFC. Basic science could fall into the existing category of *engineering research and development*.

2. *Applied Science* – This is science pursued to guide practical decision making (Hansson 2007). It may emerge from a promising basic science discovery, or it may be a new application of a different applied application. Many components of AFC practice applied science, but DEVCOM is the primary center for this type of research. Applied science would fall into the classical category of *engineering research and development*.
3. *Components of Material / Physiological Systems* – This level is includes applied science and engineering whose goal is to create a particular component of a system in material solutions, or studies organ or physiological systems in biological or medical studies. There is overlap in this area between applied science and systems engineering. An example might be a motor which helps operate a tank turret. The tank is considered the system in this case, and the turret assembly a subcomponent. The tank (with crew) is capable of military operations in and of itself – the turret assembly is not. The circulatory system is critical to the well-being of a Soldier, but does not complete military objectives divorced from the Soldier. Organizations such as DEVCOM (especially the Data Analysis Center) and Cross Functional Teams (CFTs) are involved heavily in this area. The data gathered in this level influences the parametric and behavioral modeling for the *Systems* and higher levels. *Components of Material / Physiological Systems* would fall into the classical category of *engineering research and development*.
4. *Single Systems or Soldiers* – This is the first level of the hierarchy where the subject of study can demonstrate agency. These are material "end items" and soldiers, which are the subject of many budget decisions. Scientist and engineers join with operations researchers, modeling and simulations professionals, and military "operators" to analyze and create potential solutions. The CFTs, CDIDs, and FCC's Futures Integration Directorate have primary interest at this level. High resolution mathematical and simulation models will help drive understanding of the functioning of the system itself, and frames higher level models. *Single Systems or Soldiers* development would fall into the classic category of *engineering research and development*.
5. *Engagements (System/Soldier on System/Soldier)* – This level represents the interaction between a single, or few systems/soldiers against a single, or few adversary systems or soldiers. These are generally sub-unit interactions at the tactical level of warfare. Gallagher et al. (2014), point out research "at this level require performance characteristics of the systems under investigation, which are often deduced from system level models or gathered directly from operations or experimentation". The previous hierarchies of *components (Level 3)* and *single systems* (Level 4) help establish the parametric and behavioral models essential for experimentation at this level. These types of research are well suited for operations research, modeling and simulation, and wargaming. For this reason, TRAC, CDIDs, CFTs, and FCC entities are interested and suited to conduct research in these areas. *Engagements* were a previously recognized explanatory level (Tolk 2012).
6. *Organizational Design* – This is the aggregation of material solutions and personnel into units. The final stages of this process are realized during the Force Development Process as outlined in Army Regulation 71-32. Force development uses five phases: develop capabilities, design organizations, develop organization models, determine organizational authorizations, and document organizational authorizations. The development of capabilities is realized in some ways through the first four levels of the hierarchy, but tested by the capabilities performance in the higher ten categories (organization design excluded). Before capabilities can be experimented upon in the simulated operational world, they must first be realized as a unit. While TRADOC and HQDA are responsible for final Force Development, CDIDs and FCC work together to publish prototype organizations through Operational and Organizational (O&O) Documents. In other words, O&O are the designs for emerging units. Interestingly, this task is not acknowledged explicitly in classical models, but it is a critical step to modeling operations.
7. *Battles* – Battles are a higher level of engagements. Like engagements, they require a duel of forces. Instead of system duels though, these duels are between multiple units. As such, they

require models from the previous level of *Organizational Design*. For the purposes, of this hierarchy these are tactical engagements inside a limited area of operations, sequenced over a relatively short period of time. Research on *battle* outcomes are primary the realm of CDIDs, TRAC, and FCC. Battles are aligned with the classical level of mission/battles.

8. *Major Operations in the Joint Operations Area* – Joint Publication 1 (JP1) highlights three levels of warfare (armed conflict between friendly and enemy forces): tactical, operational, and strategic (Joint Chiefs of Staff 2017). Where systems, engagements, and battles represent the tactical level, major operations and campaigns represent the operational area. By arranging tactical actions in time, space, and purpose, commanders are able to achieve strategic objectives. For the purposes of this framework, the subject of research is generally the Combined and/or Joint Task Force, or a Combined and/or Joint Component Command. Army organizations researching at this level include TRAC, CAA, FCC and Combatant Commands. In classic frameworks, this activity falls implicitly between the *mission/battle* level and the *theatre/campaign* level.
9. *Campaigns in the Theater* – When research on campaigns and operations expand beyond a single Joint Operations Area, it is appropriate to think of theater operations or *campaigns in the theater*. While closely resembling major operations, the scope at the theater level are broader, including enabling operations and the possibility of simultaneous operations in multiple JOAs. Theater operations differ from theater strategies in that the former is concerned with achieving strategic objectives in a relatively limited scope and time. The audience of interest for *Campaigns in the Theater* is similar to *Major Operations in Joint Operations Areas*. In classic frameworks, this activity falls implicitly between the *mission/battle* level and the *theatre/campaign* level.
10. *Strategies for Theaters* – JP-1 explains that “strategy is a prudent idea or set of ideas for employing instruments of national power [diplomatic, information, military, economic] in a synchronized and integrated fashion to achieve theater and multinational objectives” (Joint Chiefs of Staff 2017). Theater campaign objectives are most often set by theater strategies. Theater strategies are mostly limited to the geographic theater of a Geographic Combatant Command and are informed by higher strategies and policies. Strategy is often described in terms of ends, ways, and means (Yarger 2006). Future capabilities align with the resources, or means of a strategy. Future concepts may influence the ways or “how” of strategies. The ends of a strategy are informed by future operating environment studies. CAA, TRAC, FCC, GCC, Joint Staff elements and ASCC headquarters conduct futures research at this level.
11. *Department/Service Policies* – According to the DoD Dictionary for Military and Associated Terms (2021), Department “policy directs and assigns tasks, prescribes desired capabilities, and provides guidance for ensuring the Armed Forces of the United States are prepared to perform their assigned roles. Implicitly, policy can create new roles and requirements for new capabilities”. While policies have the ability to impact any military hierarchy level, research on policies themselves are likely to be contained at the Joint and Army Staffs, CAA, and Federally Funded Research Corporations such as Rand.
12. *Force Design* – For the purposes of this hierarchy, *Force Design* is a macro-level organizational design that aggregates subordinate unit designs, creating trade-offs where required, to propose a Service-level proposal of what the force should look like. In the Army, this may lead to the Total Army Analysis that results in the Program Objective Memorandum (POM) force (Department of the Army 2019). Organizations such as TRADOC, AFC HQ, CAA, and the Army Staff are concerned with research at this level.
13. *National Government Policy and Strategy* – All military policies are subordinate to national guidance as laid out in the Constitution, U.S. law, U.S. government policy, and National Security Strategy. While national level guidance is made by the civilian government, the guidance and expertise of the military is often sought, which may require supporting research. Also, changes of these documents will naturally have impacts lower on the military hierarchy. This is often experienced through supporting research scenarios, whose impacts extend to the tactical level.

Note: Many documents such as the National Security Strategy, National Defense Strategy, and National Military Strategy may be considered policies, despite their explicit titles (Bruscino).

14. *Regional International Governmental Policy and Strategies* – While the activities of the U.S. military are governed by U.S. policy and strategy, sometimes these policies align the military to larger alliances, treaties, or regional agreements. For example, the U.S. may hypothetically realign its use of significant weapon systems, such as mines or cluster munitions, which have impacts on future forces that may need to be researched and might create capability gaps. Another example is that U.S. forces are a part of the North Atlantic Treaty Organization, which creates procedures and concepts that must be considered and integrated.
15. *Globally Integrated Operations (U.S.)* – Combatant Commands, including Geographic Combatant Commands (GCC) conduct operations and strategies that were previously outlined in lower levels. However, when operations are conducted across GCC boundaries, the need for *Globally Integrated Operations* (GIO) occurs. While GIO is subject to national level laws and guidance, international factors in the operating environment and the scale of operations across GCCs place this level near the top of the military hierarchy. Globally Integrated Operations is primarily the concern of the Joint Staff, GCCs, CCMDs, and the supporting service staffs.
16. *Global International Strategy and Policy (U.S., Trans-, Intergovernmental)* – This level is concerned with experimenting and modeling the impacts of decisions of the U.S. Government with respect to international relations, alliances, and agreements.

3.3 Adapted Transdisciplinary Framework for Hybrid Modeling (Horizontal Axis)

While the expanded hierarchy outlined in the previous section helps combine multiple frameworks and organize levels of military activity, it does not specify the tools and activities that researchers employ at each level, which is essential for cross-discipline collaboration. If activities by different disciplines can be made explicit in a standardized way, communication across these disciplines should benefit. By adopting a version of the Trans-Disciplinary Framework discussed previously, practitioners gain appreciation of research, theory, method, tools, and applications across different fields. By extending this framework to include references on what datasets are being used for research and coordination information for the practitioners conducting research, a system is developed that enables information sharing. Matrixing this extended framework with the expanded hierarchy defined in Section 3.2 helps researchers understand the relationship between research areas more quickly. To better understand this "horizontal" categorization, the following summaries are provided from Tolk et al. (2019), as well as two newly proposed categories.

1. *Research* – collection of theories, researchers, and organizations that are part of the body of knowledge. Research is the combination of a scientific discipline with its practitioners.
2. *Theory* – Substantiated explanatory framework for a series of facts that are testable and can be used to explain past and future observations
3. *Method* – procedures and techniques capturing a regular and systematic way to conduct an analysis; includes desired interactions of those involved.
4. *Tool* – implementations supporting the application of a method; i.e. computer simulations.
5. *Application* – the instance of methods and tools used to solve a particular problem, for example the OneSAF would be considered a specific application of a simulation tool.
6. *Dataset (New)* – the location and type of sets of data used to drive applications and tools. While data might be considered an application in a particular instance, that same data might be used for multiple, different applications. For this reason, it is useful to track it as a separate category.
7. *Administrative Data (New)* – This section allows researchers to list the organizing or individual points of contacts responsible for the research line, so that other researchers can coordinate for integration of research. Other non-categorized information or notes could be included in this section.

4 POSSIBLE USES

The overall purpose for this tool is to coordinate the activities of Army and other military modernization across disciplines in a more standardized way. For example, the framework can act as a system of categorization for research, models, and tools in an organization. The framework can be used as a sensemaking device (Table 2), so that participants can understand where they fall in the hierarchy and what sort of professionals they might collaborate with to mature their research into higher levels of development – such as turning applied science into operational approaches. Sense-making might be especially useful for new leaders coming into an organization. Researchers conducting experimentation and wargaming might also use this framework to scope their event design. For example, a researcher conducting experimentation on operational level may want to ensure they consult and incorporate models of organizational design and unit-on-unit battles, before developing their campaign studies. At times, these researchers may discover appropriate models are not available, prompting them to run precursor events that would provide appropriate data to create these foundational models. Leaders of learning organizations can anticipate these gaps and use the framework to design campaigns of learning that ensure a continuous process of discovery, modeling, and aggregating of knowledge to progressively higher levels of development.

Table 2: Cross-Discipline Framework in Hypothetical Use. Here a team is "brainstorming" an approach to link their simulations, from Applied Science to Theater Operations. They discover gaps at various levels, including not knowing where to obtain appropriate data. This table adds additional columns for administrative coordination of events.

	Research	*Theory*	*Method*	*Tool*	*Application*	*Data*	*Coordinating Agency*	*POC*
Global International Policy								
Global Integrated Operations	Global Ops	All Domain Operations		Wargame			Naval War College Rand	
Regional Policy / Strategy								
National Policy / Strategy								
Total Force Analysis				Wargame	JFOS			
DoD Policy/ Service Policy								
Theater Strategies								
Theater Operations / Campaigns	Operational Art	Multi-Domain Operations	Mixed	Wargame	Operational Wargame System		USMC	
JOA Operations / Campaigns	Operational Art	Multi-Domain Operations		Sim				
Battles (Tactical Unit on Unit)	Tactics Tactics Tactical SPT			Sim Sim Sim	OneSAF FIRESIM JDLM		PM OneSAF Fires Battle Lab Sustainment BL	
Organizational Design	Unit Design							
Engagements (System on System)	System Capability			Sim Sim Sim Sim Sim	OneSAF FIRESIM FFEADS EADSIM ATCOM		PM OneSAF Fires Battle Lab Fires Battle Lab Space and Missile Defense Command Aviation BattleLab	
Single Systems/Platform or Soldiers	Networking System				Joint Network Emulator			
Components of Single Systems / Physiological Systems				Sim	Universal Controller		Night Vision and Electronic Sensor Directorate	
Applied Science								
Basic Science								

5 FUTURE WORK

5.1 Socialization of Tool

It is important to point out that this framework is in its nascent stages. The publication of this paper acts as an initial "call to action" to the community of practice to work together to appropriately integrate use of this framework. Initially, socializing this framework is meant to start a discussion that leads to additional work. Ideally, each stakeholder would evaluate their required tasks against this matrix. This may reveal the need for additional levels in the vertical hierarchy or horizontal categories.

5.2 Population of Information

Once stakeholders were aligned, they could each populate the horizontal axis with the research, theory, method, tools, and datasets that they rely on or develop. This would help to develop a common understanding of who was responsible, for what, inside the enterprise. It may also reveal gaps – levels where components are missing or responsibility for management is ambiguous. Similarly, population of the matrix may reveal areas of duplication where multiple agencies are conducting similar work, which is not currently coordinated. Either of these cases could lead to more effective allocation of resources and management across the enterprise.

5.3 Distribution and Knowledge Management

Coordination for population could occur informally between agencies or through coordinated taskings by headquarters staff. To optimize efficiency, the eventual socialization and population of information into the matrix should be routinized and embedded into a widely available knowledge management system such as the Joint Staff *Joint Experimentation Network* (JExNet) or Army Futures Command's *Forge* database. Using the matrix as the framework for a modeling database would help create meaningful associations between discipline resources, in a useful and accessible way. It might also be used to modify future versions of standards such as the Department of Defense Modeling and Simulation Community of Interest Discovery Metadata Specification (MSC-DMS) which organizes the Defense M&S Catalog. The proposed model may be of particular interest to the Simulation Interoperability Standards Organization, which is working on an international metadata standard.

6 CONCLUSION

Military modernization touches on fields from basic science to international policy. The complexity of modern military operations creates additional layers of hierarchy within this scope, requiring expanded "vertical" categorization. Meanwhile, warfare reaches across all physical and cognitive domains, requiring the expertise of a growing field of experts. To help these various disciplines work together, a system of organization that arrays research, theory, method, tools, applications, and datasets can lead to better understanding, coordination, and more rapid positive outcomes. While both military hierarchies and tools for cross-discipline modeling existed in the past the *Cross-Discipline Framework for Military Modernization* is likely the first time these two ideas have been combined to create a framework specifically designed to increase innovation in this military development. With additional exploration and modification, this framework represents a key method to understanding and accelerating research, amongst and between the diverse fields of study of the Army Modernization Enterprise.

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