# The Technology Triad:

# Reimagining the Relationship Between

# Technology and Military Innovation

by

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ABSTRACT

Existing models of military innovation assume general resistance to change within militaries that necessitates an outside influence to induce military innovation. Within these approaches, the complex relationship between technology and innovation is normally addressed by either minimizing the importance of technology or separating it from the social process of innovation. Yet these approaches struggle to reflect emerging dynamics between technology and military innovation, and as a result, potentially contribute to wasted national resources and unnecessarily bloody wars. Reframing the relationship between technology and military innovation can provide novel insights into the apparent inability of militaries to align technology with strategic goals and inform more effective future alignment.

This dissertation leverages the insights of constructivist science and technology studies concepts to develop a novel model of military innovation: referred to here as the technology triad. The technology triad describes military sociotechnical systems in a way that highlights change and innovation within militaries. The model describes how doctrine, materiel, and “martial knowledge,” a new concept that relates to socially constructed truths about the conduct of war, interact to produce change and innovation within militaries. After constructing the model and exploring an in-depth application to the development of armored warfare in the United States Army prior to World War II, the case from which the model was developed, the dissertation explores the logical extension of the technology triad to establish a deductive framework against which to test the generalizability of the model. Nuclear weapons innovation in the United States military through the end of the Vietnam War provides a test of the model at the strategic level,

and the development and employment of armed drones in the United States, Russia, Israel, and Azerbaijan provide a test of a contemporary innovation for the technology triad. Together, these three cases demonstrate that framing the relationship between technology and military innovation in terms of the technology triad can inform concrete actions that military leaders can take related to the types of technologies that are most likely to be useful in future conflicts and ways to manage military innovations to increase opportunities to achieve strategic objectives.

# DEDICATION

To the families of the fallen, whose shoulders bear the true burden of war.

ACKNOWLEDGEMENTS

The assistance of so many people was integral to completing this dissertation that it would be impossible to produce an exhaustive list. Nonetheless, several people have been especially important in my academic development and deserve my gratitude. Without Andrew Maynard's leadership, mentorship, and encouragement over these last several years, this dissertation would not have been possible. Kirk Jalbert's perspective and guidance were invaluable throughout the development of my ideas, particularly at the beginning as I attempted to translate a rough identification of a question into a meaningful research agenda. Brad Allenby's challenges in areas where my thinking was overly dogmatic forced me to think deeper about the questions I address in this dissertation. Finally, I am grateful for the time that Jeff Kubiak invested in my development. Many of the ideas to which he introduced me were foundational in the development of my own ideas.

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# DISCLAIMER

The views expressed in this document are those of the author and do not necessarily reflect the official position of the U.S. Army School of Advanced Military Studies, the Department of the Army, or the Department of Defense.

TABLE OF CONTENTS

CHAPTER Page

CHAPTER Page

LIST OF FIGURES

LIST OF ACRONYMS

ANT .......................................................................................... Actor Network Theory

DOTMLPF-P .................................................. Doctrine, Organization, Training, Materiel,

Leadership, Personnel, Facilities, and Policy

DoD.......................................................................................... Department of Defense

FCS ..........................................................................................Future Combat System

HASC..............................................................House Armed Services Committee

ISR ............................................................ Intelligence, Surveillance, and Reconnaissance

NDRC .................................................................... National Defense Research Committee

OODA ..........................................................................Observe, Orient, Decide, Act

ORSD........................................................Office of Research and Scientific Development

POW.......................................................................................................Prisoner of War

RPV........................................................................................ Remotely Piloted Vehicle

SASC................................................................... Senate Armed Services Committee

SCOT .........................................................................................Social Construction of

Technology STS................................................................ Science and Technology Studies

UAS.......................................................................................... Unmanned Aerial System

UAV........................................................................................Unmanned Aerial Vehicle

USSBS ................................................................United States Strategic Bombing Survey

PROLOGUE

In a sparse martial arts gym next to an abandoned storefront, Dania and her partner Jim engaged in a very specific form of ritualistic combat developed by Polish warriors near the dawn of the gunpowder age. The opponents moved back and forth in a flurry of whirling swords, their movements measured by the rhythmic clanging of their sabers colliding. Each slashing attack was expertly countered by a reciprocal slash from the other fighter, which put both combatants in a position to repeat the series of sweeping attacks. Eventually, one of the fighters would make an almost imperceptible mistake in timing or body position, which produced a small opening for their adversary to score a slashing blow on the hand, exposed knee, or shoulder. Even in 17th century Poland, with razor-sharp sabers, these attacks were not always meant to kill. Rather, they served as a display of swordsmanship and skill in the face of a determined enemy and to settle disputes without loss of life.[1] Unfortunately for the Polish martial class that practiced this specific style of sword fighting, when Napoleon's army brought a fundamentally different style of sword fighting to Poland, the new fighting system and the weapons that enabled it were far superior. The art of Polish saber fighting, having endured for hundreds of years, died along with its practicing masters at the tips of French rapiers.[2]

At just under five feet tall and not more than a hundred pounds in weight, one might mistakenly assume that Dania, a former collegiate fencing champion, does not represent a serious physical threat. However, as soon as she picks up a saber and starts talking about the finer points of Polish saber dueling, it is clear that underestimating

[1] Richard Marsden, *Polish Saber: The Use of the Polish Saber on Foot in the 17th Century* (S.l.: Tyrant Industries, 2015), 194.
[2] Dania Wright, Polish Saber Demonstration and Instruction, February 8, 2021.

Dania is the sort of thing someone only does once. Dania explained through the thick mesh of her fencing mask that, when someone thrusts, you attack. When someone slashes, you attack. When someone blocks, you attack. Within the Polish saber system, every movement is a form of attack, which works very well against an opponent using the same system. A polish saber fighter knew that opponents must attack with cross cutting, circular slashes exclusively because blocks and thrusts are simply absent from the Polish system.[3]

There are a number of potential explanations for the absence of these now standard sword movements in the Polish system, despite the Poles' knowledge of them. Providing an outlet for noble quarrels in the form of dueling was one of the core social functions of the fighting system. It is possible that wide open slashes were seen as a less likely to inflict life threatening wounds, as an opponent could see the attack coming and have time to initiate their own slash to counter the move. Perhaps the cavalry culture of the Polish warrior class transferred their horsebound slashing techniques to dismounted combat. The wide-legged, toe-out fighting stance of a Polish fencer, like a soldier riding a horse, would seem to lend credibility to this argument. Any attempt to definitively explain the cause for this style of fighting risks devolving into speculation, and it is not important anyway to illustrate how this obscure east-European martial art for one-on-one combat relates to the modern management of technology and war at large scale.

The absence of moves other than cross-cutting slashes is the important part. The simplest reason for this absence would be that the Polish swordfighters did not believe moves other than slashes were necessary. The Poles developed an entire closed combat

[3] Wright.

system, techniques, weapons, and a mindset, that defined their specific way of sword fighting. The techniques were slashing attacks aimed at the enemy's weapon and exposed body parts. The weapon was a light, highly curved saber with an open hand guard to enable the circular wrist movements that define the style.

Most importantly, the mindset of someone employing this Polish style assumes that their opponent will fight in the same manner. The system is internally consistent. As long as both opponents fought in the same manner, the contest was decided by each fighter's individual skill in the techniques. Even though the Polish warriors would have shifted their focus from the first blood goal of dueling to inflicting mortal wounds when fighting a war, they still used the same weapons and the same basic cross-cutting slashes in combat.

When the French invaded Poland as part of Napoleon's conquest of Europe, they brought with them the Italian *duo tempi* sword fighting style first recorded by Agrippa in the early Renaissance period.[4] The French system used a straighter blade with a closed hand guard to protect their hands while they first blocked a slashing attack, then thrust at their opponent. Dania demonstrated this covered thrust technique with a light rapier against her partner, who had had nearly a hundred-pound weight advantage on her and a much heavier weapon. When Jim slashed his saber in the classic Polish style, Dania quickly brought her sword up to parry the swing and break his momentum. As soon as his flow was interrupted, Dania immediately thrust the tip of her sword into his face mask quickly and effortlessly delivering what would have been a fatal blow in real combat.

[4] Camillo Agrippa and Ken Mondschein, *Fencing: A Renaissance Treatise* (New York: Ithaca Press, 2009).

The Poles could not simply shift from the way they practiced in peacetime to a different style in the event of combat. Dania, who is highly skilled in both the Polish saber and in the Italian *duo tempi* style, commented during her demonstration that it was difficult to shift her mindset back and forth between the two fighting systems even with deliberate effort. Furthermore, assuming that the Poles could have switched their fighting style quickly, the weapons they employed were not designed for the new techniques. Their curved blades would have been inferior to the swords meant for a parry and thrust fighting style. The entire system of Polish saber fighting, the moves, weapons, and mindset, while it worked very well against an opponent employing the same system, left its practitioners at a devastating disadvantage when they encountered swordmen from outside their system.

Today, Polish saber fencing, with its flashy, circular movements, endures as a sport worldwide, but it failed to survive as a serious warfighting technique after contact with a system that was superior for the employment of violence to achieve political aims. Even though Polish saber fencing may not be the best choice for modern armed combat, there are important lessons that can be drawn from the conditions under which it fell out of favor that are as applicable today as they would have been two hundred years ago. The interaction between the *duo tempi* and Polish sword-fighting systems was a competition between military technologies that played out on the plains of Eastern Europe. With the proper framing, the defeat of the Polish system was not all that different than any number of other failures of military technology past, present, and future. This dissertation will seek to provide that framing.

"It is the test of combat, or the perceived probable results of the test of combat – the unique domain of the military professional – that ultimately and fundamentally establishes the validity of military posture and action."

-GEN Andrew Goodpaster[5]

# CHAPTER 1

# INTRODUCTION

Karl von Clausewitz, the early 19th-century philosopher of war, redefined the nature of war by first reducing it to its essence, the duel.[6] In this manner, he took an expansive and ill-defined concept and related to a concrete example that any contemporary thinker could easily imagine. From this common point of understanding, he built a complex set of arguments to relay the nature of an entire system which was much larger and more complex than two men fighting. Drawing inspiration from his example, the investigation of technology and military innovation that follows will start with a simple duel.

Just as war was in the early 19th century, both technology and military innovation are familiar concepts to military thinkers today. But also, as war was in Clausewitz's time, the fundamental nature of the relationship between technology and military innovation remains hidden under a veil of practical experiences and traditional thinking. With every new technological advancement, teasing apart this veil to gain access to the deeper understanding of the influence technology has on military innovation underneath

[5] Andrew J. Goodpaster and Samuel P. Huntington, *Civil-Military Relations*, Studies in Defense Policy (Washington: American Enterprise Institute for Public Policy Research, 1977), 32.
[6] Sun-Tzu and Carl von Clausewitz, *The Book of War* (New York: Modern Library, 2000), 264.

has becomes a more critical endeavor to maintain some semblance of stability in the international security environment. Polish saber dueling will help illustrate some of the basic concepts that will ultimately lead to a deeper understanding of the relationship between technology and military innovation.

**Technology and Military Innovation**

The complex system of sword fighting that characterized Polish dueling likely did not start with either the shape of the sword or the specific movements the swordsmen employed. It is improbable that, at some point in the late 16th century, some master swordsman found a highly curved saber with an open hand guard and developed the modern system of Polish saber fighting to fit the saber. It is equally improbable that this same swordsman started with today's fighting system, then designed the perfect saber to enable its practice. The sword and the techniques for its use evolved together over time, and they were unique to swordsmen in that part of the world.

When the Poles employed their elaborate style of sword fighting against the Italian *duo tempi* system, which was also represented by both the physical movements and specialized weapons, the Polish swordsmen were at a severe disadvantage. Agrippa had developed the Italian style of fighting around the same time that the Poles were developing their form of saber dueling. In contrast to the development of the Polish saber system, Agrippa did start out to develop the optimum style of fighting and a sword to support this system of fighting.[7] The Italian rapier, with its long thin blade and protective hand guard, was ideally suited to the parry and thrust style of fighting. The Italians had

[7] Agrippa and Mondschein, *Fencing*.

innovated, and the French were rewarded for adopting this innovation with victory in combat over the Polish when Napoleon conquered much of Europe.[8] Further complicating this relationship, simply fielding new equipment does not guarantee successful innovation. The rapier was not superior by its design alone. It was the combination of the design of the weapon and the way the French used it that made the *duo tempi* fighting system superior to the Polish saber system.

Modern weapons systems follow these same general trajectories. The technology that a military develops is deeply influenced by the people who develop it. There is no disconnected stream of technology from which militaries can pluck weapons systems and develop new ways of fighting. At the same time, it would be overly simplistic to discount the impact of new technology on the way that militaries fight. There are times where new technology enables a completely different style of fighting, which gives the innovative army an advantage over their adversaries. As the scale of combat and the complexity of weapons systems advances beyond the simple sword duel, management of the relationship between weapons development and changes in their use becomes more difficult.

Research related to technology and military innovation tends to favor either technological or social drivers of change within militaries. Focusing too much on the impact of new technologies on the conduct of war can lead one to discount important social considerations. J.F.C. Fuller provided one of the more extreme examples of this when he said, "tools, or weapons, if only the right ones can be discovered, form 99

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[8] Bert Gevaert, "The Use of the Saber in the Army of Napoleon," *Acta Periodica Duellatorum* 4, no. 1 (April 1, 2016): 103–51, https://doi.org/10.1515/apd-2016-0004.

percent of victory."[9] In contrast, the idea that people are responsible for developing and employing technology, could imply that military innovation is primarily a sociological question. Colin Gray exemplified this way of thinking when he stated that "the use made of technology typically is more important than the technology itself."[10] Scholars that subscribe to this view of the relationship between technology and military innovation do not discount it entirely, but they do tend to downplay its importance.

Disagreements about the relationship between technology and military innovation are more than an academic dispute. Some of the most horrific chapters in the history of war can be attributed to militaries' inability to manage new technologies and innovation adequately. Wars fought with new weapons and old tactics tend to be characterized by the senseless loss of life. It took too long for the belligerents in World War I to recognize that conducting human wave attacks against modern machine guns was a losing proposition. Beyond the conduct of wars, the outcome of them is also impacted by a poor understanding of the relationship between technology and military innovation. History is replete with examples of militaries that lost wars because they failed to appreciate the impact of new technologies on the character of war. France suffered under years of Nazi occupation because the Germans had more effectively managed emerging technologies and innovation. An inadequate understanding of technology and military innovation is impactful, even in peacetime. Precious resources are wasted worldwide on militaries' failed efforts to modernize every single day. In war and peace, the inability to manage technology and military innovation is costly.

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[9] J. F. C. Fuller, *Tanks In the Great War* (New York: E. P. Dutton and Company, 1920), 308.
[10] Colin Gray, "Weapons for Strategic Effect: How Important Is Technology?," Occasional Papers (Maxwell Air Force Base (Alabama): Air War College, January 2001), 32.

This dissertation will explore the relationship between technology and military innovation with the aim of contributing knowledge that can aid in the active management of military innovation. This goal implies that the product of this research must be more than an analytical tool that can employ the benefit of hindsight to explain what happened in the past. It must provide a way of thinking about the problem at hand that can be employed by militaries in uncertain environments. The central question that drives this research is: Can reframing the relationship between technology and military innovation provide insight to address the apparent inability of militaries to align technology with strategic goals and inform more effective future alignment?

This dissertation will leverage constructivist Science and Technology Studies (STS) insights to address this question and produce a novel model of military technology and innovation. The goal of producing a model that is practically useful in the active management of technology and military innovation will necessitate a framework that is general enough to apply to a wide range of innovations and specific enough to inform actions beyond a conceptual level. A series of case studies against which the new model is tested comprises the majority of the research that informs this dissertation to determine the degree to which the model meets this high standard. The final portion of this dissertation will apply the insights of the case studies and the model to illustrate how reframing the relationship between technology and military innovation can inform more effective alignment of technology and strategic goals.

### *A Model of Military Technology and Change*

A deeper understanding of the relationship between technology and military innovation starts with a comprehensive definition of technology. Colloquially, the word technology refers to the machines, especially computers, that enable modern life. Science and technology scholars use multiple, more precise definitions of technology depending on the scholar and the subject of their research. Academic definitions of technology are normally some combination of techniques, physical artifacts, or the knowledge required to build artifacts or connect techniques with their intended outcomes.[11] The various definitions of this word point to the artificiality of the concept "technology."

There is no concrete thing called "a technology" that someone can pick up and hold in their hand. Rather, it is a word that relates to a general idea or concept. To apply this loose concept to the problem of military innovation, it is helpful to think of technology as the fuzzy boundary between the physical world and the social world. Each of the three academic meanings of the word trend towards one side of that boundary or the other. Artifacts reside in the physical world. Knowledge is a product of social interactions. Techniques, as actions performed by people in the physical world, straddle the boundary.

But this boundary is not distinct. As discussed above, social activities influence the design and function of artifacts, and artifacts influence social activities. Similar reciprocal interactions between each of the three definitions of technology can be identified. The three forms of technology co-exist within the boundary between the social

[11] Wiebe E. Bijker, Thomas Parke Hughes, and Trevor Pinch, eds., *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*, Anniversary ed (Cambridge, Mass: MIT Press, 2012), xlii.

and physical worlds. Together, the three concepts form a single, dynamic concept of technology that defines the blurry boundary between the social and the physical by giving physical form to the ideas that are socially constructed, facilitating that construction through communications in the physical world, and influencing the further development of ideas themselves through the physical embodiment of existing ideas.

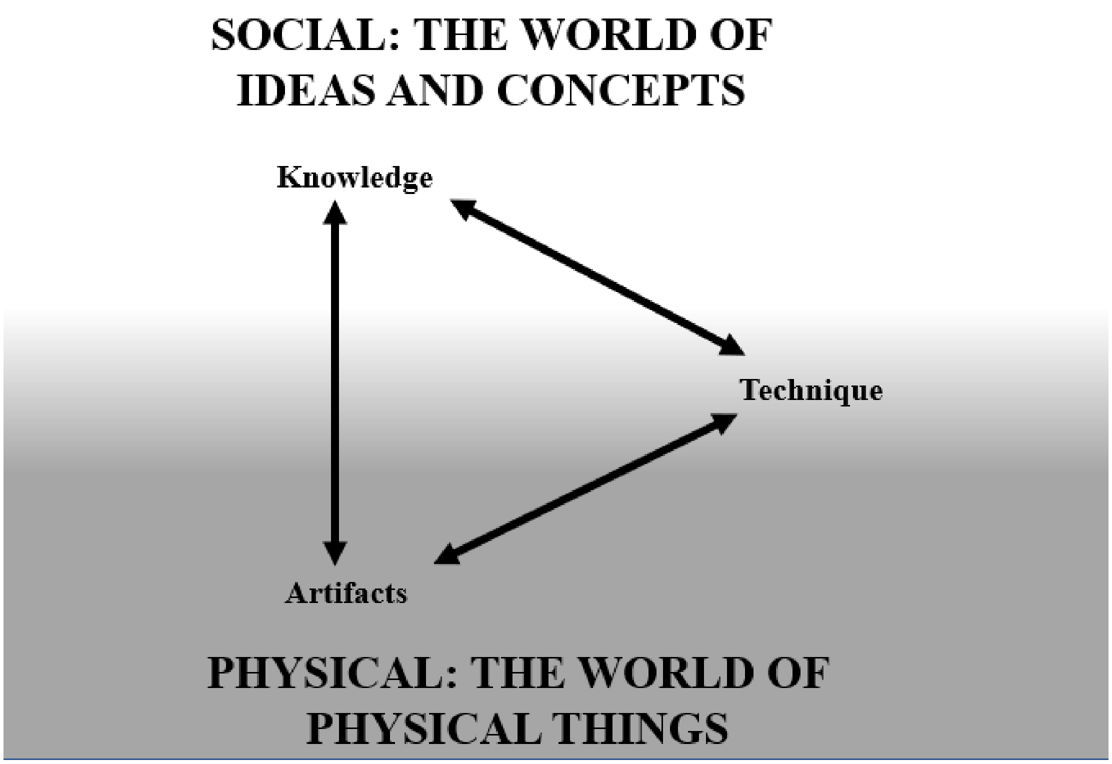


Figure 1: The three forms of technology straddle the boundary of the physical and social worlds

From this composite definition of technology, one can create an equally comprehensive definition of military technology. Artifacts are the weapons and equipment, or materiel, with which a military fights. Techniques are doctrine, or the way a military fights. To apply knowledge to military technology, this dissertation introduces the term “martial knowledge.” Martial knowledge posits the correct way to link materiel and doctrine to achieve strategic objectives and what those objectives should be in the first place. In other words, martial knowledge defines how wars should be fought and what wars are capable of accomplishing. While related to the existing idea of a “theory of victory,” martial knowledge is a more definitive concept because martial knowledge is a way of understanding reality as it exists in the present, rather than a theory for how to fight in an uncertain environment.[12] Martial knowledge is a representation of truth that has been validated through various social processes by a military. Together, these three elements, materiel, doctrine, and marital knowledge, comprise the technology triad.

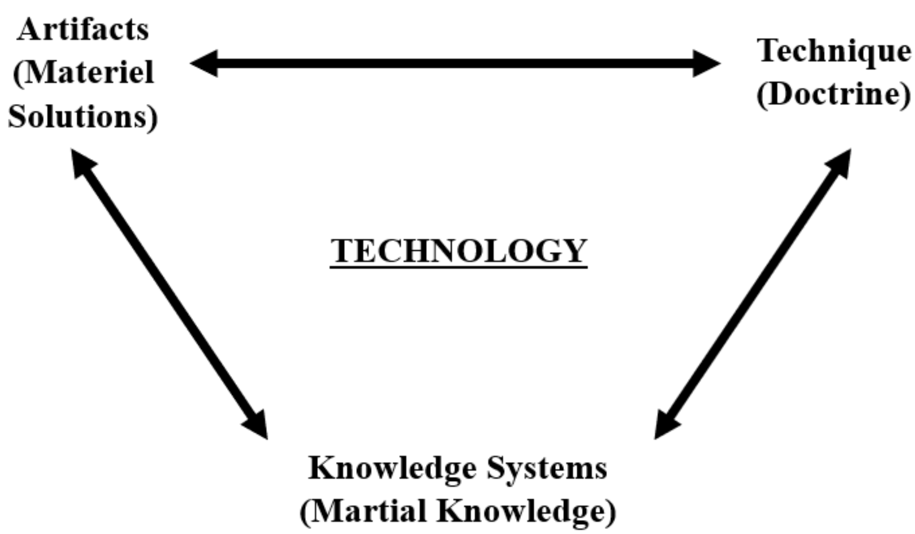


Figure 2. The Technology Triad is formed by placing each of the different forms of technology, as they apply to militaries, in relation to each other.

[12] Stephen Peter Rosen, “New Ways of War: Understanding Military Innovation,” *International Security* 13, no. 1 (1988): 134, https://doi.org/10.2307/2538898.

Even though the three elements of the technology triad are inseparable, due to their co-dependent nature, there is one important difference between them in real organizations. The fastest rate of change for each of the three elements is different as determined by its relative position between the social and physical worlds. Martial knowledge, as a purely socially generated concept, can change very quickly. In the example of the Polish saber fighters, their martial knowledge could have been that a fighting style characterized purely by slashing attacks was the best way to fight and that an adversary would employ the same system. As soon as a Polish swordsman encountered a parry followed by a thrust, assuming they lived through the encounter, their martial knowledge would have changed. The Polish fighter would then possess the knowledge that entirely different movements may be more appropriate for sword fighting. Doctrine changes slower than martial knowledge. Once the Pole was aware of the relative merits of cross-cutting slashes and thrusts, they could develop a new sword movement. But mastering this new movement would take some amount of practice and time, more time than it took to change their martial knowledge. Finally, materiel changes slowest of all. It is possible that the answer to the new style of fighting could have been a different sword or new armor. To make this change, somebody would have had to physically build the new artifact. The differences between the rates of change of the three elements become more pronounced when one considers the doctrine of entire armies and modern weapons systems that may require new factories or scientific advances for production.

The technology triad is not meant to be a predictive theory. It is intended to be a Clausewitzian theory of war; a theory of the phenomenon, not a theory of action.[13] The differing rates of change between the three elements combined with their influence on each other creates complex dynamics that do not lend themselves to projection into the future. The value of the technology triad lies in its ability to describe how militaries change, or fail to change, in relation to dynamic environments. This model provides a new way to frame military technology that can provide insights for the active management of change.

### *The Technology Triad and Innovation*

The technology triad is built upon a foundational philosophy that embraces a strong version of social constructivism. A constructivist paradigm recognizes that all knowledge is the product of social interactions. These social processes can create sperate, equally valid, and contradicting truths about reality.[14] In contrast, a positivist worldview contends that reality is objective and knowledge generation is the gradual discovery of new truths about this objective reality. There is only one version of truth for all humans in a positivist paradigm.[15] The value of relativistic world views in matters of war and strategy is well accepted.[16] However, practically useful constructivist framings of war

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[13] Sun-Tzu and Clausewitz, *The Book of War*.

[14] Norman K. Denzin and Yvonna S. Lincoln, eds., *The SAGE Handbook of Qualitative Research*, Fifth edition (Los Angeles London New Delhi Singapore Washington DC Melbourne: SAGE, 2018), 110–31; Peter L. Berger and Thomas Luckmann, *The Social Construction of Reality: A Treatise in the Sociology of Knowledge* (Harmondsworth: Penguin, 1991).

[15] Denzin and Lincoln, *The SAGE Handbook of Qualitative Research*, 110–31.

[16] H. R. McMaster, "How China Sees the World," *The Atlantic*, accessed February 14, 2021, https://www.theatlantic.com/magazine/archive/2020/05/mcmaster-china-strategy/609088/.

and combat are far less common, especially in military innovation studies.[17] In this regard, the philosophy that undergirds the technology triad makes it relatively unique in this space.

The interactions in the technology triad describe how a military constructs its own reality. Polish saber masters would have lived in a reality where engaging in a sword fight by slashing with a saber was the correct way to fight. They learned from a young age how to wield a saber in this manner. Every swordsman they encountered would have fought in the same manner. The very shape of their weapons implied that the correct way to attack was with a slash rather than a thrust. Each element of the technology triad, as it related to Polish sabers, created and maintained some portion of that reality for the Poles. The same process would have unfolded in France and Italy, but with rapiers and a *duo tempi* fighting style. As long as the two militaries never fought each other, the truth claims about each reality would have remained valid because they were internally consistent.

Military innovation occurs through a dialectic interplay of separate technology triads and the different realities that they each embody. A new technology triad questions the validity of the truth claims of the existing martial knowledge. The attack on these truth claims can come from outside the system in the form of observing another military, either directly in combat or indirectly through intelligence reports. The truth claims of a martial knowledge can also come under attack from within the military itself. People

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[17] Antoine Bousquet, Jairus Grove, and Nisha Shah, "Becoming War: Towards a Martial Empiricism," *Security Dialogue* 51, no. 2–3 (April 2020): 99–118, https://doi.org/10.1177/0967010619895660; Samuel Solvit, *Dimensions of War: Understanding War as a Complex Adaptive System*, Diplomacy and Strategy. English Series (Paris: L'Harmattan, 2012); Stuart Griffin, "Military Innovation Studies: Multidisciplinary or Lacking Discipline? [1]," *Journal of Strategic Studies* 40, no. 1–2 (January 2, 2017): 196–224, https://doi.org/10.1080/01402390.2016.1196358.

within the military can create a new local reality by altering the elements of the technology triad outside the established reality. If a military determines that the new technology triad is superior to the previous reality, then a new martial knowledge is created with updated truths. Once the military aligns all elements of its technology triad, the innovation process is complete.

Dialectic competition between realities can also describe entire wars. When the French invaded Poland, the *duo tempi* system of fighting competed with the Polish saber system. Each system was internally valid to the military that practiced them. The Polish system worked well against other Polish saber fighters.[18] It was also ideally suited for some of their intended purposes of saber fighting because slashing attacks were less likely to kill in a duel than a thrusting attack. However, the French system was more appropriate for the new shared reality that emerged when the two armies engaged in combat, where the goal of the engagement would have been to kill rather than draw first blood. By embracing a socially constructed worldview and the relativism that it implies, the technology triad produces a way to describe not only the relationship between technology and military innovation but also how this relationship can relate to strategic objectives.

Polish saber fighting can help illustrate the major concepts related to military technology and the application of constructivist worldviews to develop a deeper understanding of military sociotechnical systems, but the full complexity of these systems as they change over time exceeds the explanatory limits of the simple duel. When

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[18] The technical term for "slash" is "cut" or "cross cut." However, for those with little experience in fencing, the move appears as one would normally describe a "slash." Wright, Polish Saber Demonstration and Instruction.

Clausewitz built upon the duel to describe his vision of war, *arme blanche* still retained a place on the most technologically advanced battlefields of his time.[19] Today, militaries fight wars with equipment and weapons systems that are so complex that it is challenging to conceptually group their employment with the weapons of antiquity. In order to meet this challenge, this dissertation will start from the basic concepts outlined above, but in much greater detail, to build a model of military technology and test it against increasingly complex case studies.

**Outline of Chapters and Methods**

Chapter 2 lays the foundation for the deeper interrogation of the relationship between technology and military innovation that will follow in the rest of the dissertation. It will use the failure of a major U.S. weapons system procurement project to explore the internal mechanisms the U.S. military employs to manage the relationship between technology and military innovation. Following a review of current practices and logical assumptions bound up in those practices, the chapter will address current critiques of that system. From these critiques, the chapter will describe how this same problem has impacted other militaries throughout history to set the conditions to present the central research question of the dissertation. The chapter closes with a review of the existing literature on military innovation and an analysis on the gaps in that literature.

Chapter 3 continues the literature review to bring in a wide range of academic disciplines with a primary focus on the Science and Technology Studies (STS) literature. Following an introduction of the key concepts of science and technology studies, the

[19] Gevaert, "The Use of the Saber in the Army of Napoleon."

chapter presents a model of military technology, which is derived from careful study of the development of tanks and armor doctrine in the U.S. Army prior to World War II employing a grounded theory development methodology. Although this model is the result of a historical case study, the model is presented largely without reference to the case from which it was derived to allow for a more streamlined synthesis between the existing literature and new ideas. The logic and mechanics of the new model are described in detail to explain the philosophic foundations of the model that make it distinct from existing models of military technology. The chapter then applies this new model of military technology to produce a definition of military innovation derived from the core concepts of the model. Finally, the chapter closes with a review of the complexity leadership theory literature and application of that theory to the mechanics of military innovation, as defined by the new model of military technology.

Chapter 4 is a presentation of the historical case study that provided the empirical evidence to build the technology triad. The case is bounded in time from the invention of the tank in World War I to the establishment of the U.S. Armored Corps in 1940 and based on archival records. The case is presented chronologically using the structure of the technology triad to demonstrate how the technology provides an enhanced understanding of the relationship between technology and military innovation and produces novel insights.

Chapter 5 develops conditions that must be present in other cases for the technology triad to be generalizable beyond the development of tanks in the U.S. Army prior to World War II. The basic elements of the technology triad, relationships created by different rates of change within the technology triad, and the general process of innovation developed in Chapter 3 must all be present in other cases. Additionally, the development of locally created realities within militaries implies that competing militaries should have different realities and that these competing realities will become apparent through the conduct of combat.

Chapter 6 is a test of the generalizability of the technology triad through the application of the ideas developed in Chapter 5. The test draws from both primary and secondary sources to build a case study of the United States' nuclear strategy through the end of the Vietnam War. This enables testing against the conditions that could indicate wider generalizability as well as the ability of the technology triad to provide novel insights at different levels of war. The case in Chapter 4 focuses on the tactical and operational level of war. By focusing specifically on the strategic level of war, Chapter 6 applies the technology triad at a much higher level.

Chapter 7 tests the ability of the technology triad to provide novel insights without the benefit of hindsight present in historical case studies through the application of the model to armed drones. The case is bounded in time from the first time a missile was mounted on a predator drone to January 2021 and applies the technology triad to the U.S., Russian, Israeli, and Azerbaijani militaries. One of the main goals of the technology triad is to inform more effective active management of the relationship between technology and military innovation. This goal can only be achieved if the technology triad can enhance understanding in cases with incomplete information and the inability to predict outcomes of events. The case also further tests the generalizability of the model using the conditions developed in Chapter 5.

Chapter 8 is a conclusion chapter that consolidates the findings of the three case studies and analyzes the technology triad's effectiveness against its stated goals. This chapter also leverages the insights of the technology triad to propose concrete steps militaries can take to more effectively manage the relationship between technology and military innovation. Finally, the chapter closes by identifying several areas where future work can build on the research completed in the course of this dissertation.

**Contributions of Research**

This dissertation produces three contributions to general knowledge related to military innovation. First, the technology triad is a novel construct to describe technology and change within militaries. Doctrine and materiel are well established in military studies, but martial knowledge is a new concept. Placing the three elements of the technology triad in relation to each other produces a model that illuminates key aspects of military technology otherwise hidden by framings containing only materiel and aspects of doctrine. Additionally, the acceptance of a constructivist worldview that is foundational to the technology triad introduces a way to leverage the relativism it implies to make decisions in uncertain environments.

Second, this dissertation relates a model of military innovation that both accounts for the influence of technology and is philosophically grounded in conditions that are unique to military affairs. The model of military innovation presented in Chapter 3 provides concrete steps grounded in empirical evidence that can inform the successful management of military innovations. The definition of innovation grounded in the technology triad provides a metric against which to determine if a change is incremental or innovative. This illuminates indicators that a military can employ to identify and judge the usefulness of innovations in other militaries.

Finally, the strong embrace of social constructivism creates a new way to frame the entire concept of war. The technology triad describes local realities and enables a framing of conflict in which war is a competition of different local realities within single shared reality. This introduces new language to talk about and ways to think about the nature of strategic interactions that can be useful as the defense community is debating the impact of concepts like gray zone conflict and cyber war. Framing conflict as a competition between realities also implies new ways to prepare for and conduct war to achieve strategic objectives.

Despite the broad implications of these three contributions, there are limitations to the approaches adopted in this dissertation. The first is that the limited scope of three case studies and two vignettes falls far short of the breadth of analysis that would be necessary to make a legitimate claim that the technology triad is a truly generalizable model of military innovation. While absolute generalizability would be an ideal attribute of a model which began with the stated goal to create a practically useful tool for the management of future innovation, it is well beyond the scope of this dissertation. The general logic flow of developing a model then testing it against subsequent case studies does hint at broader generalizability beyond the case from which it was developed, but stronger claims of generalizability would be inappropriate.

Another key limitation of this research approach is that it cannot produce a predictive theory. An implicit assumption that predictive theories of complex systems with multiple actors are impossible underlies every aspect of this dissertation. If a predictive theory of military innovation is possible, this dissertation does not attempt to develop it. The limit of the ambition of this research approach was to produce a descriptive model that could provide insights that are practically useful for the management of military innovations. While, like a universally generalizable theory, a predictive theory would be ideal, a framing that can provide new ways to think about serious problems that have resisted the development of predictive theories is still valuable. Few problems are as serious or have proven as resistant to the application of scientific theories as the conduct of war. The next chapter will start by outlining the challenges associated with one aspect of this problem, the successful management of the relationship between technology and military innovation.

“The merry, fresh war we were all looking to for years has turned out to be quite different from what we thought! It is murder of troops by machines, and the horse has become almost superfluous…All the theories of decades have proved to be worthless, and now everything has to be done differently.”

-German Cavalry Officer, December 1914[20]

# CHAPTER 2

# MILITARY TECHNOLOGY AND INNOVATION

It is impossible to separate wars from the weapons that militaries employ to wage them. Those who fight a nation’s wars are called its “armed forces.” The “armed” signifier refers to the possession of weapons, or “arms,” and delineates soldier from civilian. Arms are such an important part of maintaining a nation’s security that humanity invests trillions of dollars every year to design, build, and maintain these tools. Despite the relative importance of weapons in the act of war, deliberate management of changes in weapons technology and alignment with strategic goals remains challenging for militaries. Even the most powerful militaries struggle with periods of relative stagnation in the development of new weapons and doctrine while they spend precious national resources on weapons that never end up reaching their soldiers in the field. While it may be tempting, and at times has been fashionable in certain academic circles, to produce a stinging critique of military culture and acquisition systems that cites case after case of

[20] Alan Kramer, *Dynamic of Destruction: Culture and Mass Killing in the First World War*, The Making of the Modern World (Oxford: Oxford Univ. Press, 2008), 38–39.

failure as evidence, two important considerations make this tact unfavorable.[21] First, it is not very helpful. Leveraging the power of hindsight to indicate areas where militaries should have changed when they did not or changed in a way different than they attempted does little to help manage change in the uncertain environments militaries face every day. Second, it is simply not true, at least not as a blanket criticism to be leveled against all militaries at all times.

This dissertation will pursue a deeper understanding of the relationship between technology, military change, and innovation. It will develop a framework that seeks to illuminate the relevant pieces of the complex systems that shape a military's approach to technology beyond admonitions of military traditionalism that resist and sabotage change as a matter of course. At no point is the goal of this work to criticize any person, group, culture, process, or way of thinking about defense technology. Rather, the humble goal of this dissertation is to provide novel insights related to the management of technology and change in militaries from a deep appreciation for the challenges associated with military technology. With this qualifier in mind, there is still a serious issue to address regarding the apparent inability of militaries to align technology adequately with the presumed goal to win wars.

**Future Combat System and Modernization in the U.S. Department of Defense**

After the Gulf War, Andrew Marshal, the Office of Net Assessment director in the Pentagon, commissioned a report to explore the most likely lessons the U.S. military should draw from its recent combat experience. While the defeat of the Iraqi Army was

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[21] Alex Roland, "Science, Technology, and War," *Technology and Culture* 36, no. 2 (April 1995): S83, https://doi.org/10.2307/3106691.

an unqualified success, the report that Marshall's team put together concluded that the U.S. military had failed to fully capitalize on the fundamental shifts in technology that would define future large-scale combat. Advances in computers and communications-related technologies had ushered in what was known in defense circles at the time as a "revolution in military affairs," an ill-defined term that refers to significant leaps in technology that many believed would alter the character of war.[22]

Before the decade was out, the U.S. Army had initiated the largest weapons modernization program ever attempted by the service to capitalize on recent technological advances and produce a modern fighting force.[23] Following the Vietnam War, the U.S. Army designed and fielded the M1 Abrams tank, AH-64 attack helicopter, UH-60 utility helicopter, the Patriot air-defense system, and the Bradley Fighting Vehicle known as "the Big Five" to compliment a strategic shift in focus from guerrilla war to a possible confrontation with the USSR.[24] The Future Combat Systems (FCS) was a full suite of manned and unmanned weapons systems that ranged from new self-propelled artillery pieces and tanks to Micro-Air Vehicle and ground reconnaissance robots that the U.S. Army intended to replace the legacy "Big Five" weapons systems.[25] At the heart of the full FCS program was a layered tactical network that was intended to "provide seamless delivery of both data and knowledge" from the individual soldier up to major operational commands.[26] The U.S. Army intended these modern ground vehicles and

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[22] Christian Brose, *The Kill Chain: Defending America in the Future of High-Tech Warfare*, First edition (New York: Hachette Books, 2020), 1–20.
[23] Christopher G. Pernin, *Lessons from the Army's Future Combat Systems Program* (Santa Monica, CA: RAND, ARROYO CENTER, 2012), 1.
[24] "Defense Report Editorials: New Equipment for the Army (Defense Report 76-5)," AUSA, April 11, 2017, https://www.ausa.org/defense-report-editorials.
[25] Donald Marron, "The Army's Future Combat Systems Program and Alternatives" (Washington, D.C.: Congressional Budget Office, August 2006).
[26] Dean Popps, "Showcasing the Army Future Combat Systems," *Army AL&T*, June 2008, i.

their tactical network to give Soldiers an unqualified advantage in future wars waged in the form of large-scale combat against technologically advanced nation-states.[27] Despite the emergence of a totally different kind of war following the September 11th, 2001 terrorist attacks, the program was still proceeding in April 2008. The acting Army Acquisition Executive in 2008 claimed that "the capabilities that FCS delivers will empower our Soldiers with unparalleled situational awareness, survivability, and lethality."[28] Just one year later, in April 2009, the U.S. Army canceled the entire FCS program at an estimated loss of nearly $20 billion.

To understand where the FCS program might have gone wrong, one must first appreciate the basic structure of and philosophic assumptions that underpin the U.S. military's acquisition system. Drawing from lessons learned as the Director of the Office of Scientific Research and Development (ORSD) during World War II, Vannevar Bush wrote a report for President Truman in which he outlined a proposal for the federal funding of scientific research to maximize the positive impact of that research for the nation. Bush's framework relied on his belief that federal funding of basic science, unstructured research conducted with the sole aim of increasing humanity's repository of knowledge, would yield new technology through the application of that new knowledge.[29] To justify this bold reimagining of public funding for science, Bush leaned heavily on the need to accelerate the nation's scientific progress to produce the weapons that would allow the country to prevail in future wars, just as the OSRD's work

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[27] Andrew Feickert, "The Army's Future Combat System (FCS): Background and Issues for Congress" (Washington, D.C.: Congressional Budget Office, August 3, 2009).
[28] Popps, "Showcasing the Army Future Combat Systems," i.
[29] Vannevar Bush, *Science, the Endless Frontier: A Report to the President on a Program for Postwar Scientific Research*, *Fulcrum.Org* (National Science Foundation, 1945), 9.

contributed to the United States' victory in World War II.[30] In a 1951 memo titled "A Few Quick," Bush reiterated his general belief that providing the U.S. military with weapons produced by the undirected civilian pursuit of scientific knowledge, with little or no input from military officers, was the best way to stimulate modernization in the armed forces.[31] However, in 1965, the U.S. Department of Defense commissioned a study called Project HINDSIGHT to determine "the extent to which new weapons systems are actually dependent upon the results of recent advances in science and technology" and to calculate a "quantitative measure of the return on investment in research."[32] The findings of Project HINDSIGHT were damning for Bush's vision of a structure where basic research naturally feeds military technology. The study found that "only 0.3 percent [of key weapons contributions] came from undirected science" and that "nearly 95 percent were motivated by a recognized defense need."[33]

Today, the U.S. military has fully embraced a requirements-based acquisitions process for new weapons systems. The fundamental structure of the requirements-based procurement system has remained largely unchanged for the last 50 years.[34] The U.S. military projects what the future operating environment will look like then develops an operating concept for how the Department of Defense will achieve its strategic goals within this projected environment. If the new concept generates a requirement that the current force lacks, a "capability gap," the Department of Defense addresses the gap

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[30] Bush, 2.
[31] Vannevar Bush, "A Few Quick," November 5, 1951, Vannevar Bush Papers, 139, Library of Congress.
[32] Raymond S. Isenson, "Project HINDSIGHT" (Washington, D.C.: Office of the Director of Defense Research and Engineering, October 1969), xiii.
[33] Chalmers W. Sherwin and Raymond S. Isenson, "Project Hindsight," *Science* 156, no. 3782 (1967): 1577; J. Ronald Fox, *Defense Acquisition Reform, 1960-2009 An Elusive Goal*, CMH Pub 51-3-1 (Washington, D.C.: Center of Military History, 2011).
[34] Eric Wesley and Jon Bates, "To Change an Army - Winning Tomorrow," *Military Review* 100, no. 3 (June 2020): 6–17; Fox, *Defense Acquisition Reform, 1960-2009 An Elusive Goal*.

through some combination of changes in doctrine, organization, training, materiel, leadership and education, personnel, facilities, and policy (DOTMLPF-P).[35] Materiel solutions represent the development and procurement of new equipment based on the original requirements. Any change to one of the DOTMLPF-P components to address a specific capabilities gap must be carefully coordinated and sequenced with changes proposed to address other capabilities gaps within and across services. The entire process is very laborious and detailed to prevent conflicting changes and wasted resources and can take more than six years to implement under normal conditions.[36] Despite the common critique that the current system is a byzantine morass of ineffectiveness in the pursuit of efficiency, the basic logic of this process is in line with the best practices of systems engineering.[37]

Systems engineering is the deliberate management of “hardware, software, equipment, facilities, personnel, processes, and procedures” in order “to produce system-level results.”[38] Critically, these system-level results are not arbitrary. They are determined by the requirements set at the beginning of the process and deliberately produced by the detailed management of all social and materiel elements within the system.[39] The U.S. military follows the basic systems engineering approach for modernization and thus relies heavily on the ability to accurately project requirements far enough in the future to have the time to develop and integrate new materiel solutions before they are needed. Consistent, accurate projection is difficult, if not impossible, in

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35 Yuenger, *How the Army Runs 2015-2016: A Senior Leader Reference Handbook*, 10–2.
36 Yuenger, 10–3.
37 Brose, *The Kill Chain*, 209–10.
38 Steven Hirshorn, “NASA Systems Engineering Handbook” (Washington, D.C.: NASA, 2016), 3.
39 Hirshorn, 6.

dynamic environments where requirements can change rapidly. The FCS program faced insurmountable obstacles when the U.S. Army attempted to condense the timeline of this entire process to address this challenge.

In 2008, the year before FCS was canceled, the Acting Army Acquisition Executive stated that "in many ways, we are reforming weapons system development" with the way that the U.S. Army was approaching the FCS program.[40] Their new approach called for projecting out the specific technologies that would be available 25 years in the future and taking immediate steps to begin the reorganization of the Army as the development of those technologies was just beginning.[41] The goal was to reach the realization of new concepts, organizations, and technologies at the same time. This, the program managers believed, would allow a normally sequential process to progress concurrently and significantly reduce the overall timeline of major modernization. When the U.S. Army failed to achieve the development of projected technologies on timelines compressed by the wars in Iraq and Afghanistan, there were no subsequent updates to the operational concepts and requirements.[42] Further complicating the overall design of the FCS program, the initial requirements envisioned a future war characterized by "conventional combat operations against a mechanized force in relatively open terrain," which was a far cry from the counter insurgencies fought in complex terrain that the U.S. Army was called on to execute.[43] Eventually, it became apparent that the FCS could not

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[40] Popps, "Showcasing the Army Future Combat Systems," i.
[41] Pernin, *Lessons from the Army's Future Combat Systems Program*, 21–23, 52.
[42] Pernin, 52.
[43] Andrew F. Krepinevich and Evan Braden Montgomery, "Correcting Course: The Cancellation of the Future Combat Systems Program," CSBA Backgrounder (Washington, D.C.: Center for Strategic and Budgetary Assessments, July 2009) cited in Pernin, p 53.

fulfill the immediate needs of the U.S. Army, and the Department of Defense canceled the program.

While it is impossible to know for sure how much of the technology developed for the FCS ended up making its way into other weapons systems, and there are indications that the U.S. Army employed FCS related technologies effectively in Iraq and Afghanistan, there is no question that the full FCS program was an unqualified failure.[44] In terms of just resources spent with no fielded equipment to show for the investment, the FCS was the costliest failed weapons program of the various systems that each of the services undertook to adapt to the presumed Revolution in Military Affairs of the 1990s.[45] Perhaps more costly in the long run for the U.S. Army, the failure of the FCS represented a significant blow to the credibility of the service to undertake and complete major modernization efforts at a time when many in the U.S. defense community believe that modernization is exactly what is required.[46]

## Changing Technology and Military Challenges

More than a decade after the cancelation of the FCS program, the U.S. military continues to struggle to address the challenges associated with fielding new equipment adequately in a dynamic security environment. A September 2020 House Armed Services Committee (HASC) report stated that "the nature of warfare is changing, as the weaponization of emerging technologies appears poised to change the ways wars are

[44] Pernin, *Lessons from the Army's Future Combat Systems Program*, xvii; Feickert, "The Army's Future Combat System (FCS): Background and Issues for Congress."
[45] Stephen Rodriguez, "Top 10 Failed Defense Programs of the RMA Era," War on the Rocks, December 2, 2014, https://warontherocks.com/2014/12/top-10-failed-defense-programs-of-the-rma-era/.
[46] Pernin, *Lessons from the Army's Future Combat Systems Program*, xvii.

fought and won."[47] The Clausewitzian distinction between the nature and character of war notwithstanding, this is a bold claim about the impacts that contemporary advances in technology are having on the conduct of war. The HASC report asserted that effectively addressing these changes "will require significant changes to the Pentagon's force structure, posture, operational plans, and acquisition system."[48] Christian Brose, the former Staff Director of the Senate Arms Service Committee (SASC), expressed this same concern in a 2020 book when he wrote that "the accelerating erosion of the U.S. military's technological advantage over other great powers" was the driving force behind his and Senator McCain's efforts to impose fundamental changes on the way the U.S. defense establishment framed the role of weapons systems in defense of the nation.[49]

Senior U.S. military commanders share their civilian leaderships' concerns about the ability of the current U.S. defense system to achieve its strategic objectives. Lieutenant General (Ret.) Eric Wesley, the former commanding general of the U.S. Army Futures and Concepts Center, wrote in a February 2021 article that the U.S. Army "has failed in every major modernization push since the 'Big Five' effort of the mid-1970's" and that "fundamental change to how the Army thinks about the future is required to successfully confront the country's security challenges."[50] Within a week of LTG Wesley's article, the current Chief of Staff of the Air Force and the Commandant of the United States Marine Corps co-wrote an article in the Washington Post citing concerns about advancing technology and the U.S. military's ability to field new equipment as the

[47] Seth Moulton and Jim Banks, "Future of Defense Task Force Report 2020" (House Armed Services Commitee, September 23, 2020), 21.
[48] Moulton and Banks, 5.
[49] Brose, *The Kill Chain*, x.
[50] Eric Wesley and Robert Simpson, "It's Time to Move the Army Ladder," War on the Rocks, January 26, 2021, https://warontherocks.com/2021/01/its-time-to-move-the-army-ladder/.

rationale to propose a fundamental shift in the way the Department of Defense defines readiness for combat in order to prioritize increasing future readiness over maintenance of current capabilities.[51]

Echoing the U.S. Army's approach to the FCS program, proposed solutions to the U.S. military's challenges with changing technology tend to focus on increasing the rate at which the Department of Defense adopts and fields new equipment. The general critique points to the ability of civilian technology companies to create new products on timelines much shorter than the Department of Defense is able and argues that if the regulatory structure can move faster, then the U.S. military will be better positioned to address changing technologies.[52] While there is little doubt that shorter adaptation cycles will improve performance in a dynamic environment, simply moving faster would fail to address former Secretary of Defense Ashton Carter's assertion that not only the way we fight wars but "the concept of war is changed also by technology."[53] Even if the FCS could have been fielded within a month of inception, the U.S. Army would have just had a brand-new suite of capabilities to fight a mechanized force when the war at hand was a counter insurgency. Furthermore, this approach only addresses the apparent inability of a military to effectively address changing technology from the perspective of contemporary U.S. military challenges.

[51] Charles Q. Brown Jr and David H. Berger, "Opinion | To Compete with China and Russia, the U.S. Military Must Redefine 'Readiness,'" *Washington Post*, accessed February 6, 2021, https://www.washingtonpost.com/opinions/2021/02/01/brown-berger-military-readiness/.
[52] Steve Blank, "Teaching Technology, Innovation, and Modern War at Stanford, Part 1: Adaptation and Acquisition," Modern War Institute, October 6, 2020, /teaching-technology-innovation-and-modern-war-at-stanford-part-1-adaptation-and-acquisition/.
[53] *Technology, Innovation, and Modern War* (Palo Alto, CA: Stanford University, 2020), https://mwi.usma.edu/teaching-technology-innovation-and-modern-war-at-stanford-part-1-adaptation-and-acquisition/.

Even a cursory review of military history indicates that military challenges associated with changing technology are not bounded by nationality or unique to today's technological advances. At Crecy in 1346, Edward III's English army annihilated a French force more than twice as large owing to the advantage provided by the relatively new longbow.[54] During the Austro-Prussian War of 1866, the Austrians, armed with muzzle loading rifles, suffered casualties at five times the rate of the Prussians, who were equipped with the breech-loading needle gun and had adopted their tactics to capitalize on the much higher rate of fire the new weapons provided.[55] When the Germans invaded France in 1940, Marc Bloch, a hero of the French resistance, noted that "the Germans advanced a great deal faster than they should have done according to the old rules of the game," a capability enabled through effective employment of advancements in tanks and communications technology.[56] Each of these examples, and there are many more than is reasonable to list here, represent a military that had failed to appropriately change with new technology and was dominated by another that had. In each case, the losing side was aware of the technological innovation either directly, as the French were with longbows after the English landed at Flanders in 1337, or through observations, as the Austrians were of the needle gun in the 1864 Schleswig War and the French were of blitzkrieg in Poland's 1939 defeat.[57] Despite this awareness of the innovation that would enable their

[54] Bernard Brodie and Fawn McKay Brodie, *From Crossbow to H-Bomb*, Rev. and enl. ed, A Midland Book, MB 161 (Bloomington: Indiana University Press, 1973), 39–40.
[55] Cathal J. Nolan, *The Allure of Battle: A History of How Wars Have Been Won and Lost* (Oxford, UK ; New York, NY: Oxford University Press, 2017), 279.
[56] Marc Bloch, *Strange Defeat: A Statement of Evidence Written in 1940* (New York: Norton, 1999), 38.
[57] Brodie and Brodie, *From Crossbow to H-Bomb*, 39; Wayne E. Lee, *Waging War: Conflict, Culture, and Innovation in World History* (Oxford: Oxford University Press, 2016), 375; Lloyd Clark, *Blitzkrieg: Myth, Reality, and Hitler's Lightning War-- France, 1940* (New York: Atlantic Monthly Press, 2016), 45–47.

defeat, the losing side was unable or unwilling to make the required changes to their own weapons or tactics to stave off disaster.

Despite military challenges reaching far into antiquity, the problem facing modern militaries is getting worse. If one traces the development of weapons from today's computer-enabled hypersonic missiles to the very first sharpened stick, a trend of increasing lethality becomes apparent.[58] In 1964, the U.S. Army Combat Developments Command commissioned a report titled "Historical Trends Related to Weapons Lethality," which the author, Colonel T. N. Dupuy, later used as a base for a book on the same subject.[59] The study found that not only is weapons lethality increasing, but also that increased lethality is accelerating exponentially since the industrial revolution.[60] Employing a quantitative measure of weapons lethality, Dupuy found that the H-bombs of the mid-1960s were 4 million times more lethal than the breech-loading rifles that decimated the Austrian army in 1866.[61] In 2020, a researcher in the same U.S. Army command conducted a similar study focused on just ground mobile direct-fire weapons systems from 1300-2015 CE and found that increases in weapons lethality have continued to follow the same trend of increased lethality over the last 50 years.[62]

If adequately addressing changes in technology is a timeless problem that affects all militaries, a logical goal of militaries should be to field a force that effectively harnesses new technology. Successful innovation allows militaries to gain and maintain a

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[58] Alex Roland, *War and Technology: A Very Short Introduction*, Very Short Introductions 445 (New York, NY: Oxford University Press, 2016), 7–8.
[59] Trevor N. Dupuy, *The Evolution of Weapons and Warfare* (Indianapolis: Bobbs-Merrill, 1980).
[60] Dupuy, 288.
[61] Dupuy, 92.
[62] Alexander Kott, "Toward Universal Laws of Technology Evolution: Modeling Multi-Century Advances in Mobile Direct-Fire Systems," *The Journal of Defense Modeling and Simulation: Applications, Methodology, Technology* 17, no. 4 (October 2020): 373–88, https://doi.org/10.1177/1548512919875523.

position of relative advantage over potential adversaries. Failure to innovate at best puts militaries in a position where they are forced to react to change imposed on them by their adversaries and at worst assures defeat. As weapons become more and more lethal, failure also becomes more costly. However, as the fall of France demonstrated in 1940, simply fielding new weapons is not enough. The French had both tanks and radios, just as the Germans did, but the French failed to harness the full capabilities of these materiel solutions for a wide range of reasons. A deeper understanding of the relationship between technology and military innovation may provide insights related to the apparent inability of militaries to align technology with strategic objectives and inform approaches militaries can take for more effective future alignment.

**Previous Research Related to Military Innovation and Change**

Military innovation, as a concept, is surprisingly hard to define. Scholars who practice in the fields of business management, economics, and security studies each maintain different definitions for the term "innovation" writ large. While civilian definitions of innovation tend to differ on whether innovation occurs at the point of discovery or distribution of a new idea, students of military innovation focus on the scale of change and burden of proof necessary to qualify as an innovation.[63] In his 2006 survey of literature addressing military innovation, Adam Grissom defined military innovation as "a change in operational praxis that produces a significant increase in military

[63] Benoît Godin, *Models of Innovation: The History of an Idea*, Inside Technology (Cambridge, Massachusetts: The MIT Press, 2017), 27, 34–35; Adam Grissom, "The Future of Military Innovation Studies," *Journal of Strategic Studies* 29, no. 5 (October 2006): 907–907, https://doi.org/10.1080/01402390600901067.

effectiveness…as measured by battlefield results."[64] Grissom developed this definition by consolidating the common aspects of each major change that scholars considered a military innovation to produce a definition through a consensus of the existing literature.[65] Colonel Suzanne Nielsen introduced an alternate approach to the definition of military innovation to frame her 2010 study of the post-Vietnam US Army, a necessity because the peacetime changes at the center of her research could not have qualified as an innovation under Grissom's combat-focused definition. Colonel Nielsen's definition of innovation focused on degrees of change, with lesser forms of change classified as "reform" and larger, organizational changes representing "innovation."[66] The requirement for change of some type is common to all definitions of military innovation, but the line between innovation and change becomes another layer of analysis that is difficult without a full understanding of the mechanisms of military change in general. Before addressing the question of innovation within militaries, it is helpful to frame the discussion in terms of the broader category of military change within the literature, which also includes military innovations.

The prevailing understanding of military change tends to build from the initial assertion that organizational stability in militaries is an artifact of a general resistance to change on the part of military organizations. Samuel Huntington addressed this tendency in his classic text on civil-military relations *The Soldier and the State*. He argued that senior soldiers become stuck in traditional modes of thought through an excess of

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[64] Grissom, "The Future of Military Innovation Studies."
[65] Grissom.
[66] Suzanne C. Nielsen, *An Army Transformed: The U.S. Army's Post-Vietnam Recovery and the Dynamics of Change in Military Organizations*, Letort Papers, no. 43 (Carlisle, PA: Strategic Studies Institute, U.S. Army War College, 2010).

professional obedience to orders. In his account, officers at the top of the military hierarchy then leverage their position of power to "suppress uncomfortable new developments in tactics and technology."[67] Huntington offers this possible explanation even though he also describes the ideal military officer as one who is accepting of new technology within the same work.[68]

Another popular explanation for militaries' apparent tendency to resist change draws from historical anecdotes related to the nature of humans. Machiavelli, the famous Renaissance-era stateman and philosopher, lamented that "the innovator has for enemies all those who have done well under the old conditions, and lukewarm defenders in those who may do well under the new."[69] Drawing a similar conclusion, Elting Morison explained resistance to new gunnery equipment in the US Navy at the turn of the twentieth century when he said opposition to change "springs from the normal human instinct to protect oneself, and more especially, one's way of life."[70] Both of these historical examples draw their conclusions from the observation that change is a threat to the status quo of those individuals who are happy with things the way they are.

At the organizational level, resisting change theoretically could be an approach to managing uncertainty. Herbert Simon addressed this function of organizations when he said that "institutions provide a stable environment for us" in his discussion of bounded rationality.[71] Martin Van Creveld argued along these same lines when he said that

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[67] Samuel P. Huntington, *The Soldier and the State: The Theory and Politics of Civil-Military Relations*, 19. print (Cambridge, Mass: Belknap Press, 2002), 75.
[68] Huntington, 71–75.
[69] Niccolò Machiavelli and Cary J. Nederman, *Niccolò Machiavelli's The Prince on the Art of Power: The New Illustrated Edition of the Renaissance Masterpiece on Leadership*, New illustrated ed (London, U.K. : New York: Duncan Baird Publishers ; Distributed in the USA and Canada by Sterling Pub. Co., Inc, 2007).
[70] Elting E Morison, *Men, Machines, and Modern Times* (Cambridge, Mass.: M.I.T. Press, 2008).
[71] Herbert Alexander Simon, *Reason in Human Affairs* (Stanford, Calif: Stanford Univ. Press, 1983).

militaries take specific actions to organize themselves and create a culture that reduces uncertainty because combat, the environment in which militaries ply their trade, is characterized by an excess of uncertainty. Therefore, any activity that can reduce that uncertainty is beneficial.[72] Barry Posen, widely considered the founder of military innovation studies, draws heavily from this explanation of a resistance to change in militaries to assert that civilian leadership must impose change on a military for it to happen at all.[73]

Organizations could also resist change as a result of their natural function. In *Essence of Decision*, Graham Allison explains how organizations create Standard Operating Procedures (SOPs) to routinize the activities of the organization. These SOPs provide for more efficient coordination of efforts between groups of people to serve the function of the organization. However, the retrospective nature of SOPs also orients the organization to conduct future activities in the same manner as past activities, which produces inflexible organizations.[74] Nielsen applied this model to militaries as a way to explain how the normal functions of the military as a large organization bias it towards a resistance to change.[75] Similarly, Terry Pierce's *Disruptive Technologies* develops a theory related to military innovation and technology that argues militaries resist major changes because they are efficiently managing the introduction of minor changes, a process which he calls "sustaining innovations."[76] Both Nielson and Pierce described a

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72 Martin Van Creveld, *Technology and War: From 2000 B.C. to the Present* (New York : London: Free Press ; Collier Macmillan, 1989).
73 Barry Posen, *The Sources of Military Doctrine: France, Britain, and Germany between the World Wars*, Cornell Studies in Security Affairs (Ithaca: Cornell University Press, 1984), 59–60.
74 Graham T. Allison and Philip Zelikow, *Essence of Decision: Explaining the Cuban Missile Crisis*, 2nd ed (New York: Longman, 1999).
75 Nielsen, *An Army Transformed*.
76 Terry C Pierce, *Warfighting and Disruptive Technologies: Disguising Innovation*, 2004.

natural tendency to resist change in militaries as a byproduct of organizational processes geared towards efficiency.

Despite its many manifestations, the general theme that militaries resist change is prevalent in the literature related to military change. This is an important part of understanding the body of scholarship dedicated to those instances where militaries do change. Change of all types, including innovation, becomes an activity that requires a force that is greater than the resistance the military presents to it. Models which aim to describe military change seek out those forces that are strong enough to overcome an assumed resistance to the change. This, in turn, has important implications for the way that the models explain the internal mechanisms of change within a military.

Grissom identified the civil-military, inter-service, intra-service, and cultural models of change as the four major schools of thought related to military innovation and change.[77] Each framework seeks to describe the environmental, organizational, and cultural factors that cause a military to overcome its apparent resistance to change. There is also a fifth theory, Michael Horowitz's adoption-capacity theory. Although this is a predictive theory of military diffusion, it shares many of the same foundational concepts with models of military change in general and is therefore relevant to a foundational understanding of existing ideas that seek to describe why militaries change.

Barry Posen developed what Grissom refers to as the civil-military model of change in *Sources of Military Doctrine.*[78] In this seminal work, Posen evaluated organizational factors within the military, international relations, geographical considerations, and technological change as possible explanations for why militaries

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[77] Grissom, "The Future of Military Innovation Studies."
[78] Posen, *The Sources of Military Doctrine*.

change using a comparative analysis of the development of British RAF fighter command, French methodical battle, and German Blitzkrieg prior to World War II. Ultimately, he argued that the strongest impetus for military change occurred when the perception of a looming war was high. This induced the civilian leadership of a country to force change upon their military. He also argued that technological advancements provide a very weak explanation for the change that occurred in these three militaries.[79]

While Posen favored pressures external to the military to explain the catalyst for change, the inter-service model of military innovation relies on the internal desire of individual services to compete for resources as the driver of change. Andrew Bacevich's history of the US Army's Pentomic divisional structure is a good example of this model in practice. In this study, Bacevich explained how the US Army's desire to remain relevant compared to the US Air Force and the US Navy at the dawn of the atomic age spurred the creation of organizational structures and weapons focused on the use of tactical nuclear weapons.[80] Similarly, Owen Cote argued that inter-service rivalry could serve as a sufficient cause for military change through an account of the US Navy's relationship with the US Air Force related to the development of the Polaris and Trident II submarine-launched ballistic missiles.[81] Within this model of military change, technology serves as a vehicle for the separate services to wage bureaucratic and budgetary fights.

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[79] Posen.

[80] A.J. Bacevich, *The Pentomic Era: The Army Between Korea and Vietnam* (Washington, D.C.: National Defense University Press, 1986).

[81] Owen Cote, "The Politics of Innovative Military Doctrine: The U.S. Navy and Fleet Ballistic Missiles" (PhD diss., Political Science, MIT, 1996).

The intra-service model of military change, developed by Stephen Rosen and prominent in *Winning the Next War,* is another internally focused framework.[82] However, the resemblance of the terms "intra-service" and "inter-service" is misleading. Rosen's model for military change is much more nuanced than the comparatively simpler fight over resources on which the inter-service model relies. Rosen asserted that it is impractical to develop a universal model of change that applies to militaries at all times in every situation.[83] He developed three separate models of innovation from this position: peacetime innovation, wartime innovation, and technological innovation. His concept of peacetime innovation relied on senior military leaders to develop concrete career paths for junior officers based on a "theory of victory" about future combat. This career path allows junior officers to rise through the ranks within a new military specialty. Over time, the promotion of these junior officers changes the structure of the military. Rosen argued that peacetime change is a relatively slow process due to this generational turnover. In wartime, this same theory of victory defines the intelligence that a military can collect and the frame of reference through which the military evaluates collected intelligence. Because he envisioned change as a relatively slow organizational process and technological innovation as a completely separate process, Rosen argued that wartime change is unlikely to occur in time to make a significant difference in the outcome of a war. To describe the role of technological innovation, Rosen relied on push and pull models of innovation, where scientists either push new technologies, as Bush proposed, or the military produces a demand for new technology, as project HINDSIGHT found

[82] Stephen Peter Rosen, *Winning the next War: Innovation and the Modern Military*, Cornell Studies in Security Affairs (Ithaca, NY London: Cornell University Press, 1994).
[83] Rosen, 5.

was more common. In these models, technology can serve as a catalyst for a new theory of victory in a broad sense. However, his intentional separation between technological change and the two social drivers of change leads him to conclude that technological innovation is essentially an exercise in managing uncertainties rather than an integral component of military change in general. The multiple and independent modes of change in Rosen's model make it complicated. At its core, though, this theory is still an effort to understand what makes a military overcome a presumed natural tendency to resist innovation. In other words, it seeks to explain why militaries change when the prevailing wisdom says they really should not.[84]

The most recent major school in military change studies, the cultural model of change, is also the most diverse.[85] The assertion that cultural norms drive the actions of military members forms the general core thesis of the various studies that fall under this category. A good example of this is Theo Ferrell's study of the Irish Republican Army (IRA) in the 1930s, where he argued that IRA leadership refused to accept guerilla tactics because they saw themselves as professional officers modeled after the British Army.[86] This institutional isomorphism, the tendency for organizations in a field to become similar over time, is another common place aspect of cultural theories of military change.[87] Within cultural studies, the answer to why militaries change is philosophically similar to that which is proposed by the other three schools of thought. In his 2017 survey of military change literature, Stuart Griffin points out that although cultural studies of

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[84] Rosen, *Winning the next War*.
[85] Grissom, "The Future of Military Innovation Studies"; Griffin, "Military Innovation Studies."
[86] Theo Farrell, "World Culture and the Irish Army, 1922-1942," in *The Sources of Military Change: Culture, Politics, Technology* (London: Lynne Rienner Publishers, 2002), 69–90.
[87] Terry Terriff, "U.S. Ideas and Military Change in NATO, 1989-1994," in *The Sources of Military Change: Culture, Politics, Technology* (London: Lynne Rienner Publishers, 2002), 91–118.

military change espouse constructivist philosophical foundations, they still accept an "external reality that sets the requirements" for change.[88] Dima Adamsky's study of the cultural factors that determined how Russia, the United States, and Israel reacted to new information technologies in the 1990s illustrated Griffin's point when Adamsky stated, "structural factors and emerging technologies represent the independent starting point for military transformation."[89] Griffin argued that this softer form of constructivism relegates cultural explanations of military change to secondary considerations after positivist causal explanations.[90] Within the cultural school of military change, technology runs the gambit from a non-factor, such as Ferrell's study of the IRA, to the starting point for, but not a determinant factor of, change in Adamsky's book.[91]

The final model of military change provides an explanation for the diffusion of military innovations. Michael Horowitz's Adoption Capacity Theory differs from the four schools of military innovation and change because it assumes that a successful demonstration of a new innovation or change external to the military is sufficient to produce an imperative for a military to change. Adoption capacity theory posits that one can determine the likelihood of a military to adopt a new military method or technology by analyzing both the financial cost of adoption and three factors that define the organizational capital of the adopting military. These three factors are investment in military research and development, length of time since the last major change of the military, and the degree to which the military defines its core function as a specific task

[88] Griffin, "Military Innovation Studies."
[89] Dima Adamsky, *The Culture of Military Innovation: The Impact of Cultural Factors on the Revolution in Military Affairs in Russia, the US, and Israel* (Stanford, Calif: Stanford University Press, 2010).
[90] Griffin, "Military Innovation Studies."
[91] Adamsky, *The Culture of Military Innovation*; Theo Farrell and Terry Terriff, eds., *The Sources of Military Change: Culture, Politics, Technology*, Making Sense of Global Security (Boulder, Colo: Lynne Rienner Publishers, 2002).

or a broad goal. Through statistical and qualitative analysis of past military innovations, Horowitz found a strong correlation between these factors and the likelihood of a military to adopt a major change.[92] While this theory assumes that a military is compelled to change from the beginning, it seeks to determine if the military will actually adopt a specific change by measuring the degree to which the military is organizationally resistant to change. Therefore, it is similar to Grissom's original four drivers of military change in its goal to describe the organizational factors that facilitate change within a military.

Each of the five models of military change possesses a strong internal logic and historical consistency when they are measured against the cases that informed their development. However, a quick application of these models to the development of the tank in the US Army prior to World War II demonstrates their relative weakness as generalizable theories. The civil-military model of change stipulates that militaries should stagnate in times of peace, but the U.S. Army established the experimental Mechanized Force in 1928, at a time when the world was still enjoying the peace following World War I.[93] In 1939, Major General Herr, the Chief of Cavalry, did relate the cost to modernize his force in terms of the cost of Navy and Army Air Corps equipment, which would seem to support the inter-service model of change. However, he also stated that he wanted to use the money to fund an expansion of the horse cavalry as well as the mechanized cavalry, which challenges the assertion that the Army would change to gain

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[92] Michael Horowitz, *The Diffusion of Military Power: Causes and Consequences for International Politics* (Princeton, N.J: Princeton University Press, 2010).
[93] Daniel Van Voorhis, "Mechanization" (Transcript of lecture delivered at the Army War College and discussion with audience, October 13, 1937), G-3 Course No. 12, 1937-1938, U.S. Army Heritage and Education Center, Carlisle Barracks.

increased resources within the U.S. Military. Then, in 1940, the speed with which the U.S. Army established the Armored Corps challenges the intra-service model of change's claim that peacetime change moves at the pace of retiring officers.[94] Throughout the 1930s, the heterogenous cultures of the branches within the U.S. Army are inconsistent with the institutional isomorphism underlying the most insightful cultural models of change.[95] Finally, it is difficult to assess the appropriateness of Adoption Capacity Theory without the statistical data that one would need to conduct the quantitative analysis. But the underlying assumption that the successful demonstration of a new military method is sufficient to incite a desire to change is not supported by the Chief of Infantry's response to the successful German invasion of Poland when he said, "Let's don't [sic] go on that as recasting any role for the tank. I think we should adhere to the role of the tank as an infantry auxiliary."[96] The application of these five models as predictive theories may be outside their intended scope, but the ability to transcend individual cases would be a helpful attribute of these models if practitioners are going to use them to take specific actions in the real world.

Beyond a general ambivalence regarding the relationship between technology and military change, a reliance on the logical foundation of an inherent resistance to change within the military could be one reason for the inability of the existing models of military change to adequately describe the development of tanks in the U.S. Army prior to World War II. The way that each of these theories describes how militaries change over time is

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[94] Christopher Gabel, *The US Army GHQ Maneuvers of 1941* (Washington, D.C.: Center of Military History, 1992), 24.
[95] Farrell, "World Culture and the Irish Army, 1922-1942."
[96] George Lynch, "The Infantry" (Transcript of lecture delivered at the Army War College and discussion with audience, September 20, 1939), MSG G-3 Course No. 6, 1939-1940, U.S. Army Heritage and Education Center, Carlisle Barracks.

closely linked to the particular driver of change that the theory identifies for the military to overcome a presumed resistance to change. For example, as soon as a researcher identifies that the catalyst for change in a military is competition over budget share between services, as in the inter-service model of change, the mechanisms through which this change manifests itself are necessarily described in terms of the effect on the budget. Cote's detailed discussion of how both Posen and Rosen used the same case of innovation within fighter command in the RAF prior to World War II to highlight their competing theories is a prime example of this effect.[97] Both scholars were able to make compelling arguments for completely different mechanisms of change depending on the driving force for change that they identified at the beginning of their study. This suggests that the general approach of assuming militaries resist change then determining why a military changed in a case or group of cases, despite the tendency to remain static, is a poor technique to develop a general theory of how militaries change.

In addition to producing competing explanations for the same historical events, models derived from an emphasis on why militaries change fail to provide insights related to those times when militaries do not change. Stasis is a base assumption within these models that requires no explanation. One notable exception is Pierce's disruptive technologies approach, which also questions the utility of discounting the active management of stasis in militaries when analyzing the relationship between technology and innovation.[98] However, the application of his model requires the benefit of hindsight and is therefore inadequate for the active management of new technologies. Only when looking back on history does it become clear that some lack of change was an

[97] Cote, "The Politics of Innovative Military Doctrine: The U.S. Navy and Fleet Ballistic Missiles."
[98] Pierce, *Warfighting and Disruptive Technologies*, 3.

inappropriate course of action for the environment a military encountered at a later time. Models that assume stasis as the base condition are similarly ill-suited for the active management of innovation because they imply solutions that focus on removing barriers to change with little regard to the type of change that is required.[99]

**The Way Forward**

The inability to adequately manage technological change within militaries is a challenge that is not unique to any one military or period in time. Those militaries that innovate more successfully than their adversaries have a distinct advantage when their nations resort to violence to achieve political aims. The complexities of sociotechnical systems may prohibit the development of any truly generalizable and predictive theory of military change and technology. However, prescriptive models of military change, such as those reviewed above, that identify specific drivers and mechanisms of change that are not widely applicable could cause more harm than good for organizations through wasted resources and a false sense of progress.

As the assumption of a resistance to change is fundamental to the existing models of military innovation, minor changes to these models will not address this shortfall. A new way of understanding and describing military change is necessary if the goal is to produce insights that leaders can use to make decisions regarding technology in uncertain environments. Ideally, this model should both make no assumptions that are counter to

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[99] Jamie Morin and Bill Laplante, “What We Don’t Know About Military Innovation,” Defense One, October 20, 2020, https://www.defenseone.com/ideas/2020/10/what-we-dont-know-about-military-innovation/169398/.

the words of the actors in the system and adequately account for the relationship between technology and military innovation.

This leads to the main research question of this dissertation. Can reframing the relationship between technology and military innovation provide insights to address the apparent inability of militaries to align technology with strategy and inform more effective alignment? The next chapter will introduce ideas from science and technology studies that can provide an alternative lens through which to view the relationship between military innovation and technology.

“The experience of using any tool changes the user’s awareness of the structure of reality and alters his or her sense of the human possibilities within it.”

-Paul Edwards, *The Closed World*[100]

# CHAPTER 3

# THE TECHNOLOGY TRIAD

Related to the assumption that militaries naturally resist change, each of the existing models of military change also assumes “the existence of an external reality that sets the conditions for innovation.”[101] As demonstrated towards the end of the previous chapter, these positivist attempts to explain the highly complex social interactions involved in the relationship between technology and military change can produce inaccurate or conflicting descriptions of the system. Positivist framings of military innovation require hindsight to evaluate good and bad stasis in organizations. Constructivism, as a concept, removes this requirement because it provides a framework that can illustrate how change and stasis in a military are neither good nor bad until it is tested in war. Militaries exist in a constructed reality in the strongest sense of the word, and the relative goodness or badness of stasis and change in militaries is solely dependent on internally generated truths until the military is tested in war. Even then, war is a fluid concept that may or may not test the goodness or badness of a particular way of fighting for the military. Constructivism embraces this ambiguity as a philosophical base from

[100] Paul N. Edwards, *The Closed World: Computers and the Politics of Discourse in Cold War America*, Inside Technology (Cambridge, Mass: MIT Press, 1996), 29.
[101] Griffin, “Military Innovation Studies.”

which to understand military change, but it also brings its own challenges for application in the real world. A desire to provide practical advice to military leaders and policy makers may have induced an intellectual conservativism within military innovation studies, as an academic field,  that avoids acceptance of a purely constructivist explanation for military change.[102] The challenge for a researcher who intends their work to be useful for national security professionals becomes to find a way to capitalize on both of these strengths: the potential for novel insights enabled by constructivist framings and the practicality of positivist assumptions. The model explained in detail in this chapter will endeavor to rise to this challenge while also retaining a logic that is both philosophically consistent and readily applicable to the conditions of life as humans actually live it.

**Science and Technology Studies: Sociotechnical Systems**

Co-production is a foundational theory within Science and Technology Studies (STS) and a useful starting point to explore the basic concepts within this broad inter-disciplinary field related to society, technology, and the interactions within the system that they create. Developed by Sheila Jasanoff, co-production is the idea that technology and society evolve and change together. From the Polish saber example at the start of the dissertation, that system of fighting was both a product of the Polish society and an influence on the way Polish society changed over time. More formally, co-production is “the proposition that the ways in which we know and represent the world (both nature

[102] Griffin.

and society) are inseparable from the ways in which we choose to live in it."[103] Recognition of the reciprocal relationship between technology and social activity provides a powerful lens through which to understand socio-technical systems and is foundational to the logic that underpins this dissertation. However, to create a model of military technology that can inform concrete actions requires more granularity specific to military socio-technical systems. The broad strokes with which co-production paints are not sufficient alone.

If co-production is an overly broad intellectual framing of socio-technical systems, then Bruno Latour's Actor Network Theory (ANT), another central methodical framework within the STS tradition, would be at the other end of the spectrum with its emphasis on the agency of individual actors within the system.[104] Importantly for the study of militaries and change, ANT provides a robust intellectual framework to employ empirical evidence in the form of the actual words of the actors in question and discard an assumed resistance to change within militaries. ANT starts from the prospect that social theories that explain people's actions absent persistent interaction between actors do not exist. ANT asserts that relationships between actors are changing and constantly updated through local interactions with each other and physical objects rather than held in place by some unseen and unmeasurable social or cultural force. A natural resistance to change within bureaucracies is a prime example of the type of social theory to which Latour was referring. To understand a system through the lens of ANT, one must allow

[103] Sheila Jasanoff, ed., *States of Knowledge: The Co-Production of Science and Social Order*, International Library of Sociology (London: Routledge, 2010), 2.
[104] Bruno Latour, *Reassembling the Social: An Introduction to Actor-Network-Theory*, Clarendon Lectures in Management Studies (Oxford ; New York: Oxford University Press, 2005).

the actors to speak for themselves.[105] For example, when Colonel Kinzie Edmunds gave a lecture at Fort Leavenworth in July 1940 and said, "the horse is still far from being obsolete," one must assume that Colonel Edmunds believed what he said rather than speak for him and presume that what he really meant was something along the lines of "I am a horse cavalry officer, and I value my individual identity as such above speaking truth to a lecture hall of officers on the eve of a world war," as some popular explanations for the existence of horse cavalry late into the 1930s would suggest.[106]

Allowing actors to speak for themselves and rejecting the social theory that militaries naturally resist change has important implications for understanding the relationship between technology and military change. It shifts the framing of the question away from a position that seeks some prime mover force to break a relatively stable bureaucracy from its stasis. Instead, the prospect of change must be considered a constant where the most relevant question is *how* does this change unfold? Nielsen observed that Williamson Murray took this very approach in his classic historical account *Military Innovation in the Interwar Period* when he said, "the study assumes that innovation is natural and the result of a dynamic environment in which organizations must accept change if they are to survive."[107]

Focusing on *how* militaries change, rather than *why* they change, does not dismiss the importance of external factors on the behavior of the system. Rather, it is meant to

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[105] Latour.
[106] Kinzie Edmunds, "Lectures for Special Course: CMTC (Business Men's Camp), Lecture No. 2: The Arms and Services" (Transcript of lecture, July 1940), Combined Arms Research Library, Ft Leavenworth; Edward Katzenbach, "Tradition and Technological Change," in *American Defence Policy*, Fifth (Baltimore: The Johns Hopkins University Press, 1982), 638–50; David E. Johnson, *Fast Tanks and Heavy Bombers: Innovation in the U.S. Army, 1917-1945*, Cornell Studies in Security Affairs (Ithaca: Cornell University Press, 1998).
[107] Nielsen, *An Army Transformed*, 15; Williamson Murray and Allan R. Millett, eds., *Military Innovation in the Interwar Period* (Cambridge: Cambridge Univ. Pr, 1996), 5.

provide balance to the analysis to produce a description that is equally valid for periods of relative stability as well as instances of change. This balance allows the resulting description of the system to avoid overemphasis on specific drivers of change and produces a more comprehensive understanding of the entire system.[108]

So, if change is constant and actively sought by the military, then *how* is military change related to technology? ANT also illustrates the importance of technology in the behavior of social systems by explaining how material objects can influence the actions of humans if those humans are predisposed to interact with that material object.[109] Within ANT, actors can be either human actors or inanimate artifacts, sometimes referred to as "actants" in the literature, as long as they influence some action from other actors.[110] Latour used the example of a seatbelt buzzer in his car to explain this concept. The design of his vehicle, an artifact, induced him to wear his seatbelt because the car was designed in such a way to produce an irritating sound if he did not. Of course, he could have disabled the seatbelt buzzer. But then, he would have changed the design of the car in the process, and the original design would have induced this action instead of wearing the seatbelt.[111] ANT provides a useful tool to conceptualize the impact of the material objects that the military uses on the methods that the military employs.

If ANT helps describe the influence that materiel can have on the military, then the Social Creation of Technology (SCOT) method of analysis developed by Wiebe

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[108] Wiebe E. Bijker, *Of Bicycles, Bakelites, and Bulbs: Toward a Theory of Sociotechnical Change*, Inside Technology (Cambridge, Mass: MIT Press, 1995), 14–15.
[109] Edwin Sayes, "Actor–Network Theory and Methodology: Just What Does It Mean to Say That Nonhumans Have Agency?," *Social Studies of Science* 44, no. 1 (February 2014): 134–49, https://doi.org/10.1177/0306312713511867.
[110] Bruno Latour, "Where Are the Missing Masses? The Sociology of a Few Mundane Artifiacts," in *Shaping Technology/Building Society: Studies in Sociotechnical Change*, ed. Wiebe E. Bijker and John Law, Inside Technology (Cambridge, Mass: MIT Press, 1992), 225–58.
[111] Latour.

Bijker and Trevor Pinch illuminates the influence that people in the military can have on the design of materiel.[112] Within SCOT, relevant social groups each possess a preferred design of a specific technology to address considerations unique to that group. This produces multiple viable designs for a single technology. Over time, groups redefine their problem and the corresponding technological solution to that problem to align with other groups. This shrinks the number of possible designs for the technology in question. Ultimately, all groups close on a single design for the technology, which then becomes the standard form for that technology. In this manner, the social interactions of the people within and between groups exert a powerful influence on the design of technology.[113] Militaries contain a plethora of relevant social groups in the form of branches, units, and levels of command within the hierarchy. SCOT can provide a framework to understand how these elements within a military exert influence on the shape of technology.

Together, ANT and SCOT provide a a higher degree of understanding of the relationship between the military and technology than either one can alone. They each help explain different aspects of the larger co-production of technology and society.[114] SCOT can help address the critique that ANT minimizes or completely ignores the power imbalances between groups of people, and ANT can counter the tendency of SCOT to prioritize social drivers of change at the expense of the influence that technology has on people. [115] Using ANT and SCOT together in the same analysis could possibly be inappropriate because SCOT is technically the type of social theory that ANT eschews.

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[112] Bijker, Hughes, and Pinch, *The Social Construction of Technological Systems*.
[113] Bijker, *Of Bicycles, Bakelites, and Bulbs*.
[114] Jasanoff, *States of Knowledge*.
[115] Ignacio Farias, Celia Roberts, and Anders Blok, eds., *The Routledge Companion to Actor-Network Theory* (London ; New York: Routledge, Taylor & Francis Group, 2020).

Latour himself noted that SCOT, while insightful, would not fit within the framework of ANT owing to the role that an unseen social force plays in SCOT.[116] However, within militaries, the social interactions between individuals and groups are heavily influenced and stabilized by organizational artifacts ranging from uniforms to regulations, just as ANT prescribes. There is no need to rely on an ill-defined social force because it is maintained by physical objects and interactions that one can witness directly. With this slight modification to the original SCOT framework related to the way it defines relevant social groups and explains the interactions between them, ANT and SCOT can share a common philosophical footing to explain the relationship between military change and technology.

That said, even the increased explanatory power of these two frameworks regarding military change and technology still falls short of the ultimate goal of this dissertation to produce a model that can inform more effective future alignment of technology and strategy. A common way to address the role of technology in military change in the literature is to simply say, "it is not the technology that matters, but how you use it." This simplifies the relationship between militaries and technology by granting dominance to social considerations. Van Creveld made a variation of this argument when he wrestled with the role of technology in the changing character of war, and so did Horowitz when he made the ability of a military to appropriately adjust its structure for new innovations the critical component for successful change.[117] This is also very similar to Adamsky's conclusions studying the technological change following the

[116] Latour, *Reassembling the Social*, 10.
[117] Van Creveld, *Technology and War*; Horowitz, *The Diffusion of Military Power*.

1990s that cultural factors determine how a military will react to a new technology and, therefore, determine how this technology influences change in the military.[118]

Another way to frame this relationship between technology and the way people use it comes from Braden Allenby and Daniel Sarewitz's three levels of technology.[119] In this model, level I technologies are the physical artifacts that people use to achieve some goal. Level II technologies are sociotechnical systems that include both people acting and the objects with which they act. Level III technology represents a higher level of complexity at the "Earth system" level where "human, built, and natural elements interact in ways that produce emergent behaviors that may be difficult to perceive."[120] Allenby and Sarewitz explain that focusing on level I technologies is insufficient to solve problems that involve level II and III systems.[121] In terms of military effectiveness and technology, that would support the many security studies scholars who claim that the specific form of a technology does not matter as much as how militaries employ it. But level I technologies are still a part of level II and level III technologies and influence those more complex systems in some way.[122]

An ANT analysis of how level I technologies influence level II and III technologies would indicate that the type of technology is important in the way people use it. Conversely, the same analysis through the lens of SCOT would indicate that the way a technology will be used determines its design. The conflicting and circular

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[118] K. I. Bjerga and T.L. Haaland, "Doctrinal Innovation in a Small State," in *Contemporary Military Innovation: Between Anticipation and Adaption*, CASS Military Studies (London ; New York: Routledge, 2012).
[119] Braden R. Allenby and Daniel R. Sarewitz, *The Techno-Human Condition* (Cambridge, Mass: MIT Press, 2011).
[120] Allenby and Sarewitz, 63.
[121] Allenby and Sarewitz, 94–95.
[122] Allenby and Sarewitz, 137.

arguments presented by these two frameworks do not provide answers for people who are trying to manage real organizations beyond the observation that it is important to appropriately integrate new technology into the existing system and culture. How would one do that without the ability to predict the future, and what are the relevant considerations? ANT and SCOT, while important, only start to provide relief to the amorphous and intricate interactions between the military and technology. A deeper dive into STS can provide methods of framing the most relevant aspects of the military sociotechnical system to understand the relationship between technology and military change in dynamic systems.

**Technology: A Multi-Faceted Concept**

With a general background on previous thinking related to military change and some basic sociotechnical systems concepts in place, a more comprehensive definition of the concept "technology" forms the logical base from which to build an initial model to describe technology and military change and can help explore some of the complexities of military sociotechnical systems. Martin Heidegger, in his treatment of technology, demonstrated how inclusive a definition of technology could be when he said, "The manufacture and utilization of equipment, tools, and machines, the manufactured and used things themselves, and the needs and ends that they serve, all belong to what technology is."[123] More recently, Eric Schatzberg explained in his critical history of the concept of technology that the wider corpus of STS literature tends to use the word "technology" in different ways to describe distinct concepts within the broader definition

[123] Martin Heidegger, *The Question Concerning Technology and Other Essays*, trans. William Lovitt, Harper Perennial Modern Thought (New York; London Toronto: HarperCollins Publishers, 2013), 4.

outlined by Heidegger.[124] Each of these three uses of the word technology can be found in existing treatments of military technology.

First, technology can refer to applied knowledge, such as in the basic research and applied science model of innovation championed by Vannevar Bush.[125] Van Creveld exemplified this definition of military technology when he explained: "technology as a certain kind of knowhow, as a way of looking at the world and coping with its problems."[126] This framing of technology gave primacy to the social influences in sociotechnical systems and enabled Van Creveld to draw broad conclusions about the way that technology, as a social process, influences a military's understanding of war.[127] Jasanoff employed a similar definition to serve as the cornerstone for her development of co-production when she described technology as "knowledge and its material embodiments."[128]

Jasanoff's use of the word "technology" starts to blur the distinction between knowledge and the more colloquial use of the word technology to refer to physical objects, which is the second of the three definitions of the word. In this framing, technology can refer to the industrial arts, which includes material objects, or artifacts, and the body of knowledge required for their manufacture.[129] This framing of technology lends itself to discussions related to the types of analysis of military technology that seek to describe technological influences on military affairs as an opposite force to social influences. Thomas Mahnken employed this definition in his book *Technology and the*

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[124] Eric Schatzberg, *Technology: Critical History of a Concept* (Chicago ; London: The University of Chicago Press, 2018), 212.
[125] Bush, *Science, the Endless Frontier*.
[126] Van Creveld, *Technology and War*, 1.
[127] Van Creveld, *Technology and War*.
[128] Jasanoff, *States of Knowledge*.
[129] Schatzberg, *Technology*, 212.

*American Way of War Since 1945*, where he argued that services within the U.S. military "molded technology to suit their purpose more often than technology shaped them."[130] Mahnken's assessment favors social factors over material in the way that militaries change over time, but his more narrow framing of technology as a concept precludes an analysis that could address the full complexity of the military sociotechnical system.

Finally, technology can refer to technique, which encompasses "all skills and procedures for achieving a specific end."[131] Alex Roland employed this framing of technology to distinguish technology from physical artifacts in his historical survey of military technology. Roland focused on technology as an activity that "is purposeful, human manipulation of the material world," and the weapons that militaries employ are the outputs, or artifacts, of these activities.[132] He then used this definition of technology to draw a balance between the social and material influences that shaped the way militaries evolved historically.

The three definitions of the word technology in military applications are useful for highlighting different aspects of the boundary between social and physical worlds, but individually they only describe a specific aspect of a larger system. To more fully understand the complex dynamics of military sociotechnical systems, it is more useful to think of the different definitions as alternate perspectives on a single concept. While Schatzberg argued that a single word to describe three different concepts induces a certain amount of confusion in parts of the STS literature, exploring how they might be

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[130] Thomas G. Mahnken, *Technology and the American Way of War since 1945* (New York Chichester: Columbia University Press, 2010).
[131] Schatzberg, *Technology*, 232.
[132] Roland, *War and Technology*, 5–6.

related to a common concept, as Heidegger contended, can help illuminate the nature of technology.[133]

## A New Model: The Technology Triad

Even though the three meanings of the word technology are distinct, they are still related and are often referenced as a group within the literature. For example, in his article "The Three Faces of Technological Determinism," Bruce Bimber states that "other definitions [of technology] are increasingly inclusive, incorporating processes for producing artifacts, knowledge about artifacts and processes, and even systems of organization and control."[134] Similarly, Atsushi Akera, while referring to models of innovation in *Calculating a Natural World*, describes a process to create "knowledge, artifacts, and instrumental practices."[135] These three meanings are often listed together because, in practice, they are deeply interconnected.

The real-world manifestations of these concepts form a triad where it can be difficult to separate them from one another. The technology of a lever can demonstrate this in action. The lever itself would be an artifact, which could be any item of the correct shape and strength. Technology could also refer to the technique of leverage to achieve the end of trading distance traveled for the force applied at the end of an object used as a lever. Finally, applying the knowledge of the effect of leverage could adequately describe the technology as well. These concepts can also rely on one another to derive meaning.

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[133] Schatzberg, *Technology*, 212; Heidegger, *The Question Concerning Technology and Other Essays*.
[134] Bruce Bimber, "Three Faces of Technological Determinism," in *Does Technology Drive History? The Dilemma of Technological Determinism* (Cambridge, Massachusetts: The MIT Press, 1994), 87–88.
[135] Atsushi Akera, *Calculating a Natural World: Scientists, Engineers, and Computers During the Rise of U.S. Cold War Research* (Cambridge, Massachusetts: MIT Press, 2008), 341.

For example, knowledge about the correct length for a lever in a given application both determines the size of the artifact and the manner in which one would apply leverage. Rather than try to determine which of these three meanings of the word "technology" are appropriate for understanding its relationship with military change, it is more useful to treat them as a single, complex concept.

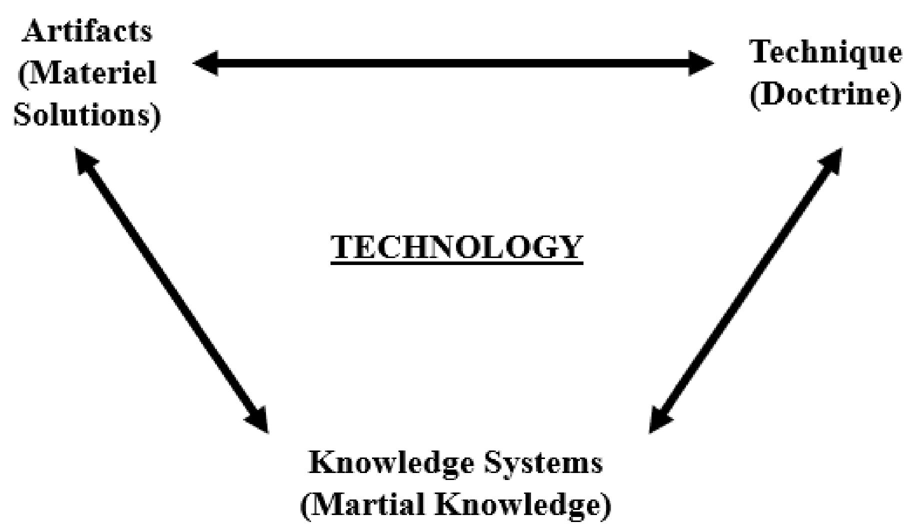


Figure 3: The Technology Triad

For military technology, the three broad definitions of general technology correspond very well to two concepts that are already well-established in the military and one new concept. Artifacts become the weapons and equipment that militaries fight with, or "materiel." Technique becomes methods of employment for military forces, or "doctrine." And finally, applied knowledge becomes the new concept, which I refer to as "martial knowledge." As a new concept, martial knowledge is explained in great length below, but for now, it is sufficient to define it as the knowledge related to a series of truths that describe the best way to win a war. For example, the knowledge that a machine gun is a more effective standoff weapon than a longbow would be an example of the martial knowledge that fielding a squad automatic weapon produces a more effective infantry squad than fielding a squad designated longbowman. Together, these three elements form the “technology triad,” a novel model that represents a dynamic system that changes over time.

Military change requires a transition from one state of being to another. The relative rates of change in the real world for each of the three aspects of the technology triad are different. Martial knowledge can change nearly instantaneously with new information. A military’s doctrine takes longer to adjust, as the people must be re-trained. Finally, producing materiel solutions on the same scale of the change in doctrine takes even longer because not only must industry build the new equipment, but industry must also build the machines to build the equipment, and so on. These different rates of change produce a complex system, with each element interacting with and influencing the other two at each point of their transformation. Each of the interactions between the three elements becomes a point of inquiry to develop understanding, which ultimately will create opportunities for deliberate management of the whole system.

## The Logic and Mechanics of the Technology Triad

The technology triad is a model of the complex relationships that exist at the boundary between the social and physical worlds within militaries. While structurally similar to various existing models of military innovation, it is philosophically unique in the degree to which it embraces a strong form of social constructivism. What follows is a description of the underlying logic that enables this potentially extreme position and how the mechanics of the technology triad address existing critiques that pure constructivist frameworks are difficult to relate to concrete actions related to the management of large organizations.

### *The Technology Triad and Other Existing Models of Military Technology*

Echoing Plato's *Republic* and Clausewitz's trinity, the technology triad is a three-element model, but the technology triad's structure is not based on tradition.[136] The number of elements in the technology triad is exactly three for a very important, foundational reason: it is the smallest number of independent variables in a system that can produce chaotic behavior.[137] Keeping with Albert Einstein's view of theory development that things should be made as simple as possible, but no simpler, any model that hopes to adequately address the complex relationships present in social systems must have at least enough elements and interactions within those elements to produce complex behavior.[138] A model that contains four or more elements could also produce complex relationships, but larger models would also be more difficult to visualize how the elements of the model interact with each other. A model with three elements becomes the simplest model that can hope to represent a complex military socio-technical system without being so simple that it fails to provide critical insights.

On the surface, the technology triad may look similar to other models of technology. Most of these models also have three elements, and one model, which is

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[136] Plato and C. D. C. Reeve, *Republic* (Indianapolis: Hackett Pub. Co, 2004); Sun-Tzu and Clausewitz, *The Book of War*.
[137] Glenn James, *Chaos Theory: The Essentials for Military Applications* (Newport, RI: Naval War College, 1996), 45.
[138] Albert Einstein, "On the Method of Theoretical Physics," *Philosophy of Science* 1, no. 2 (1934): 163–69.

notable for its ubiquity in the United States Department of Defense modernization doctrine, comprises eight interrelated elements. These similarities are either less important than the differences or result from the nature of and central question regarding military technological innovation. The aforementioned three levels of technology in Allenby and Sarewitz's *The Techno-Human Condition* is not technically a model but a hierarchical taxonomy of increasing complexity within technological systems.[139] But it does bear some resemblance to the technology triad, and contrasting the two framings can help further define the technology triad. Both the technology triad and the three levels taxonomy are comprised of groups of three interrelated systems, and Level I technologies and materiel solutions are exactly the same concept. Level II technology requires some creative interpretation to map onto doctrine, but the concepts are similar and can be considered analogous. The third element is the crucial difference between the three levels of technology and the technology triad. Where Allenby and Sarewitz's framing describes Level III technologies that exist above the other two levels of technologies with interconnectedness between systems the important distinction, the technology triad brings in the concept of martial knowledge that is adjacent to materiel and doctrine with rates of change within the three elements the important distinction.

The function of these two framings accounts for these differences. The three levels of technology illustrate the interconnectedness of systems that include both people and artifacts within society and the preeminence of social considerations when socio-technical systems are meant to address specific problems or manage certain situations. The technology triad also puts people and artifacts in relation to each other to explore the

[139] Allenby and Sarewitz, *The Techno-Human Condition*.

influence of both social and material influences on a military's efforts to prepare for and win wars. However, with a focus on understanding military change and innovation, the three elements within the technology triad interact with each other simultaneously, rather than in a hierarchical structure, to highlight the influence of changes within the system over time. The technology triad is not meant to be a better representation of socio-technical systems than the levels of technology; the technology triad is meant to address different aspects within military socio-technical systems over time. Other similar models of military technology, however, do aim to address the concept of change within military socio-technical systems over time, just as the technology triad does.

In 2010, Andrew Ross introduced one such model called the "military innovation triad" that focused specifically on military technological innovation and change. This is the most superficially similar model to the technology triad with a three-element structure, the name "triad," and an attempt to relate weapons to doctrine.[140] However, the underlying logic of the two models is distinct. Figure 4, below, shows the three elements of Ross's triad: technology, doctrine, and organization. When Ross refers to "technology" in his model, he means specifically "weaponry and weapons systems," which would be more accurately described as technological artifacts in the science and technology studies literature and are accounted for within the technology triad as materiel.[141] Ross describes doctrine as the "software" needed for a military to operate weapons and associated systems.[142] The difference becomes apparent in the third element, the one beyond things

[140] Andrew L. Ross, "On Military Innovation: Toward an Analytical Framework," *SITC* 2010, no. Policy Brief 1 (September 1, 2010), https://escholarship.org/uc/item/3d0795p8; Tai Ming Cheung, Thomas G. Mahnken, and Andrew L. Ross, "Frameworks for Analyzing Chinese Defense and Military Innovation," in *Forging China's Military Might: A New Framework for Assessing Innovation* (Baltimore: Johns Hopkins University Press, 2014), 15–46.
[141] Ross, "On Military Innovation," 1.
[142] Ross, 2.

and the way people use them. Ross uses "organization" as the third element in his triad. This is another example where science and technology studies concepts help provide important insights to understand these relationships. In the technology triad, organization is considered an aspect of doctrine because it is really nothing more than the techniques a military employs to produce collective action to solve some problem, presumably to prepare for or win a war.[143] With an understanding of doctrine and organization as two types of techniques, Ross's triad becomes a dyad that omits an important consideration, martial knowledge, that helps explain how and why materiel and doctrine change the way they do over time. Despite this omission, Ross's model does hit on an important commonality shared with the official U.S. Army models that aim to understand military technological innovation: the relationship between weapons and how they are used.

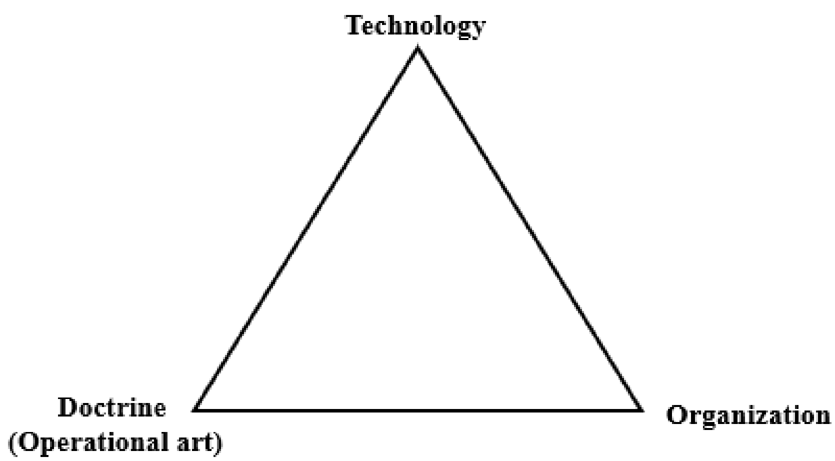


Figure 4: Andrew Ross's Military Innovation Triad[144]

The most widely used model for military change within the U.S. military is also, at its core, an attempt to put materiel and doctrine in relation to each other. The

[143] Jacques Ellul, *The Technological Society* (New York: Vintage Books, 1964), 22.
[144] Ross, "On Military Innovation."

DOTMLPF-P framework enables U.S. military to address any identified capability gap by making a change to one or several of these eight points of influence within the system. Furthermore, any change to one element of DOTMLPF-P could potentially create an imbalance within the system that would require further changes to other elements. Despite DOTMLPF-P's eight integrated elements and practical effectiveness to help synchronize change across large organizations, it is a reductionist management technique that is much more similar to Ross's dyad than it is to the technology triad. Each of the eight elements of DOTMLPF-P could be designated as a form of doctrine or materiel. For example, materiel and facilities are both physical objects that fall within materiel in the technology triad, and the other six elements of DOTMLPF-P are various forms of technique, or doctrine.

The U.S. Army's most recent modernization strategy simplifies DOTMLPF-P to "how we fight," "what we fight with," and "who we are."[145] Once again, doctrine and materiel are central to the model, with some other factor to account for the indirect and complex relationship between weapons and how they are used. On the surface, "who we are" seems like it could be a fundamentally new concept that does not fit neatly within doctrine or materiel, but careful study of the Army Modernization Strategy reveals that "who we are" is "more fully articulated in the 2019 Army People Strategy" released in the same year.[146] The 2019 Army People Strategy, while a clear departure from earlier

[145] Ryan McCarthy, James Mconville, and Michael Grinston, "2019 Army Modernization Strategy: Investing in the Future" (Department of the Army, 2019).
[146] McCarthy, Mconville, and Grinston, 8.

personnel management practices, is still an organizational technique for the professional development and management of people within the U.S. Army, and thus a technique.[147]

Understanding the complex interactions between weapons and the way militaries use them is the primary goal of models of military technological change. It is logical that the technology triad would share a superficially similar structure to other models of military technology both in form and function. The form of the technology triad, three interrelated elements, shared with the three levels of technology, Ross's military innovation triad, and the Army Modernization Strategy, is a functionally simple model that still holds the potential to illustrate complex relationships within the system. Furthermore, two of the three elements of these models, materiel and doctrine, are dictated by the central questions surrounding military technology. Therefore, it makes sense that a model that aims to address the relationship between technology and military innovation, like the technology triad, would share a basic construct with other similar models of materiel, doctrine, and a third element to help understand the interactions of the first two elements.

The third element is the key distinction that makes the technology triad fundamentally different than existing models. By leveraging philosophical concepts borrowed from science and technology studies, the technology triad introduces a novel concept, martial knowledge, as the third element in the system. Similar to the way a deeper appreciation for materiel as artifacts and doctrine as technique help illustrate how earlier attempts to identify a third element to relate to weapons and their use have fallen

[147] Ryan McCarthy, James McConville, and Michael Grinston, "The Army People Strategy" (Department of the Army, October 2019).

short of the mark, a deeper appreciation for the nature of knowledge can demonstrate how martial knowledge forms a distinct concept within the technology triad.

### *A Practical Interpretation of Knowledge and Military Affairs*

Martial knowledge is the concept that unlocks a new way of framing the relationship between weapons and their use, and the critical component of martial knowledge is its local validity and global variability in practical applications like the conduct of war and the management of military organizations in times of peace. If the basic definition of martial knowledge is knowledge related to the best way to win a war, the local validity of martial knowledge means that each military holds its own unique understanding of the best way to win a war. It is important to note that the local nature of all knowledge, and martial knowledge especially, is not merely an acceptance of variability of beliefs between cultures but is a way to describe how groups of people understand the very nature of reality to such a degree that they take actions based on that understanding to preserve their existence. To better understand how martial knowledge can represent multiple contradicting truths, rather than just describe differing understandings of some universal truth, it is useful to compare this practically oriented concept with philosophical treatments of the nature of knowledge. What follows is a foundation for a theory of martial knowledge.

#### *The Nature of Knowledge*

Philosophical treatments of knowledge come from a contentious line of inquiry within the broader intellectual pursuit of epistemology called "analysis of knowledge," which seeks to define the necessary and sufficient qualities for knowledge.[148] The classical analysis of knowledge defines knowledge as a "justified true belief."[149] Within this structure, any proposition that a person justifiably believes is true and is, in fact, true would count as knowledge, and any other proposition would not. For example, guessing the outcome of a fair coin flip, even if the person making the guess believed deeply in their ability to predict the outcome, would not count as knowledge because there is no way they could be justified in this belief. In 1963, Edmund Gettier challenged this intuitive and simple definition of knowledge when he demonstrated two cases of a justified true belief that would not fit within traditional views of knowledge.[150]

Gettier's examples provided concrete cases where a person could essentially make a lucky guess but also be justified in their belief in the truthfulness of their guess. Bertrand Russell provided a good example of a "Gettier case" in 1948 when he described how a man with a broken watch could know the correct time twice a day.[151] Because Russell's watch example predated Gettier's paper by 25 years, Russell argued that the man did not satisfy the requirements for a justified belief due to the malfunctioning watch. Gettier's contribution to the analysis of knowledge was the identification that the person's belief in the accuracy of the watch could be justified because he may have no indication to suspect that it was broken; yet the justified true belief did not qualify as

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[148] Jonathan Jenkins Ichikawa and Matthias Steup, "The Analysis of Knowledge," in *The Stanford Encyclopedia of Philosophy*, ed. Edward N. Zalta, Summer 2018 (Metaphysics Research Lab, Stanford University, 2018), https://plato.stanford.edu/archives/sum2018/entries/knowledge-analysis/; Matthias Steup and Ram Neta, "Epistemology," in *The Stanford Encyclopedia of Philosophy*, ed. Edward N. Zalta, Fall 2020 (Metaphysics Research Lab, Stanford University, 2020), https://plato.stanford.edu/archives/fall2020/entries/epistemology/.
[149] Jennifer Nagel, *Knowledge: A Very Short Introduction*, First edition, Very Short Introductions 400 (Oxford: Oxford University Press, 2014), 48.
[150] Edmund L. Gettier, "Is Justified True Belief Knowledge?," *Analysis* 23, no. 6 (1963): 121–23, https://doi.org/10.2307/3326922; Nagel, *Knowledge*, 48.
[151] Nagel, *Knowledge*, 46.

knowledge because the logic for the justification, the position of the watch hands, was disconnected from the condition that produced the truth, the time of day. Gettier's paper inspired several different approaches to amend the classical, justified true belief, definition of knowledge to account for these sorts of cases.

Alvin Goldman developed an idea called reliabilism to addresses Gettier cases, where he replaced justification with a requirement for knowledge to emanate from a process that reliably produces true beliefs.[152] Returning to the watch example, the man's justified true belief that the time indicated on the watch was correct would not count as knowledge under the requirements set forth by Goldman's reliabilism. In that case, observing the position of the hands on the watch is not a reliable process to produce true beliefs because the watch was malfunctioning, even though the man was not aware of that condition. The central idea of reliabilism is that even though a lucky guess is justified in some cases, it would never be a reliable source of truth in those cases.[153] In this manner, reliabilism seeks to avoid the challenges associated with justification by replacing them with this new concept. Goldman himself admitted that the concept of reliability is ambiguous, with no way to set an adequate level of reliability to produce knowledge independent of the truth condition of a specific proposition.[154] This renders reliabilism a potentially useful intellectual framing for the consideration of the nature of knowledge. However, its reliance on some objective truth that may be unknown to the people in question makes it less attractive for practical application to real-life situations.

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[152] Nagel, 53; Alvin Goldman and Bob Beddor, "Reliabilist Epistemology," in *The Stanford Encyclopedia of Philosophy*, Winter 2016 (Metaphysics Research Lab, Stanford University, 2016), https://plato.stanford.edu/archives/win2016/entries/reliabilism/.
[153] Ichikawa and Steup, "The Analysis of Knowledge."
[154] Goldman and Beddor, "Reliabilist Epistemology."

As martial knowledge is inherently practically oriented, some other way of thinking about knowledge is required.

Martial knowledge draws from existing philosophical treatments of knowledge to fulfill its role in the technology triad as a practically useful concept with clear application in military organizations. Gettier demonstrated that justified true belief is a philosophically incomplete definition of knowledge. Reliabilism addresses this issue by relying on an appreciation of objective truth that real organizations are unlikely to achieve. Martial knowledge combines elements from both of these framings of knowledge to create a practical concept of knowledge. It is important to note that martial knowledge would not fall into the group of concepts that Clifford Geertz contemptuously labeled "practical epistemologies," in which "an idea is 'true' so long as to believe it is profitable to our lives," in the words of William James.[155] Rather, martial knowledge draws inspiration from the Roman philosopher Seneca who held that philosophy is an undertaking for everyday life, that its lessons should be practically useful.[156]

Martial knowledge builds on the concept of justification from the classical knowledge analysis structure by acknowledging that any organization must have some internally valid reason to claim a piece of knowledge is true. The different forms this justification can take in a military will be addressed in the next section of this chapter, but for now, it is adequate to acknowledge their existence and note that they could range from something as simple as the senior officer affirming the truthfulness of a belief to full

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[155] Clifford Geertz, *Local Knowledge: Further Essays in Interpretive Anthropology*, 3. ed., [repr.] (New York, NY: Basic Books, 2001), 151; William James and Alburey Castell, *Essays in Pragmatism* (New York: Hafner Press, 1948), 155.
[156] Lucius Annaeus Seneca and Robin Campbell, *Letters from a Stoic - Epistulae Morales Ad Lucilium.*, 2014, xxii.

force on force peacetime experimental maneuvers. Gettier's argument that if a belief is true, but the justification for that true belief does not produce the belief, then an assertion cannot be formally considered knowledge is still valid, but not for the concept of martial knowledge.

The central aspect of martial knowledge is the belief in the truth of an assertion rather than the relationship between the justification for that belief and the truthfulness of the belief. In a real organization, if a belief is validated to be true, but for some other reason than it was originally thought to be true, the members of the organization would just update their internal justification for the belief and go on about their business. Of course, the status of the justification itself could be a form of knowledge with its own claim to truth and important implications for aspects of a military such as tactics or internal procedures, but this line of reasoning leads down a philosophical rabbit hole that distracts from the critical aspects of martial knowledge. Therefore, martial knowledge takes an approach to knowledge that is much closer to reliabilism, where justification is a fluid concept that changes with the environment. However, martial knowledge differs significantly from reliabilism in its basic assumption about the nature of truth. The reliability of a process to produce a belief in reliabilism is dependent on the truthfulness of the belief, even if the person in question may not be aware of the truthfulness of the belief. As mentioned before, this does not lend itself to practical application. Martial knowledge addresses the truth aspect of reliabilism by adopting a fundamentally different basic position on the nature of truth.

*Constructivism*

Martial knowledge relies on the constructivist assumption that there is no objective truth. Within a martial knowledge, the truthfulness of a belief is determined locally and may not qualify as truth in another military that holds a different martial knowledge. Multiple competing versions of martial knowledge can and do exist across all the militaries of the world. Martial knowledge embodies a concept of knowledge within a military about how to fight a war that is analogous to agent-based models, where individuals agents only have access to the knowledge to which they were exposed, either directly or as a member of a group. This departure from earlier analytic frameworks of knowledge produces a situation where martial knowledge can both retain the logically sound ideas of reliabilism and reflect the way people live in the real world, absent access to some objective truth. Constructivism may be an extreme and potentially counter-intuitive worldview, but its ability to provide beneficial understanding in the real world is significant.

The basic premise of constructivism is quite simple; constructivism is a form of relativism that accepts knowledge and the truth that defines it as constructions of social activities.[157] It is useful to define constructivism in contrast to realism, an alternate worldview. There is one objective truth in a realist view of the world, and science is on a quest to uncover it. Over time, science, which is a social process, slowly uncovers more and more of this truth through careful study of nature. Understanding is a consequence of nature; this would be the view of science that has been taught in United States elementary

[157] Maria Baghramian and J. Adam Carter, "Relativism," in *The Stanford Encyclopedia of Philosophy*, ed. Edward N. Zalta, Fall 2020 (Metaphysics Research Lab, Stanford University, 2020), https://plato.stanford.edu/archives/fall2020/entries/relativism/.

schools for decades. Constructivists turn this relationship around. A constructivist world view considers nature the product of, or consequence of, the social processes performed by scientists.[158] Fully understanding the implications of this worldview becomes quite challenging as it implies that different types of social processes, or the same social process conducted by different groups of people, can produce alternate versions of nature. Reconciling the disconnect between different constructed versions of nature and the obvious existence of the physical reality we all inhabit is an important question within constructivist science studies.

A full review of the philosophy of science is well beyond the scope of this dissertation, nor is it necessary to gain the requisite appreciation of how the physical sciences can be so heavily influenced by social processes that social processes are the critical contribution to martial knowledge. For the purpose of further defining martial knowledge, it is sufficient to note a few major themes in previous research related to how social processes in the actual conduct of science can influence the production of scientific knowledge, even when the people producing the knowledge have access to a physical world with which to conduct experiments, such as they do in the conduct of the natural sciences. The sociologist Robert Merton was one of the first influential scholars to start to define how interactions between people influence the production of knowledge through science. In 1935, he noted that "science is a social outgrowth and the direction of scientific research is largely induced by social factors."[159] Merton expanded on this basic

[158] Baghramian and Carter; Michel Callon and Bruno Latour, "Don't Throw the Baby out with the Bath School! A Reply to Collins and Yearley," in *Science as Practice and Culture*, ed. Andrew Pickering (University of Chicago Press, 1992), 350.
[159] Robert King Merton, "Science and Military Technique," *The Scientific Monthly* 41, no. 6 (1935): 542–45.

recognition that the progress of science is dependent on the actions of people to define an ideal normative structure. Adherence to this structure by the scientists, in Merton's view, would allow them to produce objective science. In 1942, Merton wrote an article that laid out the four necessary attributes, or ethos, of science: universal application of the results of science, community ownership of ideas, lack of personal interest in the conduct of science, and organized skepticism.[160] This sociological approach to the conduct of science stood in contrast to contemporaneous philosophical views on the conduct of science, such as those held by Karl Popper.

Karl Popper's full treatment of the conduct of science is quite detailed and involved, but the idea that all true science is falsifiable is the central claim.[161] He derives this conclusion from the induction problem, the idea that even if a scientist observes an apparent cause-effect relationship many times, there is no way to know for sure that it will be consistent forever. This means that scientific theories cannot lay claim to the way things are, only that they have not been proven false. To Popper, this quest to falsify previously held beliefs is the conduct of science, and any claim that is impossible to falsify, due to the nature of the claim, cannot qualify as science. This logical approach to the definition of science largely eliminates the role of social impacts on science but not completely. Popper did not discount the importance of human interaction in the conduct of science, noting that his definition of science required an agreement amongst "parties

[160] Robert King Merton, *The Sociology of Science: Theoretical and Empirical Investigations* (Chicago: University of Chicago Press, 1973), 267–78.
[161] Karl R. Popper, *The Logic of Scientific Discovery*, Repr. 2008 (twice), Routledge Classics (London: Routledge, 2008), 18.

interested in truth," but he still stopped well short of giving social processes center stage in the actual conduct of science, once such an agreement was achieved.[162]

In 1962, Thomas Kuhn directly challenged Popper's ideas about falsification in science, which deprived Popper of the agreement needed to define science and put the social processes between scientists back at the forefront in the conduct of science even more than Merton's ideas had.[163] Both Merton and Popper had approached their definitions of science from the perspective of what science *ought to be.* Merton saw ideal scientific pursuit as a normative ethos practiced by scientists, and Popper explained science as a logical construct derived from the inability to produce definitive statements about the future with only past events to draw from. Alternatively, Kuhn sought to explain how science actually progressed historically, and in the process, produced insights that challenged the objectivity of the natural sciences.[164]

Drawing from the actions of scientists during past scientific advancements, Kuhn's explanation for the way science changed placed far greater weight on the broad social acceptance of established theories, which he called paradigms, than on the relative explanatory power of any scientists' work. His structure for scientific changes, in the simplest form, would start with an established scientific theory, which he called a "paradigm." That established paradigm would adequately explain all or most unexplainable aspects of the world that previous paradigms could not. However, there would still be several unsolved aspects of the natural world that scientists would apply the new paradigm to solve as the course of what he called "normal science." Only once

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[162] Popper, 15.
[163] Thomas S. Kuhn and Ian Hacking, *The Structure of Scientific Revolutions*, Fourth edition (Chicago ; London: The University of Chicago Press, 2012).
[164] Kuhn and Hacking, 1.

generations of scientists had attempted and failed to explain enough physical phenomena within that paradigm could some other paradigm come and take its place. Prior to that point, the accepted paradigm was the only acceptable way to frame the natural world.

Kuhn used this model to directly challenge falsifiability as the predominant path of science; he explained that discontinuities between the established paradigm and the observed world actually drove scientists to alter their understanding of the world in terms of the established paradigm and not the other way around.[165] Furthermore, when Kuhn studied the actual conduct of science, rather than a logical construct of the ideal of scientific endeavor, he found that "failure to achieve a solution discredits only the scientists and not the theory."[166] Kuhn's observation that adherence to socially acceptable paradigms could determine the output of science, even in the face of contrary evidence, shifted the locus of generation for new knowledge away from some objective, logical place, as anti-relativists such as Popper would have liked it back, towards the potentially subjective human to human interactions that defined the conduct of science. Kuhn did, however, stop well short of claiming that social processes defined the truth on which science rested. He only claimed that the social processes that drive changes in science have a much larger impact on our interpretation of that truth than the view of science for which Popper argued.

Despite Kuhn's resistance to claim social processes define truth absolutely, his work inspired a new field of study called the "sociology of scientific knowledge."[167] Scholars who contributed to the sociology of scientific knowledge took a practical

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[165] Kuhn and Hacking, 145–46.
[166] Kuhn and Hacking, 80.
[167] John Law, "STS as Method," in *The Handbook of Science and Technology Studies*, Fourth Edition (Cambridge, Mass: MIT Press, 2017), 31–57.

approach to scientific knowledge, where the relative truthfulness of knowledge relies on the usefulness of that knowledge to solve relevant problems. This idea stems from Kuhn's observations that both true and false theories stem from the same social processes.[168] Through its relationship to truth and the authority to define it, the sociology of scientific knowledge is the most similar framing of knowledge to martial knowledge of those discussed thus far. The truthfulness or falsity of a martial knowledge rests exclusively on its ability to inform materiel and doctrinal solutions to win a war. There is no absolute truth when it comes to warfighting. What may work in one situation could be absolutely catastrophic in another.

This framing of scientific knowledge is also similar to martial knowledge in the implicit allowance that there can be multiple "truths" that are closely guarded by interested parties.[169] Thomas Gieryn built on the early work in the sociology of science to identify the way that scientists create cultural boundaries around the demarcation between science and other activities, which further countered Popper's asocial demarcation of science.[170] Within Gieryn's work, scientists actively manage their interactions with the public in a manner to reinforce their own expertise and preclude those who might challenge the knowledge that scientists have created from participating in the construction of new knowledge by labeling those activities as "non-science."[171] This boundary construction implies that those who are excluded from scientific activity hold their own beliefs, and the determination of the truthfulness of the competing beliefs

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[168] Law.
[169] Thomas F. Gieryn, "Boundary-Work and the Demarcation of Science from Non-Science: Strains and Interests in Professional Ideologies of Scientists," *American Sociological Review* 48, no. 6 (December 1983): 781, https://doi.org/10.2307/2095325.
[170] Gieryn, 781.
[171] Gieryn, 782.

is best described as a social activity. The intellectual direction of the sociology of scientific knowledge program of study departs significantly from a view of science that is based on an objective reality, but constructivism, as a concept, can be taken even further.

Shortly after Thomas Kuhn wrote *The Structure of Scientific Revolutions* and around the same time the earliest work in the field of sociology of scientific knowledge, Peter Berger and Thomas Luckmann published *The Social Construction of Reality*, in which they proposed a similarly named "sociology of knowledge."[172] The ideas Berger and Luckmann espoused are essentially constructivism taken to the extreme logical conclusion where the social interactions between humans do not just give form to the nebulous truths they believe in but actually define the fundamental nature of reality. Berger and Luckmann built their ideas from the observation that the real world in which we all live is defined by its intersubjectivity with other humans. Intersubjectivity in this context is a common subjectivity, the philosophical concept that describes the way a person orients themselves to the world around them physically, culturally, and conceptually.[173] For example, Berger and Luckmann explained how the important distinction between what we would classify as physical reality and a dream in a person's head is that multiple people share the same perceptions of the world in reality rather than the experience of a dream, which is confined to a single person. Other than this physical intersubjectivity, a dream is a reality for the person who experiences it.[174] Berger and Luckmann expanded this basic concept to show how all aspects of the reality we inhabit

[172] Berger and Luckmann, *The Social Construction of Reality*.
[173] Stephen West, "Philosophize This! 'Frankfurt School Part 6, Art as a Tool for Liberation,' Episode 113 - Transcript," Philosophize This!, December 2, 2017, https://www.philosophizethis.org/podcast/episode-113-transcript.
[174] Berger and Luckmann, *The Social Construction of Reality*, 37.

are defined by the degrees to which it is shared by other people. The logical extension of this argument is that there can be and are several different realities between different groups of people. As mentioned earlier, this is a major argument against purely constructivist accounts of the world, when it is obvious there are certain aspects of reality that are not made up through the interactions of people. The philosopher Eugene Rosa argued against this strong position of constructivist ontologies when he noted that the passing of time is a common experience for all humans, even early civilizations in South America, which had no interaction with their European counterparts.[175]

*The Absence of War and the Social Construction of Martial Knowledge*

The apparent impossibility of multiple independent realities in the obvious presence of a physical reality that is not dependent on human beliefs is a valid critique of absolute constructivism, but it is not relevant when applying these ideas to martial knowledge. The presence of alternate truths that result from a constructivist philosophy is the key feature of martial knowledge, not a weakness in the theory. Purely constructivist accounts of science have to contend with the physical reality within which scientists perform their research. The ability for scientists to conduct their experiments in the same physical world collapses the multiple physical realities that an extreme interpretation of constructivism would imply. Karl Popper actually used this observation as a key component of science, explaining that "the objectivity of scientific statements lies in the fact that that they can be inter-subjectively tested."[176] As the discussion above related to

[175] Eugene A. Rosa, "Metatheoretical Foundations for Post-Normal Risk," *Journal of Risk Research* 1, no. 1 (January 1998): 15–44, https://doi.org/10.1080/136698798377303.
[176] Popper, *The Logic of Scientific Discovery*, 22.

social processes in science demonstrates, there are still important considerations related to the way different groups of people interpret and understand the results of experiments they conduct in the physical world. But the common, grounding presence of a physical world limits the degree to which different interpretations can vary, especially on the scale of day-to-day human life. For example, despite the Lakota Ghost Dancers' absolute belief that their ceremonial shirts would deflect bullets at Wounded Knee, Popper's inter-subjective world of physics tragically proved otherwise.[177] Long periods of peace deprive the formulation of martial knowledge from an inter-subjective reality within which a common martial knowledge can emerge. Constructivism provides an intellectual foundation to help explore how these different versions of martial knowledge can form within militaries. In other words, the local nature of truth within constructivism is at the forefront of the concept of martial knowledge, where different militaries can each maintain their own independent, completely valid, and contradictory truths in times of peace that are later tested when war breaks out.

There is a growing sentiment in security and defense-related fields that the concepts of "war" and "peace" may be less relevant today and in the near future. Authors like Sean McFate and David Kilcullen draw from contemporary "Gray Zone" operations or "liminal warfare," where military and para-military organizations conduct combat in non-declared wars such as the Russian annexation of Crimea, to argue that war and peace are better understood as nebulous concepts that are concurrently present in any strategic conflict.[178] This is a helpful characterization of the war and peace dyad if the goal is to

[177] Dorothy M. Johnson, "Ghost Dance: Last Hope of the Sioux," *Montana: The Magazine of Western History* 6, no. 3 (1956): 42–50.
[178] Sean McFate, *The New Rules of War: How America Can Win- against Russia, China and Other Threats*, 2019, 59–82; Emily Knowles, "SOME THINGS CHANGE, SOME STAY THE SAME," *US Army War*

accurately describe the complexities of strategic interactions and avoid the intellectual blind spots that an overly simple conception of war and peace may produce. However, the technology triad and the concepts upon which it is built are designed to make necessary simplifications of reality to produce a useable model of technology and military change. To this end, it is helpful to acknowledge that there is a fundamental difference between a nation whose population's primary concern is their physical safety because some other group has decided to kill them for their political beliefs and a nation where people go about their day-to-day activities free from the threat of politically motivated violence. These two situations may be the extremes of war and peace, and everything in between is some combination of the two. However, identifying a potentially artificial boundary between war and peace is well within the accepted norms of historical and contemporary thinking related to the nature of war and a useful simplification to illustrate how martial knowledge is locally maintained.[179] The technology triad relies on Clausewitz's basic presumption that war is force with the aim to compel an enemy and that war is differentiated from other forms of human interaction to that same end through the use of violence.[180] This distinction between war and other activities that are "war-like" will help demonstrate the limits of martial knowledge in peacetime and, when taken as a whole with the technology triad, the impacts of these limits on the conduct of war. A more nuanced discussion of the impact of a war and peace dichotomy within the logic of

*College War Room* (blog), September 27, 2019, https://warroom.armywarcollege.edu/podcasts/nature-character-pt1/; David Kilcullen, *The Dragons and the Snakes: How the Rest Learned to Fight the West* (New York, NY: Oxford University Press, 2020).

[179] Donald Stoker and Craig Whiteside, "Blurred Lines: Gray-Zone Conflict and Hybrid War—Two Failures of American Strategic Thinking," *Naval War College Review* 73, no. 1 (January 24, 2020), https://digital-commons.usnwc.edu/nwc-review/vol73/iss1/4.

[180] Carl von Clausewitz, Michael Eliot Howard, and Peter Paret, *On War*, First paperback printing (Princeton, N.J: Princeton University Press, 1989), 75, 149.

the technology triad will be addressed in Chapter 5. To enable construction of the logical base for the technology triad, accepting the traditional requirement for mass political violence to create a divide between war and peace will help provide a guardrail for the development of the technology triad.

When a military is not actively engaged in combat, it lacks a "laboratory" within which to test its theories against some common frame of reference with potential adversaries, so its martial knowledge becomes a local knowledge that is unique to that military. A detailed discussion of the ways that militaries form their unique martial knowledge follows in the next section, but for now, it is sufficient to give a quick example from the second half of the 20$^{th}$ century. In *The Closed World,* the science and technology studies scholar Paul Edwards explained how the United States developed an understanding of the correct way to fight a nuclear war using Operations Research methods.[181] Operations Research evolved from Systems Analysis, which were statistical techniques the United States Military used in World War II to determine the safest times for convoys to cross the North Atlantic and the most efficient bombing tactics in Japan. According to Edwards, the critical difference between Operations Research and Systems Analysis came from the lack of real-world data to employ Operations Research to develop nuclear strategy. There had never been a full-scale nuclear war, so the analysts that employed these methods needed to rely on data obtained from assumptions and simulations. Using these methods, the United Stated defined a martial knowledge that influenced materiel solutions and doctrine for nuclear war. This martial knowledge related to nuclear war was a reflection of the assumptions and simulations that

[181] Edwards, *The Closed World,* 119–20.

organizations like the RAND corporation developed for the United States military rather than a reflection of an actual nuclear war. Even today, any knowledge that any military holds related to the correct way to wage a nuclear war is built in a similar manner, because thankfully, there has never been a general war characterized by the wide employment of nuclear weapons.

It is important to note that this martial knowledge is more than just an untested theory in practice. It is treated as the truth that it is when it comes to buying weapons and determining force posture to prepare for some future war. Every day, people bet their very existence on the truths represented by this martial knowledge. It takes on the mantle of truth through the various epistemological mechanisms that justify this truth, just as a justified true belief is knowledge in the classical framing.

Justified true belief is a more appropriate framing of martial knowledge than applications that would stem from reliabilist interpretations of knowledge because just as wars are discrete states from peace, each war is different in some way. In Clausewitz's famous proclamation, war is like a "chameleon, because in each concrete case it changes somewhat its character."[182] Advances in each of the three elements of the technology triad, weapons, doctrine, and martial knowledge, are partly responsible for the changing character of war. But more importantly, war is a social activity that takes place in its own unique circumstances between thinking and adapting belligerents. Each war is a complex interaction where the lessons of one may not transfer well to another. Furthermore, strict adherence to the lessons of a past war set up a military for defeat from an enemy that can learn to avoid the demonstrated strengths from an earlier war.[183] This means that there

[182] Sun-Tzu and Clausewitz, *The Book of War*, 282.
[183] Kilcullen, *The Dragons and the Snakes*.

can not be a qualification for martial knowledge to represent truth produced through reliable processes because the adversarial strategic environment makes this practice invalid.

Martial knowledge is a practically oriented concept that draws from earlier philosophical works on the nature of knowledge and truth to produce a new way of conceptualizing both as they pertain to the conduct of war. Despite the philosophical inadequacies of the justified true belief structure of knowledge, it is a useful approximation to understand how people in organizations make decisions when the level of uncertainty is high, such as war. In these situations, people must have some reason to assign truth to information, or produce knowledge, when the type of empirical truth possible in physics is beyond their capabilities, which is common in the types of complex systems represented by organizations with people in them and the critical factor in questions regarding war and peace. This reason to assign truth to information is socially constructed through knowledge systems in the absence of the ability to test the truthfulness of martial knowledge directly. Even "hard science" has its own indeterminate boundaries that are largely social constructions to build understanding, but in war, a social practice, these boundaries make a uniform framing of truth even more tenuous. Without the pluralism of martial knowledge, knowledge could still change, but it would do so independent of materiel and doctrine. Acceptance that martial knowledge and the truth it defines are variable, rather than some march towards an objective knowledge or truth, sets the conditions for the entire technology triad to become a constantly changing system with feedback loops where knowledge does not drive materiel and doctrine in a unilateral way, but reciprocal interactions create feedback loops to martial knowledge that produce complex behavior on the system as a whole. The next several sections will explore in detail how each of the three elements of the technology triad develops in relation to each other.

### *Martial Knowledge*

Acceptance that martial knowledge is constructed by local social processes doesn't help explain what those processes might be or how the other two elements of the technology triad are involved in this construction of martial knowledge. Building off of the previous section's theory of martial knowledge as a special kind of variable local knowledge that militaries produce through social processes, this section will explain the mechanics of that production to understand how materiel and doctrine can influence the development of martial knowledge. Once again, science and technology studies provide the intellectual grounding for this analysis with the body of research related to knowledge systems.[184] Broadly speaking, knowledge systems are the institutional, cultural, and epistemological relationships and norms that enable the social creation of all forms of knowledge. Clark Miller and Tischa Munoz-Erickson's research regarding how organizations create knowledge drew from a broad body of knowledge systems-related scholarship and identified four key areas for analysts to focus on when evaluating a knowledge system.[185] Miller and Munoz-Erickson's research identified four main influences for the production of knowledge within organizations: epistemologies, values, prior knowledge, and organizational structures. These four influences plus allowances for

[184] Clark Miller and Tischa Munoz-Erikson, *The Rightful Place of Science: Designing Knowledge* (Tempe, AZ: Consortium for Science, Policy, and Outcomes, 2018).
[185] Miller and Munoz-Erikson.

the political, social, and economic circumstances within which a military operates provide a systematic framing for the generation and validation of martial knowledge that illuminates both the influence of martial knowledge on materiel and doctrine and the reciprocal influences of materiel and doctrine on martial knowledge that define the technology triad in practice.

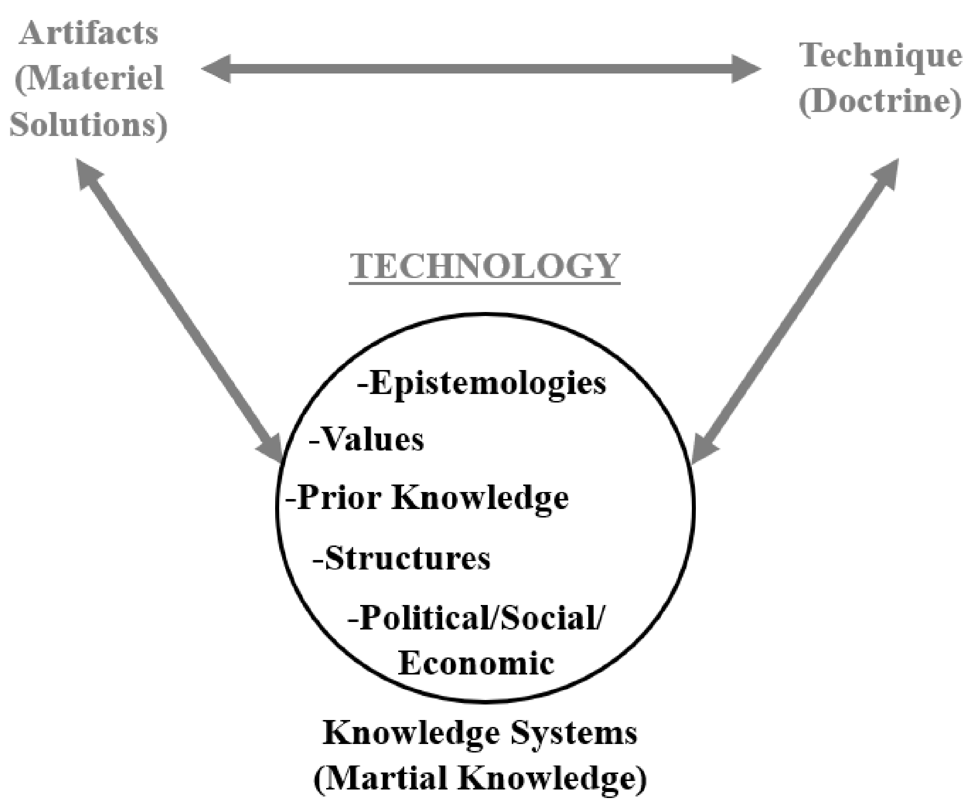


Figure 5: Military Knowledge Systems

*Epistemologies*

Returning to the justified true belief structure, to qualify as knowledge, the adoption or rejection of new beliefs requires justification. Justification is a critical component of martial knowledge, even beyond the basic justification for any true belief to be considered knowledge, because of the high cost of failure in war. Daniel Kahneman's prospect theory, one of the key contributions that led to his Nobel Prize for work related to behavioral economics, explains how people are generally risk-averse.[186] According to this theory, people place a higher value on the loss of some amount of money than they would on gaining the exact same amount of money. This effect is magnified in military matters where the cost of failure is extraordinarily high, and it forces new ideas to stand the test of validation before they can be accepted by a military as martial knowledge. Field-Marshal Viscount Slim, the leader of the British Army in Burma in World War II, articulated this requirement when he observed that of the "young men interested in selling short cuts to victory" in Supreme Headquarters, "few of them had anything really new to say, and the few that had, usually forgot that a new idea should have something to recommend it besides just breaking up normal organization."[187] Field-Marshal Slim's "something to recommend it" is the heart of a knowledge system and falls under the category "epistemologies" in Miller and Munoz-Erikson's work.[188] Within the technology triad, epistemologies are the logical and rational models that a military relies on to justify martial knowledge.

Martial knowledge epistemologies are further subdivided into internal and external epistemologies, which roughly map onto deductive and inductive reasoning, respectively. Internal epistemologies are those ways of producing new knowledge that are contained within the military in question. Much of the military innovation literature

[186] Daniel Kahneman, *Thinking, Fast and Slow*, 1st ed (New York: Farrar, Straus and Giroux, 2011).
[187] William Joseph Slim Slim, *Defeat into Victory: Battling Japan in Burma and India, 1942-1945 ; with a New Introduction by David W. Hogan Jr*, 1st ed (New York: Cooper Square Press : Distributed by National Book Network, 2000), 202–3.
[188] Miller and Munoz-Erikson, *The Rightful Place of Science: Designing Knowledge*.

would refer to this as experimentation, but any training exercise must also be considered a form of internal epistemology.[189] In the contemporary United States military, DoD level simulations, field exercises with prototype equipment, and normal day-to-day home station field training exercises are all part of the internal epistemologies. Each of these activities that a military performs is critically important to test new ideas and identify potential trouble spots in materiel and doctrine prior to a war. However, the absence of actual combat in training maneuvers creates an artificial element to these tests that cannot be discarded. The very structure of the maneuvers themselves relies on predetermined estimates of the effectiveness of the various weapons systems that umpires used to determine the outcome of these mock battles. While staged maneuvers are arguably more effective than concepts that may not even stand up to ideal conditions of a peacetime test, they are still internally generated within the knowledge system and reliant upon the values, structures, and prior knowledge of that knowledge system for their basic design. Even when militaries draw from lessons of actual combat, the martial knowledge that is generated from these lessons is still subject to the influence of the military knowledge system.

External epistemologies that help justify martial knowledge are organizational efforts to receive and effectively interpret information related to materiel and doctrinal developments external to the military organization in question, such as the actions of allies or potential adversaries. The information that feeds external epistemologies can come from a wide range of sources, from peacetime air shows to observations of combat operations in which the military in question is not involved. That the information comes

[189] Michael Horowitz and Shira Pindyck, "What Is Military Innovation? A Proposed Framework" (SSRN, December 15, 2019), https://ssrn.com/abstract=3504246 or http://dx.doi.org/10.2139/ssrn.3504246.

from an outside source that the military cannot influence is the key distinguishing factor between information that feeds internal epistemologies and the information that feeds external epistemologies.

The external epistemologies in the military knowledge systems that generate martial knowledge are similar to the concept of testimony in philosophical treatments of knowledge in general. Testimony, in its most simple form, is knowledge that is received from another source. For example, if a person comes in a room and says that it is raining outside, and one adopts the belief that it is in fact raining, then that belief is based on testimony. Epistemologists through the years have disagreed whether this belief, even if true, could count as actual knowledge given the possibility that the person giving the testimony could be misleading their audience.[190] On one extreme, John Locke argued that no knowledge gained through testimony could count as knowledge. According to Locke, one would have to integrate the information gained through this conversation with prior knowledge, such as the weather forecast, and other observations, such as if the person giving the testimony is carrying a wet umbrella. On the other extreme, the direct view of testimony asserts that one can gain knowledge directly from a knowledgeable informant.[191]

As discussed earlier, martial knowledge is a special type of knowledge that is fundamentally shaped by the extreme consequences of adopting a false belief as truth. As such, the external epistemologies that process information from outside the military rely on a combination of testimony and internal epistemologies to generate knowledge. In *Leviathan and the Air-Pump,* Shapin and Schaffer describe how early enlightenment

[190] Nagel, *Knowledge*, 72–86.
[191] Nagel, 80.

natural philosophers developed a set of social norms in the form of scientific inquiry to address problems of testimony and produce matters of fact.[192] This is analogous to the processes that militaries use to evaluate information from outside the military and update their martial knowledge. Observations and intelligence reports from outside sources are tested within internal epistemologies, both formally and informally, before that information can achieve the status of martial knowledge.

Other than the source of the information that the military relies on to justify their beliefs, the practical impacts of internal and external epistemologies are the product of similar fundamental influences. They both rely on the same constructivist assumptions that built the foundation for martial knowledge. For example, suppose one would assume that there is an objective truth related to the effectiveness of materiel solutions to military problems. In that case, information related to the effectiveness of weapons, especially that which derives from observations of actual combat, should have a noticeable and uniform impact on the development of doctrine and materiel of any military with the resources to capitalize on the received information.

In practice, however, the diffusion of military innovations is anything but uniform. Horowitz's *The Diffusion of Military Power* uses a mixture of quantitative and qualitative methods to propose organizational markers to assess a military's likelihood of adopting a new innovation.[193] While a useful tool for the analysis of past innovations, the indicators that he highlights do not provide actionable insight for military leadership that is actively trying to decide how they should react to some development in another

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[192] Steven Shapin and Simon Schaffer, *Leviathan and the Air-Pump: Hobbes, Boyle and the Experimental Life*, 1. Princeton paperback print., with corr (Princeton: Princeton Univ. Press, 1989), 39–40.
[193] Horowitz, *The Diffusion of Military Power*.

country. If the military attempts to directly apply Horowitz's indicators to determine if they should adopt an innovation, then the model becomes tautological. As the case studies in this dissertation will demonstrate, it is helpful to visualize the information from both internal and external epistemologies as interpreted through the lens of the knowledge system of the observer.

In more strategic applications of Boyd's Observe, Orient, Decide, Act (OODA) loop, the "orient" step draws from this same framing of the use of information to create knowledge.[194] Often, the tactically focused act of physically orienting a fighter aircraft in relation to the enemy hides this other meaning of the word where a strategic leader orients the information they receive in relation to their own understanding of truth and reality. The understanding of truth and reality through which militaries interpret the information produced by internal and external epistemologies is intricately linked to and relies on each of the elements of the military knowledge system that ultimately produces martial knowledge. Framing deliberate justification of beliefs to produce martial knowledge as organizational epistemologies is necessary but not sufficient to understand the production martial knowledge without also acknowledging the influence of the other parts of the military knowledge system.

*Values*

Of the five broad influences that comprise the military knowledge system, values and the related but distinct concept of value are two of the most important factors in the production of truth in a military due to the constructivist nature of martial knowledge.

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[194] Frans P. B Osinga, *Science, Strategy and War: The Strategic Theory of John Boyd* (London; New York: Routledge, 2007), http://site.ebrary.com/id/10155759.

The philosopher, Isaiah Berlin, provided a succinct definition for values when he described them as "the ends that men pursue for their own sake."[195] In his 2020 discussion of military virtue ethics, the retired Dutch Brigadier General Peer de Vries provided an organizationally focused definition of values as the "goals or duties that people or institutions find important," he went on to explain that "Often, these values are founded on ideas of what is good or evil."[196] The values that guide a military's actions may be explicitly stated, managed, and inculcated within the formation to further the mission of the military, such as the U.S. Army's "Seven Army Values," which make them relatively easy to identify.[197]

However, notions of good and evil within a military are also reflections of the society from which the military draws its soldiers and within which it operates. For example, the current obligation codified in the law of armed conflict for militaries to protect civilians from the harmful effects of hostilities reflects the values of our modern society.[198] History is replete with examples of societies that did not share the same foundational values related to the sanctimony of human life and, as a result, viewed civilian deaths either with indifference or even as a legitimate means through which to accomplish their objectives.

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[195] Isaiah Berlin, *The Crooked Timber of Humanity: Chapters in the History of Ideas*, Second Edition (Princeton ; Oxford: Princeton University Press, 2013), 11.
[196] Peer de Vries, "Virtue Ethics in the Military: An Attempt at Completeness," *Journal of Military Ethics*, October 21, 2020, 11, https://doi.org/10.1080/15027570.2020.1814048.
[197] "AR 600-100 Army Profession and Leadership Policy" (Headquarters, Department of the Army, April 5, 2017).
[198] "FM 6-27 The Commander's Handbook on the Law of Land Warfare" (Headquarters, Department of the Army, August 2019).

The concept of value, while etymologically similar to values, refers to the relative worth of a thing without the distinction of good or evil.[199] A military could value physical things, such as the resources necessary to wage war, but the impact of value on the production of martial knowledge is greatest when the concept of value is applied to attributes or virtues of individual soldiers and formations.[200] The "quick thinking" prized by the U.S. Cavalry for its officers in the 1930s is an example of an assessment of relative worth by a military.[201]

In practice, the boundary between values and value within a military is blurred and results in the two concepts producing similar impacts on the production of martial knowledge. The fifth of the U.S. Army's seven values, honor, very clearly maps onto the concept of values as it pertains to good and evil due to the absolute nature of honor. A person is either honorable or not; there are no gradations of honor. Furthermore, somebody who lacks honor could conceivably be considered an "evil person." However, the final U.S. Army institutional value, personal courage, is probably more appropriately considered as a virtue or in relative worth to a soldier who displays less personal courage. Even at the extreme, it would be difficult to consider someone "evil" simply because they lack personal courage. Despite a mixture of notions of good and evil and assessments of relative worth within the U.S. Army's official institutional values, it still produces a uniform influence. Distinctions between values and value are helpful for an analyst to identify these influences within a military, but they both produce a similar effect as

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199 Andrew Maynard and Elizabeth Garbee, "Responsible Innovation in a Culture of Entrepreneurship: A US Perspective," in *International Handbook on Responsible Innovation: A Global Resource* (Cheltenham, UK ; Northampton, MA: Edward Elgar Publishing, 2019), 496.
200 de Vries, "Virtue Ethics in the Military."
201 John Herr, "The Cavalry" (Transcript of lecture delivered at the Army War College and discussion with audience, September 19, 1938), G-3 Course No. 4, 1938-1939, U.S. Army Heritage and Education Center, Carlisle Barracks.

guides for the actions of the soldiers within the organization. This guiding influence goes beyond the organization's day-to-day activities and extends deep within the production of martial knowledge and the truth that it represents.

The pervasive influence of value and values judgments on the production of truth is not intuitively obvious without considering the full impact of the constructivist assumptions upon which the concept of martial knowledge is built. In 1907, the philosopher William James made the bold assertion that "the true is the name of whatever proves itself to be good in the way of belief."[202] In other words, according to James, truth is the quality humans assign to those beliefs that provide the most good in their lives. The increase in "good" could come in the form of a value judgment that would avoid some evil or in the form of an increase in perceived value for some quantity, quality, or virtue that the person assesses has more worth than some other quantity, quality, or virtue. James completed his assertion with the qualification that "good, too, for definite, assignable reasons," which means that a person cannot simply choose to hold a belief simply because it provides the most good in their life.[203] This is where value judgments interact with epistemologies and how these judgments influence every aspect of the production of martial knowledge. The internal and external epistemologies that a military employs are those "definite, assignable reasons" to hold a belief.

As previously discussed, the epistemologies that produce martial knowledge are themselves subject to the constructivist assumptions and value judgments that the military holds. Research related to the way people assess risk in real-life situations

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[202] William James, *Pragmatism: A New Name for Some Old Ways of Thinking* (Auckland, N.Z.: Floating Press, 2010), 57, http://search.ebscohost.com/login.aspx?direct=true&scope=site&db=nlebk&db=nlabk&AN=332787.
[203] James, 57.

illustrates this effect. Paul Slovic's work related to the affect heuristic found that the positive or negative feelings a person has towards an activity have a significant impact on the relative risk that person associates with the activity.[204] This is a potentially counterintuitive finding considering that the relative risk of the types of activities that Slovic explored in his research, such as flying on an airplane or riding a motorcycle, can be quantified according to the likelihood and magnitude of a catastrophe while participating in those activities.

Andrew Maynard's research in the field of risk innovation addresses this by showing that risk is more appropriately described as a threat to value.[205] In the case of riding a motorcycle, a person's assessment of risk could be related to either the relative value of a healthy life absent injury from a motorcycle accident or the value derived from the joy experienced riding a motorcycle. Combining the findings of these two areas of research implies that people produce their own assessments of risk based on their relative feelings towards an activity that are a result of a person's perception of the risk to some value that the activity possesses. The heterogeneous values and value assessments within a population therefore account for the varied assignments of risk. This conforms to the way people interact with their environment, where some people take risks that others would never consider appropriate despite the ability to uniformly quantify risk in terms of likelihood and magnitude.

The same logic applies to the way organizational values and value judgments impact the production of martial knowledge within a military. Judgments related to what

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[204] Paul Slovic, *The Feeling of Risk: New Perspectives on Risk Perception*, Earthscan Risk in Society Series (London ; Washington, DC: Earthscan, 2010).
[205] Andrew Maynard, "Why We Need Risk Innovation," *Nature Nanotechnology* 10, no. 9 (September 2015): 730–31, https://doi.org/10.1038/nnano.2015.196.

is not evil or which increase in relative worth is most important influence decision making at every step of knowledge production, from the determination of which potential beliefs should be tested to the design of the experiments that validate new knowledge. In peacetime, there is no laboratory within which to test beliefs, which means that the influence of value judgments can create experiments that decouple from other militaries and the future combat operations peacetime militaries will conduct as the experiments justify beliefs as truth or produce martial knowledge.

### *Prior Knowledge*

Values and estimations of relative worth are not independent variables within the military knowledge system; they are themselves products of complex relationships between earlier versions of the knowledge system and observed outcomes of behaviors and decisions informed by prior knowledge. An important aspect of martial knowledge is the acceptance of that knowledge as fundamental truth, rather than an untested theory or a possible truth, by the military that produced it. This means that, despite the socially constructed nature of martial knowledge, the practical effect of martial knowledge is that it forms the firm base from which militaries produce new knowledge. The acknowledgment of the influence of prior knowledge is not a restatement of the common claim that militaries "train for the last war." The historians Williamson Murray and Alan Millet demonstrated in their research of military innovations between the World Wars that militaries rarely actually fully embrace the lessons of their last war.[206] Rather, the

[206] Murray and Millett, *Military Innovation in the Interwar Period*, 313–14.

concept of prior knowledge within a military knowledge system is an observation of the way humans interact with and make sense of the world around them.

Prior knowledge is a critical component of both explicit and implicit knowledge generation. The most basic application of this statement would be an acknowledgment that knowledge does not generate from a void; all new knowledge is a combination of prior knowledge and new evidence to produce new insights. For example, a military cannot evaluate the possible implications of some new weapon without a pre-existing notion of the relationship between the effects of that weapon and the conduct of operations. However, one can explore the influence of prior knowledge much more deeply. At the individual level, Timothy Williamson explained in his treatise on knowledge that "one should proportion one's belief in a proposition to the support which it receives from one's knowledge."[207] Williamson generated this rule as a means to address the problem of old evidence in the generation of new knowledge. The proportional aspect of the acceptance of new knowledge accounts for the eventuality that new propositions will contradict propositions that were previously held to be true. By "proportioning one's belief," a person can achieve the correct balance of weighing new evidence against prior knowledge. Of course, Williamson's work is highly philosophical in nature, and the practical application of discerning the appropriate proportion of new evidence to prior knowledge in real life can be quite difficult. This is especially true in complex knowledge systems, such as those that exist in militaries, that are built upon prior knowledge received from generations of previous soldiers. Militaries transmit this prior knowledge in time through formal means, such as professional education and

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[207] Timothy Williamson, *Knowledge and Its Limits*, Repr (Oxford: Oxford Univ. Press, 2009), 189.

manuals, and informally through mentorship and training. The members of the military then explicitly use this prior knowledge to inform the generation of new knowledge in light of the evidence provided by internal and external epistemologies.

Prior knowledge also exerts a powerful influence on the implicit generation of knowledge by setting the conditions to explain the way things are and ought to be because every truth that people hold about the world around them is the product of some prior knowledge-generating event. The anthropologist Clifford Geertz referred to this implicit understanding of the world as "experience-near concepts," which means "that ideas and the realities they inform are naturally and indissolubly bound up together."[208] Experience-near concepts are more than some transitive form of knowledge where if one knows that A equals B and later learns that B equals C, then they can deduce that A equals C. An experience-near concept takes on more the quality of the old proverb that a fish has no concept of water. Prior knowledge has the practical effect of defining the "water" within which a military exists and against which any new proposition or belief must be evaluated. This "water," or the reality that is informed by prior knowledge, lives and is expressed within a military through "common knowledge" and the values judgments which take on the quality of common knowledge in practice.

The influence of prior knowledge is strongest when the new information to be evaluated is open to the kinds of interpretation that are necessary when producing martial knowledge during peacetime. Robert Jervis noted this effect when he said, "people assimilate incoming information to their preexisting beliefs, tentative ideas and expectations will grow firmer as the person is exposed to a stream of ambiguous or even

[208] Geertz, *Local Knowledge*, 58.

arguably disconfirming information."[209] Returning to Timothy Williamson's rule that belief should be proportional to the knowledge one holds, new evidence that could challenge an existing belief is also represented by the knowledge one holds. If the new evidence is contradictory to the existing martial knowledge, a military must apply judgment to assess the degree to which this new evidence is relevant to the question at hand. In peacetime, a military could disregard the disconnect between an existing martial knowledge and new evidence that is the result of an internal epistemology as a byproduct of a poorly designed maneuver or simulation. Similarly, a military must weigh evidence from external epistemologies against the degree to which the conditions of the other military are applicable to the environment within which the military assessing the new evidence operates. In this manner, the influence of prior knowledge can present the appearance of institutional conservatism by producing a high standard for new evidence which challenges accepted martial knowledge. In 1907, William James noted this when he said that "truths have once for all this desperate instinct of self-preservation and of desire to extinguish whatever contradicts them."[210] Prior knowledge could not have this level of influence on a military knowledge system if the truth that martial knowledge represents was not held as a fundamental reflection of reality, which it can only achieve by standing the test of justification and through coherence with the values judgments of a military that influence epistemologies and are themselves a reflection of prior knowledge. Despite martial knowledge's status as truth, not all prior knowledge that informs it is equal in practice.

[209] Robert Jervis, *System Effects: Complexity in Political and Social Life* (Princeton, N.J: Princeton University Press, 1997), 150.
[210] James, *Pragmatism*, 58.

*Organizational Structures*

Power relationships within militaries influence the knowledge that flows across structures within the military knowledge system as new martial knowledge is generated. The formal rank structure of modern militaries is a simple application of this idea. Berger and Luckmann highlighted the importance of power relationships when they introduced their concept of "universe maintenance," which referred to the social processes that allowed specific people or groups to define truth and the nature of reality for the rest of society through the management of knowledge production.[211] In their work, this power is held by experts who lay claim to a body of knowledge that defines reality for the rest of a society, such as religious scholars in theocracies. A similar effect within militaries imparts significant influence on the types of martial knowledge that a military generates, where the input of senior officers is given far more credence than those of a lower rank. However, in practice, rank is not the only determinant of organizational power within a military, and power relationships are bound to the generation of knowledge within a military beyond simple hierarchical relationships.

The ability to produce new knowledge creates its own type of power that influences the generation of knowledge. The philosopher Michael Foucault explained how states in the eighteenth century undertook a series of transformations to organize the production of knowledge within society into the categories, or disciplines, and structures that we would recognize today as the modern academy.[212] These transformations had the

[211] Berger and Luckmann, *The Social Construction of Reality*, 134–35.
[212] Michel Foucault et al., *Society Must Be Defended: Lectures at the Collège de France, 1975 - 76*, 1st ed, Lectures at the Collège de France (New York: Picador, 2003), 180–81.

effect of giving the state the ability to centralize the production of knowledge within universities that had the power to determine which types of knowledge would be generated and along which trajectory that generation would follow.[213] In Foucault's description of the disciplining of knowledge, the state did not cede its authority to the Universities; rather, it delegated this important task to universities and exerted control over their efforts through research funding and laws.

Analogous centers of knowledge production exist in militaries in the form of research centers, military colleges, and experimental units. These formally designated organizations within a military do not produce knowledge independent of the hierarchical command structure; they produce knowledge with the authority granted to them by the command structure. This authority to produce martial knowledge as a function of their assigned mission gives these organizations more institutional power than other units that may generate tacit knowledge in the conduct of their routine operations and produces a lateral flow of knowledge within a military to complement the vertical one up and down the chain of command. Furthermore, the members of these organizations may be drawn from the members of the military, the students of a war college, for example. These pockets of epistemic authority within a military provide a mechanism within the knowledge system for members of the normal force to gain much greater influence with key decision makers than would have been possible as members of normal units. Hierarchical rank structures and explicit knowledge-generating organizations within a military combine to produce the social structures that influence the generation of martial knowledge through the interactions of shared and contradictory epistemologies, value

[213] Foucault et al., 183–85.

judgments, and reservoirs of prior knowledge between the links of people produced by those structures.

*Political, Social, and Economic Factors*

The final influence on the production of martial knowledge comes from the political, social, and economic environment within which the military operates. This influence is different from the previous four in that it should be visualized as the outside world within which the open system represented by the other four elements interact with each other. The influence of political, social, and economic factors can be indirect, such as the constant influence of society on the people who comprise the military, or they can be direct, such as formal pressure on the military to take some action by political leadership or economic restrictions. Creating an artificial boundary between the military and epistemological influences outside the system facilitates an enhanced understanding of how militaries produce and validate their martial knowledge. This final influence on that production and validation accounts for those things outside the system that would otherwise be excluded by treating the military as a closed system.

Socio-technical imaginaries are a conceptual tool to help understand how a group of people think about the appropriate place of technology in their society and the actions that those people take to achieve that result. They are "collectively held, institutionally stabilized, and publicly performed visions of desirable futures, animated by shared understandings of forms of social life and social order attainable through, and supportive of, advances in science and technology."[214] In this context, sociotechnical imaginaries are

[214] Sheila Jasanoff and Sang-Hyun Kim, eds., *Dreamscapes of Modernity: Sociotechnical Imaginaries and the Fabrication of Power* (Chicago ; London: The University of Chicago Press, 2015), 153.

helpful to understand the way society can informally influence the martial knowledge of a military. Application of this tool to the military can help describe how societal, or external, factors influence the way that the members of a military generate and validate martial knowledge. For example, Jasanoff and Kim observed that "a well-known feature of the American sociotechnical imagination is that technology's benefits are seen as unbounded."[215] This observation is very similar to Mahnken's claim that "reliance on advanced technology has been a central pillar of the American way of war."[216] Mahnken's argument that the U.S. military believes in the effectiveness of technology to solve more problems than it creates is a reflection of that same general understanding of technology in the wider public.

Political, social, and economic factors include formal, as well as informal, pressures on a military's martial knowledge because in practice, external direct control of the military is less effective than simple hierarchical framings would suggest.[217] Control over the military, especially on matters such as innovation that are often considered the purview of professional soldiers, is normally exerted through less direct measures, such as budget control.[218] The influence of these indirect controls is similar in effect to the way a sociotechnical imaginary influences the martial knowledge of a military. It is part of the social reality within which the military must achieve its strategic objectives.

The military knowledge system is a complex interplay of different types of influences that all work together to produce martial knowledge, which is truth for that

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[215] Sheila Jasanoff and Sang-Hyun Kim, "Sociotechnical Imaginaries and National Energy Policies," *Science as Culture* 22, no. 2 (June 2013): 190, https://doi.org/10.1080/09505431.2013.786990.
[216] Mahnken, *Technology and the American Way of War since 1945*, 5.
[217] Brose, *The Kill Chain*, xvi.
[218] Deborah D. Avant, *Political Institutions and Military Change: Lessons from Peripheral Wars*, Cornell Studies in Security Affairs (Ithaca: Cornell University Press, 1994), 135.

military. Militaries create truth during peacetime without the ability to test and validate assumptions against the combat conditions those assumptions address, which denies martial knowledge the advantage of any traditional sense of objectivity. Each of the influences that are present within the military knowledge system is the product of social interactions. Epistemologies are ways of thinking and evaluating new evidence. Values and estimations of worth are deep-seated beliefs that are held by members of the military and codified in its practices. Prior knowledge is the existing truth that was produced by an earlier version of the knowledge system that lacked some of the inputs available to the current version of the knowledge system. Structures are formal and informal power relationships between people and groups. Finally, the socio-political environment is the larger social system within which the military operates.

Each of the military knowledge system components is always present, to one degree or another, during the generation of martial knowledge; the relative strength of the influences at any given time is situationally dependent. Each of these beliefs, external influences, and personal actions all work together to define truth for the military, which the technology triad represents as martial knowledge. Truth is always subject to updating, but the more each of these elements reinforces a truth, the less likely they are to be questioned in the first place, much less overturned once questioned by the very system that produced them in the first place. Because this knowledge is created and verified within the knowledge system in a way that is coherent with the logic of the organization, this knowledge becomes the basis for truth that creates the reality rather than some theory of truth or untested belief. The legitimacy of martial knowledge for the military that possesses it is the critical factor of this concept to understand how it influences the other elements of the technology triad.

*Marital Knowledge and the Technology Triad*

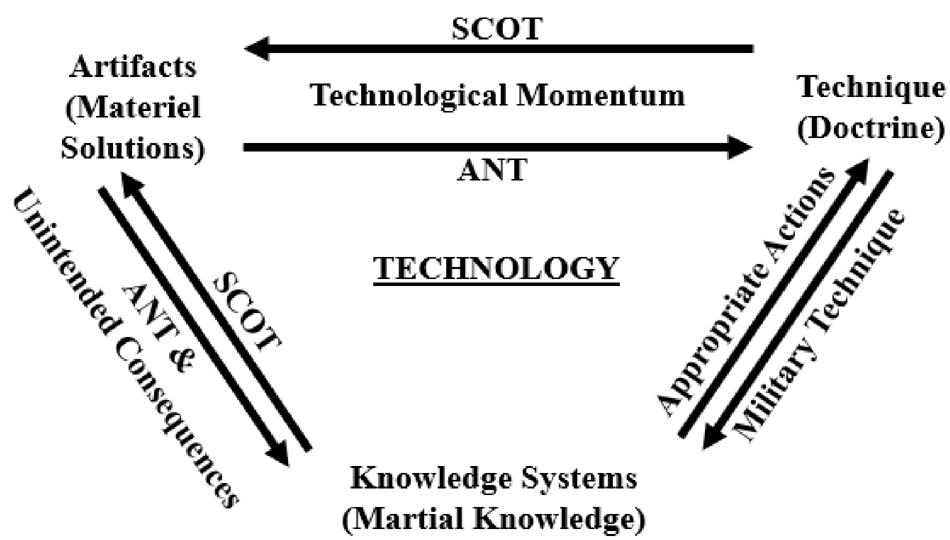


Figure 6: Relationships between the elements of the technology triad

Returning to the technology triad, the interactions between the elements of the technology triad are the critical aspect of this framing that produces the novel insights to help understand how technology and militaries change over time. As the definition of reality, martial knowledge held by a military has a profound impact on the materiel solutions and methods of employment that a military develops to fight current and future wars. However, materiel solutions exist in the physical world, which makes them resistant to simplistic constructivist influences. No matter how much a military knowledge system reinforces some belief that is counter to the laws of physics, the physical reality to which all humans are subject will not permit materiel solutions that conform to that belief. Bjiker's Social Construction of Technology (SCOT) provides a useful tool to understand how socially constructed martial knowledge can influence the development of physical materiel solutions (See Figure 6).

When viewed through the SCOT construct, a military's knowledge system produces the truth that dictates both the relevant social groups' definitions of problems and the range of possible materiel solutions available to solve these problems. Bijker developed the theoretical concept of "technological frames" to account for "all elements that influence the interactions within relevant social groups and lead to attribution of meanings to technical artifacts," or materiel solutions in the technology triad.[219] Technological framings are not directly interchangeable with martial knowledge, because technological framings also include exemplar artifacts.[220] In the technology triad, all physical objects are represented by materiel solutions. However, the way different technological framings of relevant social groups influence those groups' preferred materiel solutions is directly applicable to the discussion of the influence of martial knowledge on the shaping of materiel solutions.[221] Within a single military, there will be competing knowledge systems based on relatively small differences in the elements of the knowledge system, which produces competing ideas for the proper weapons to wage war. These different versions of martial knowledge and the relationships between the

[219] Bijker, *Of Bicycles, Bakelites, and Bulbs*, 123.
[220] Bijker, 126.
[221] Bijker, 124.

different relevant groups that hold them define the design of materiel solutions for that military as resources are dedicated to one design over another. For example, John Law and Michel Callon's analysis of the Royal Air Force's development of the 1950's era TSR.2 aircraft demonstrated how inadequately managed competing visions of the aircraft between the Royal Air Force, the Royal Navy, the Treasury, and the Ministry of Supply produced a materiel solution that failed to solve the problems perceived by each of the relevant social groups and was ultimately abandoned by the Ministry of Defense.[222] Despite the varied nature of martial knowledge in a military, the military as a whole possesses a knowledge system comprised of the resultant interactions of the subordinate knowledge systems that produces a base, or unchallenged, martial knowledge.

The unchallenged martial knowledge that applies to every branch equally exerts an even stronger influence on the development of materiel solutions and doctrine because it represents something analogous to "common knowledge." In *The Scientific Way of Warfare*, Antoine Bousque describes how metaphysical understandings of the way the world works influenced the materiel and doctrines that militaries employed to fight wars throughout history. For example, he illustrated how visualizing the universe as a massive clockwork in the 17th and 18th centuries directly influenced the closed order battle drills of the most successful armies of the time.[223] Bjerga and Haaland noted this effect as well when they said that constructivist studies of military change "focus on how doctrines are formed by perceptions of 'appropriate behavior' within networks of professional officers

[222] John Law and Michel Callon, "The Life and Death of an Aircraft: A Network Analysis of Technical Change," in *Shaping Technology / Building Society: Studies in Sociotechnical Change*, ed. Wiebe E. Bijker and John Law (Cambridge, Mass: MIT Press, 1992), 21–52.
[223] Antoine Bousquet, *The Scientific Way of Warfare: Order and Chaos on the Battlefields of Modernity*, 2009.

educated at the same institutions, working in the same organizations, and sharing a distinct view of the world."[224] The 'appropriate behavior' Bjerga and Haaland are referencing is a direct reflection of a military's martial knowledge and exerts a strong influence on the development of doctrine within that military (See Figure 6).

As the definition of reality, it may be tempting to assume that martial knowledge is the prime mover within the technology triad, and each of the other two elements is driven by this concept. Certainly, the authors of the U.S. Army's official history of The Ordnance Department's preparations for World War II believed that the development of weapons starts from the development of conceptual "models for predetermined use" in 1955.[225] The U.S. Department of Defense still holds a version of this view today with their capabilities-driven procurement models, which require the development of Joint Concepts of operations at the very beginning of the process.[226] This 'knowledge first' framing of technological change within a military, besides its implicit assumption that a military can produce martial knowledge that can indicate which future materiel solutions and doctrine are best, only accounts for the two arrows originating with martial knowledge in Figure 6. The research from which the technology triad is born indicates that both materiel solutions and doctrine produce reciprocal influences on martial knowledge that must not be ignored. The next section will address the first of those two influences by further explaining the role of materiel solutions within the technology triad.

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[224] Bjerga and Haaland, "Doctrinal Innovation in a Small State," 90.

[225] Constance McLaughlin Green, Harry Thomson, and Peter C. Roots, *The Ordnance Department: Planning Munitions for War*, United States Army in World War II, The Technical Services (Washington, D.C.: Office Of the Chief of Military History, Department of the Army, 1955), 192.

[226] Yuenger, *How the Army Runs 2015-2016: A Senior Leader Reference Handbook*, secs. 10–4.

### *Materiel*

After an in-depth description of martial knowledge, the descriptions of materiel and doctrine require less attention, as both concepts are well established in discussion related to weapons and how militaries use them. Simply put, materiel solutions are the physical equipment a military has actually fielded to its force, everything from sophisticated fifth-generation airplanes to uniforms and tents, that militaries use to fight wars and the associated technological and industrial capacity required to actually build them. Where martial knowledge is purely a construct resulting from social processes, materiel solutions are grounded in physical reality dictated by the laws of physics. However simple the basic idea of materiel may be, unraveling the influence of physical objects, or artifacts, on the social world is an intellectual minefield. At every step, there is the danger of slipping into the trap of technological determinism, the idea that the natural evolution of technology determines human development.[227] In light of the earlier discussion of SCOT, it may be tempting to take the extreme opposite view and assert that humans build artifacts, which would imply that any influence of artifacts is best understood as a social phenomenon. However, even the most basic considerations of the impact of weapons on the conduct of war indicate that artifacts, or materiel, must influence the social world in some manner.[228] It would be disingenuous to attempt to understand the dynamics of military change without considering the effect that materiel can have on the system at all. Careful definitions for materiel solutions in relation to doctrine and martial knowledge frame the elements of the technology triad in a manner to

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[227] Merritt Roe Smith and Leo Marx, eds., *Does Technology Drive History? The Dilemma of Technological Determinism* (Cambridge, Mass: MIT Press, 1994).
[228] Max Boot, *War Made New: Technology, Warfare, and the Course of History, 1500 to Today* (New York: Gotham Books, 2006).

minimize the risk of intellectually slipping towards technological determinism in the analysis of military innovation.

The boundary between materiel solutions and doctrine exists where actions taken by a military transition from the production to the employment of weapons. The technology triad is a simplification of a complex and flowing system of concepts that would be continuums from one corner to the next if the goal was a more accurate representation of reality. The boundaries between the elements become useful simplifications of reality to explore the interactions within the technology triad. Definitions of technology writ large that previous scholars have employed can expose this continuum and provide points of reference to draw the distinction between materiel and doctrine where it is most useful for the technology triad's intended purpose. To construct his adoption capacity theory, Michael Horowitz defined technology as "'hardware' such as rifles, artillery, and bombers."[229] This is the colloquial use of the word 'technology,' the physical objects with which people interact to accomplish specific objectives, and represents the far-left corner of the technology triad diagram in Figure 6. Moving further along the spectrum from artifacts to technique, one encounters what Schatzberg called 'industrial arts' in *Technology,* which he defined as "the means and methods for transforming the material world."[230] Industrial arts are clearly actions that people perform, but for the sole purpose of 'transforming the material world." Moving one step closer to technique, Alex Roland, the military technology historian, defined technology as "a process of altering the material world to serve some human purpose."[231]

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[229] Horowitz, *The Diffusion of Military Power*, 5.
[230] Schatzberg, *Technology*, 232.
[231] Roland, *War and Technology*, 5.

Roland's addition of 'some human purpose' implies that altering the material world is an intermediate step towards the primary objective of technology writ large in his definition. This distinction between serving some higher objective and simply transforming the material world is where the distinction between materiel and doctrine exists in the technology triad. It is the difference between actions meant to produce military equipment and actions intended to achieve military objectives, or the way that militaries use that equipment. Materiel thus becomes the industrial arts, applied to military matters, plus the artifacts that the industrial arts produce.

The distinction between materiel solutions and martial knowledge is defined similarly by focusing on how truth can be generated and validated within either materiel or martial knowledge. The capacity to produce military equipment, an important component of materiel in the technology triad, includes certain types of specialized knowledge to transform the material world. In his history of Vannevar Bush, G. Pascal Zachary explained that President Truman identified three requirements for a nation to build an atomic weapon: "basic scientific knowledge, engineering 'know how,' and the 'industrial capacity and resources necessary to produce the bomb.'"[232] These three requirements illuminate the continuum between martial knowledge and materiel the way previous, more narrow definitions of technology did for materiel and doctrine. Martial knowledge is analogous to 'basic scientific knowledge,' and materiel encompasses 'industrial capacity.'

The line between materiel and martial knowledge lies between scientific knowledge and engineering know how, with scientific knowledge as part of the martial

[232] G. Pascal Zachary, *Endless Frontier: Vannevar Bush, Engineer of the American Century* (New York: Free Press, 2018), 305.

knowledge and engineering a component of materiel. This distinction should not be confused with a hierarchal relationship between science as knowledge production and engineering as application of that same knowledge, as Bush would have advocated and consistent with the predominant way of framing scientific and engineering knowledge through most of the second half of the 20th century.[233] Rather, martial knowledge and engineering knowledge are different kinds of knowledge owing to the epistemologies available to the two corresponding nodes of the technology triad: materiel and martial knowledge. As noted earlier, military knowledge systems employ both internal and external epistemologies to determine justifiable true belief, which are both heavily influenced by the remainder of the knowledge system resulting in the socially constructed and validated martial knowledge. Engineering knowledge, while not totally immune to social influences, has access to an epistemology tied to the laws of physics, which are common to all humans. In his work related to the production of engineering knowledge, Walter Vincenti, himself an aeronautical engineer, detailed at great length the degree to which empirical testing of new ideas through rigorous mathematical and physical modeling, such as wind tunnels and prototyping, can serve as the ultimate test of truth in engineering knowledge.[234] This is fundamentally different from the production of martial knowledge, which relies on socially driven epistemologies even when the laboratory of actual combat is available to a military owing to the strong influence of prior knowledge already discussed and the lasting impact of materiel and doctrine on martial knowledge, which will be discussed below. With a definition of materiel as the fielded physical

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[233] Bush, *Science, the Endless Frontier*; Walter G. Vincenti, *What Engineers Know and How They Know It: Analytical Studies from Aeronautical History*, Repr, Johns Hopkins Studies in the History of Technology, N.S., 11 (Baltimore, Md.: Johns Hopkins Univ. Press, 1997), 4; Godin, *Models of Innovation*, 82–83.
[234] Vincenti, *What Engineers Know and How They Know It*, 16–40.

equipment with which militaries fight wars along with the capacity, industrial and intellectual, to build that equipment, the relationships between materiel and the other two elements of the technology triad can be explored in more depth.

*Materiel and the Technology Triad*

There are two primary ways that materiel solutions influence the rest of the technology triad. One can be considered as a limiting function, and the other is an enabling function. The limiting function is simply that the physical constraints of a materiel solution dictate what can and cannot be accomplished with the materiel solution, and the enabling function are the unexpected capabilities that a materiel solution demonstrates once fielded. ANT, described earlier with the seatbelt buzzer, and technological momentum can help illuminate how materiel solutions perform a limiting function on doctrine. The design of military equipment dictates what its function is not far more than what the equipment's function is. For example, in the full set of possible actions a soldier can undertake in the conduct of combat, from performing maintenance to destroying a bunker, each piece of equipment is optimized for a small subset of those actions. A pistol is ill-suited to destroy a tank, just as a tank is ill-suited to conduct a sophisticated cyber attack. This same idea applies to more nuanced differences and design trade-offs for individual pieces of equipment. A tank can either be fast and light or slow and heavy but not fast and heavy due to the limits of engines and suspension. When a military commits to one design or another for a piece of equipment, they are simultaneously committing to a method of employment in combat for that piece of equipment that fits within its design parameters.

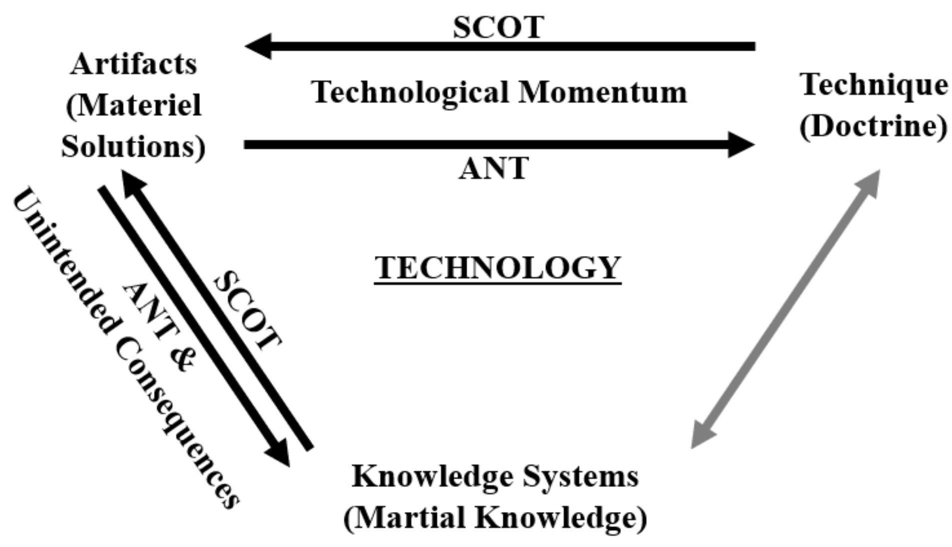


Figure 7: Materiel and the Technology Triad

Of course, a military can always, and often does, redesign equipment to adapt to new methods of employment, but that takes time. The mature socio-technological systems Hughes describes in his concept of technological momentum can frustrate efforts of a military to quickly alter existing designs of weapons.[235] Since materiel solutions represent the means for production as well as the actual objects produced, a major redesign of a tank to meet some new requirement would necessitate altering the production facilities as well. Even though materiel solutions are always changing, the current design of a materiel solution exerts an influence over the doctrine of a military for some period of time. The limiting function of materiel is not limited to doctrine; it also influences martial knowledge.

[235] Thomas Parke Hughes, "Technological Momentum," in *Does Technology Drive History? The Dilemma of Technological Determinism* (Cambridge: MIT Press, 1994), 101–13.

The limiting function of materiel on martial knowledge derives from the complex relationship between artifacts and the way humans understand the world. In 1967, Rear Admiral J. C. Wylie published the book *Military Strategy: A General Theory of Power Control,* where he drew on a lifetime of military service to argue that the military manner of thinking is heavily influenced by the service culture and ultimately the machines that particular officers employ to wage war.[236] In his view, the equipment that officers use determines not just the manner that they fight wars but also the way they see the world.[237] Wylie's professional insights reflect research within the science and technology studies community related to the influence of technological artifacts on the production of knowledge. For example, Shapin and Schaffer described Boyle's experimental air pump as a "reifying engine," which had the capacity to take nebulous theoretical ideas and elevate them to the status of truth through Boyle's interactions with the material object.[238] More recently, Antoine Bousquet explained in a symposium on the future of drones that unmanned aerial vehicles are best understood as an extension of a soldier's cognitive process the way that using a pencil and paper to complete a challenging math problem blurs the distinction between mental processes that occur in the mind and those that are stored and completed on the paper.[239] The specific mechanisms that allow materiel to influence martial knowledge are less important than the apparent effect that material objects have on the way people create sense of the world around them. By interacting with materiel solutions in a specific form, members of a military come to internalize

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[236] Jr Wylie Joseph Caldwell, *Military Strategy: A General Theory of Power Control.*, 2014, http://ebookcentral.proquest.com/lib/kcl/detail.action?docID=1652779.
[237] Jasanoff, *States of Knowledge*; Jasanoff and Kim, *Dreamscapes of Modernity*; Jasanoff and Kim, "Sociotechnical Imaginaries and National Energy Policies."
[238] Shapin and Schaffer, *Leviathan and the Air-Pump*, 28.
[239] Antoine Bousquet and Jairus Grove, "Drone Futures" (Virtual Public Seminar Series, University of New South Wales, Sydney, September 2, 2020), https://www.dronewitnessing.com/drone-futures.

those forms of the materiel solutions as exemplary artifacts, to use Bijker's term.[240] By anchoring martial knowledge to a pre-existing materiel solution, the influence these physical objects have on the progress of martial knowledge produces the limiting function on the development of new ideas just as prior knowledge does within the military knowledge system. Despite this limiting function, just as prior knowledge can and does get updated within the knowledge system, there are also instances where materiel exerts the opposite influence on the technology triad through an enabling function.

Materiel solutions perform their enabling function on the technology triad through martial knowledge by demonstrating what is possible. In his essay "Three Faces of Technological Determinism," Bruce Bimber explains how scholars espouse a "soft determinism" when they account for the unintended consequences produced by the introduction of a new technology into complex systems.[241] Langdon Winner exemplifies this logic in his book *Autonomous Technology*.[242] In this book, Winner argued that the physical forms of technology and their impact on our actions combine in complex and unpredictable ways to produce what he calls 'technological politics' that influence the way we live our daily lives just as much as traditional politics. He argues that technological politics are not deliberately planned or explicitly approved by the population the way traditional politics are.[243] Because these outcomes are not deliberately planned, Bimber argues that they are unintended in nature.[244] Allenby and Sarewitz

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[240] Bijker, *Of Bicycles, Bakelites, and Bulbs*, 125.
[241] Bimber, "Three Faces of Technological Determinism."
[242] Langdon Winner, *Autonomous Technology: Technics-out-of-Control as a Theme in Political Thought* (Cambridge, Mass: MIT Press, 1977).
[243] Winner.
[244] Bimber, "Three Faces of Technological Determinism."

directly addressed the tendency of technology to produce unintended outcomes arising from complexity when they said, "[t]echnologies often surprise us because they introduce into society novel capabilities and functionalities whose uses are constantly being expanded and discovered-capabilities and functionalities that interact with other technologies, and with natural and social phenomena, in ways that cannot be known in advance."[245] Through these unintended consequences, materiel solutions perform an enabling function within the technology triad by updating the state of martial knowledge. The fielding of a weapons system to perform one function, for example, the intent of early tanks to provide protection for infantry from machine guns, can produce unexpected outcomes, like massive shock and fear in the enemy that came to define armor combat in World War II, that represent the true potential of any materiel solution when understood through a different martial knowledge.

The enabling link from materiel solutions to martial knowledge can be difficult for militaries to detect and appropriately address. Because materiel solutions answer problems defined by the martial knowledge of a military, these unintended consequences can occur outside of the reality the martial knowledge represents. Misidentifying unintended consequences of materiel solutions can cause severe mismatches between what is possible with a materiel solution and the doctrine through which the military employs that material solution. William Ogburn referred to this tendency for social systems to move slower than technological systems as "cultural lag."[246] In military applications of this idea, cultural lag and a weak materiel to martial knowledge link is how retrospectively absurd tactics can arise, such as the French reliance on methodical

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[245] Allenby and Sarewitz, *The Techno-Human Condition*, 39.
[246] Godin, *Models of Innovation*, 152.

battle and fixed fortifications on the eve of World War II.[247] Conversely, a nimble military knowledge system that can identify the full potential of an existing materiel solution can produce a decided advantage for a military, just as the German use of tanks did over the French. This advantage arises from the ability of the military to employ existing equipment in a new manner consistent with the updated martial knowledge, which leads to the final element of the technology triad.

### *Doctrine*

Doctrine, while less than 200 years old in its current form, has become integral to the way modern militaries function.[248] Yet, despite its ubiquity amongst the militaries of the word, a common definition eludes theoreticians and practitioners alike. Definitions of doctrine can be expansive, to the point where they blur the line between doctrine and martial knowledge. For example, Lieutenant Colonel Harald Hoiback, from the Norwegian Defense University College, argues that a military's doctrine should be considered a complex interplay of theory, authority, and culture within that military.[249] Each of these three components of Lieutenant Colonel Hoibak's framing of doctrine is accounted for by martial knowledge within the technology triad. The North Atlantic Treaty Organization (NATO), one of the highest military commands in the world, holds a similar view of doctrine and defines it as "fundamental principles by which the military forces guide their actions in support of objectives."[250] NATO's focus on underlying

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[247] Bloch, *Strange Defeat*.
[248] Harald Hoiback, "What Is Doctrine?," in *Contemporary Military Innovation: Between Anticipation and Adaption* (New York: Routledge, 2012), 21–23.
[249] Hoiback, "What Is Doctrine?"
[250] "FM 1-02 Operational Terms and Graphics" (Headquarters, Department of the Army, 2010).

principles, rather than the actions that subordinated commands must perform, makes sense considering NATO's strategically oriented focus, but it is still on the martial knowledge side of the distinction between martial knowledge and doctrine in the technology triad. Moving further away from marital knowledge, The U.S. Army defines doctrine as "fundamental principles, with supporting tactics, techniques, procedures, and terms and symbols, used for the conduct of operations and as a guide for actions of operating forces, and elements of the institutional force that directly support operations in support of national objectives."[251] The U.S. Army's definition includes not only 'fundamental principles' but also 'tactics, techniques, and procedures.' This is the transition point from martial knowledge to doctrine that can illuminate the relationship between ways of understanding the world and actions militaries take to navigate within that understanding.

Within the technology triad, doctrine is the collection of actions that a military takes to achieve the goals dictated by its martial knowledge. At its most basic level, doctrine is simply the way that a military fights. Osinga adopted a similar definition of doctrine for his study of Boyd's strategic theories when he said, "[d]octrine is the aggregate of fundamental methods of fighting, often tacit or implied."[252] The actions individual soldiers take as members of a team fall under the umbrella of doctrine, as do the combined efforts of entire militaries. Doctrine provides a common language for members of a nation's military to communicate with one another and a framework through which to coordinate their actions towards a common goal. It includes formally

[251] "ADP 1-01 Doctrine Primer" (Headquarters, Department of the Army, July 31, 2019), 1–2.
[252] Osinga, *Science, Strategy and War*, 9.

dictated roles and activities that individuals and units must perform as well as the informal activities those soldiers undertake in pursuit of their objectives.

This framing of doctrine as a collection of actions a military takes draws its inspiration from the way scholars use the term technique. Schatzberg defines technique as "all skills and procedures for achieving a specific end."[253] However, this definition of technique fails to distinguish between those actions a military may perform to produce materiel solutions and those actions a military performs to prepare for and win wars. In *The Technological Society*, Jacques Ellul further divides technique into several categories and notes that mechanical techniques are the most well-known, so much so that he chooses not to discuss them directly within his book.[254] The technology triad follows Ellul's logic and removes materiel solutions and its associated processes from the discussion of technique to produce a remaining set of actions that represent a military's doctrine. The source of the desired ends is the distinguishing characteristic between actions that belong in materiel and actions that belong in doctrine. Actions in materiel are intended to produce materiel solutions, and those that belong in doctrine are intended to achieve the objectives dictated by martial knowledge. With doctrine as a concept thus delineated, artificial as it may be, one can explore how it relates to the other two elements.

### *Doctrine and the Technology Triad*

The underlying logic of the technology triad recognizes martial knowledge is a product of human actions, and as such, technique exerts a powerful influence on the way

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[253] Schatzberg, *Technology*, 232.
[254] Ellul, *The Technological Society*, 22.

that people understand the world. This influence can impact both individuals and entire organizations. At the individual level, Michel Foucault explained how people employ "technologies of the self," which are personal actions such as self-care and introspection, to "attain a certain state of happiness, purity, wisdom, perfection, or immortality."[255] He argued that a person's actions lead directly to an enhanced understanding of the world and that person's relationship to it. Daniel Kahneman's work related to heuristics in decision making affirms this general observation. Kahneman explained how humans employ two systems of thinking: system one for automatic, daily activities and system two for careful deliberation. He argued that people tend to apply the heuristics that drive system one thinking in situations where system two thinking is more appropriate.[256] The manner in which people act in everyday life influences the manner that they think in ways that are so natural to the conduct of life that those ways of thinking are easily overlooked. This effect is only magnified when it is scaled to the organizational level and people's patterns of thought and ways of understanding problems are constantly reinforced by the actions and thought patterns of the other members within the organization. Previous doctrine becomes the pre-existing knowledge from which the military knowledge system creates new truths to define reality at both the individual and organizational levels.

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[255] Michel Foucault et al., eds., *Technologies of the Self: A Seminar with Michel Foucault* (Amherst: University of Massachusetts Press, 1988), 18.
[256] Kahneman, *Thinking, Fast and Slow*.

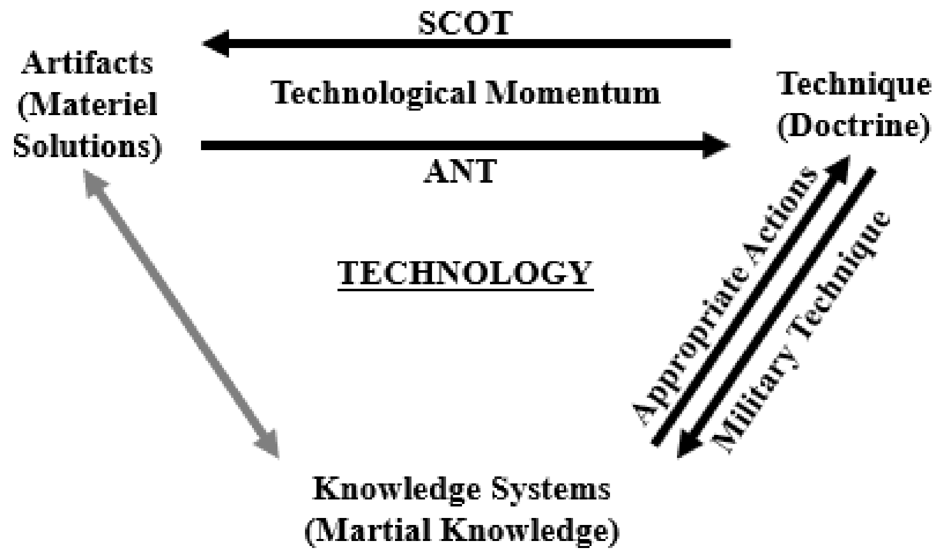


Figure 8: Doctrine and the Technology Triad

Ellul highlighted the way that doctrine has the most profound impact on the production of martial knowledge at the organizational level with his concept "technique of organization," which he argued is "applied to warfare and ensures the power of an army at least as much as its weapons."[257] Ellul's concept of technique is far more expansive than the conceptual bounds established around doctrine above, which is closer to the colloquial English meaning of the word technique.[258] However, Ellul explicitly used the example of Fredrick the Great's close order battle tactics to describe "military technique," which is a form of organizational technique.[259] In Ellul's formulation, tactics, which are actions, are a reflection of the same concept as methods of organization; this is consistent with the definition of doctrine as actions that militaries take to achieve

[257] Ellul, *The Technological Society*, 22.
[258] Ellul, xxv.
[259] Ellul, 229.

objectives. As discussed in the section that explained martial knowledge, the structure of a military exerts a strong influence on the production of martial knowledge. In this manner, the organizational doctrine that a military follows influences the production of martial knowledge directly and has an indirect influence on materiel, owing to the previously discussed impact of martial knowledge on materiel.

The influence of doctrine on materiel can also be direct, and once again, STS concepts illuminate how the nodes of the technology triad relate to each other. SCOT can help demonstrate the ways that doctrine influences the materiel solutions militaries employ by showing how the intended use of a materiel solution bounds the definition of working and non-working in the relevant social groups. The presence of left-handed tools in the world is a simple example of how the intended use of an artifact influences its design at the individual level. When the German army put a radio in every one of its tanks prior to World War II in order to meet the communications requirements of their emerging armor doctrine, they demonstrated how doctrine can influence the design of materiel at the organizational level.[260]

As one considers complex social groups, application of this concept is rarely as straightforward as the German radio example, but the general influence of technique on materiel to perform that technique remains. Thomas Hughes's concept of technological momentum explains how complex socio-technical systems form around a certain type of materiel, such as rail roads, that require the development of technical experts and manners of organizing people, techniques, to maintain and operate the railroads. These

[260] Barry Watts and Williamson Murray, "Military Innovation in Peacetime," in *Military Innovation in the Interwar Period* (New York: Cambridge University Press, 1996), 373.

techniques, in turn, influence the very design of the railroad in a feedback loop.[261] So, even in large organizations with little or no central management, the actions that people take to function within that organization exert significant influence on the design of the materiel that the organization employs to achieve its objectives. Another important consideration that Hughes explains with technological momentum relates to how socio-technical systems become harder to change over time as the techniques and artifacts become more interdependent, which introduces a new idea to the discussion of the technology triad that to this point has been absent: the importance of temporal effects within the technology triad.

### *Temporal Interactions Within the Technology Triad*

The specific delineations between the three elements of the technology triad are the result of original research on the development of tanks and armor doctrine in the U.S. Army prior to World War II, but the basic elements of the technology triad draw heavily from pre-existing thinking and research about the nature of technology and knowledge. The distinctions drawn between the elements of the technology triad above are artificial but not arbitrary. By putting the three elements in relation to each other and viewing technological change within militaries through that lens, a new insight emerges; each of the elements of the technology triad is always changing, but at different rates that are limited by the nature of each element independently. This insight, made possible by breaking out the three elements and putting them in relation to each other, starts to bring

[261] Hughes, "Technological Momentum."

the technology triad from the realm of pure theory and indicates how military leaders might leverage this framing in practice.

In September 2020, General John Murray, the Commanding General of the U.S. Army Futures Command, explained that his responsibility for the nation is to describe what the future environment might look like, develop concepts to fight within that environment, develop organizational constructs to carry out those concepts, and finally to develop the technologies for those organizations. He noted that in an ideal world, each of those steps would happen in order, but in reality, all four steps are occurring simultaneously.[262] General Murray's four objectives for Army Futures Command are roughly analogous to the elements of the technology triad. The goal of managing military sociotechnical systems with the technology triad becomes to keep each of the three elements of the technology triad as close to in harmony as possible.

Maintaining alignment between the three elements of the technology triad is much easier in concept than it would be in practice because each of the elements is themselves a complex system that changes at fundamentally different rates, even under ideal conditions. The quickest rate of change the elements of the technology triad can achieve is different for each element, but in practice, the elements would never achieve their fastest rate of change. Competing organizational priorities will always introduce complexities to the system. A military's martial knowledge may be updated nearly overnight due to some new demonstration by an adversary or civilian technology to reflect the perceived need for a new piece of equipment. However, that military must

[262] John Murray, *Virtual Fireside Chat with General John M. Murray*, YouTube, Virtual Fireside Chat (Washington, D.C.: Center for a New American Security, 2020), https://www.cnas.org/events/virtual-fireside-chat-with-general-john-m-murray.

physically build the new equipment, which takes more time, and perhaps even build the factory and develop the engineering knowledge necessary to build the equipment, adding to the fastest rate of change for the militaries material. With modern weapons, the industrial capacity required can be quite complex in its own right. Even if the military already possesses sufficient quantities of the equipment to align with a new martial knowledge, new doctrine must be developed and trained within the force to use the old equipment in a new way. At their fastest rates of change, once one considers the realities of large organizations, new doctrine can update quicker than building new equipment but can never update as fast as martial knowledge. These differing rates of change open up the opportunity for the technology triad, as a conceptual tool, to combine two aspects of military innovation that are normally separated in the literature: peacetime innovations and wartime innovations.[263]

The philosophical foundations of the technology triad derive from the idea that militaries cannot test their martial knowledge in a laboratory, like scientists can, during peacetime. The lack of truly objective measures makes martial knowledge a social construction, which would also imply that when a military is at war, then the structure of the technology triad might start to lose its philosophical grounding and ability to provide insights. This is not the case for two reasons. The first is that not all wars are equal. This is a shorthand way of saying that war is a fundamentally social activity subject to its own set of political influences that can make universal acceptance of the lessons of a war near impossible. For example, the U.S. Government spent more than $50 billion on nuclear

[263] Rosen, *Winning the next War*.

weapons-related costs in fiscal year 2008, right at the height of the troop surge in Iraq.[264] Despite active combat operations, the United States continued to funnel resources towards weapons that could not possibly be employed in one of the two wars at the time. This could imply that decision-makers within the government judged that the wars in Iraq and Afghanistan were not adequate representations of the types of wars for which the nation needed to continue to prepare, that the possession and maintenance of such weapons aided the war despite their lack of employment, some combination of those two possibilities, or some unknown reason. Whatever reason the U.S. Government may have had to continue to maintain these weapons, their lack of employment in the war means that their design and the doctrine for their use remained a product of a purely socially constructed knowledge. The second reason the technology triad retains explanatory power in wartime innovation relates to the rates of change within the triad. Even if all combatants can agree that some current war is the only one that matters and that the combat within it has demonstrated the objective validity of some martial knowledge, the other two elements of the technology triad must still update to meet the new martial knowledge. Despite the apparent primacy of marital knowledge, the interactions within the triad are not unidirectional, from marital knowledge to doctrine and material exclusively, even in the improbable condition of universal objectivity in war. A change to one element has an influence on the other two simultaneously. The unintended consequences of new materiel solutions can update the previously held martial knowledge at any time. The greater the difference between the actual, not ideal, rates of

[264] Deepti Choubey and Stephen I. Schwartz, "Nuclear Security Spending: Assessing Costs, Examining Priorities" (Washington, D.C.: Carnegie Endowment, January 12, 2009), https://carnegieendowment.org/2009/01/12/nuclear-security-spending-assessing-costs-examining-priorities-pub-22601.

change of the elements of the technology triad, the more opportunity there is for there to be multiple changes to one element before the next one can adjust. This multiplies the complexities of the emergent system and further challenges leaders who are trying to successfully manage the change whether they have access to a "combat laboratory" or not.

The complexities inherent in the relationship between technology and military change may initially seem like an intangible web of causes and effects. However, the technology triad provides a framework to parse out the most relevant elements of the system and start to understand their interactions with one another. It is critical to note that the tech triad indicates the most relevant elements, not the most important elements. Relevant indicates that shifting environments can make different elements more or less important depending on the specific situations. David Kilcullen echoed Williamson Murray and Barry Watts when he asserted that "technologi[cal artifacts] themselves are the least important element of innovation."[265] The technology triad provides a structure within which to disagree with this assertion. Materiel solutions take the most time to implement, so they are different but no less important. This understanding, in turn, can start to imply management strategies for policymakers charged with maintaining an effective military. For example, the lasting impact that materiel has on doctrine indicated by ANT combined with relatively slow rates of change for material solutions compared to martial knowledge can inform choices about which weapons are the best long-term investments. In this manner, a purely constructivist interpretation of knowledge generation and reality can translate to practical applications to help manage military

[265] Kilcullen, *The Dragons and the Snakes*, 63.

change relative to technology. Furthermore, the technology triad brings into focus how the slower changes in doctrine and materiel influence the understanding of reality defined by martial knowledge and how the link from martial knowledge to the other two elements can actually reinforce previously held truths. The combination of social and physical aspects of the technology triad as a whole work together to create a comprehensive and self-reinforcing reality. This is one of the more important, perhaps the most important, insights one can gain from framing military technology in terms of the technology triad.

### *The Technology Triad creates reality in any meaningful sense*

The social construction of reality is far from a novel concept; it is literally the title of the book written in 1966 that founded sociology of knowledge as an academic field.[266] Despite constructivism's general acceptance in a wide range of fields, from international relations to philosophy of science, previous treatments of military innovation, especially those that consider the challenge of technological innovation, have struggled to adequately account for the social influences on the production of knowledge that define reality.[267] It can be difficult to account for the stubborn resistance of the physical world to bend to socially produced definitions of reality when devising models intended for practical application in war, which is a social endeavor, but one defined by the presence of physical force.[268] The technology triad overcomes this hurdle by accounting for the social influences on the physical world, thus treating the material world as a feature rather than a flaw in the development of a constructivist approach to understanding

[266] Berger and Luckmann, *The Social Construction of Reality*.
[267] Griffin, "Military Innovation Studies," 206.
[268] Clausewitz, Howard, and Paret, *On War*, 75.

military change and innovation. In order to demonstrate how the technology triad builds on constructivist philosophies to produce martial knowledge, which is a concrete statement about the nature of reality by a military, and deliver novel insights, it is useful to contrast it against similar ways of thinking in a number of fields.

One of the earliest reflections of constructivist assumptions in the western canon of military thought comes from Clausewitz. He wrote that the best strategic theory for a commander in chief to follow "never forces him into opposition with himself in order to obey an objective truth."[269] Clausewitz's willingness to disregard 'an objective truth' in order to arrive at the best strategy at least implies tacit acceptance that a commander's perception of objective truth might, in fact, be false. Of course, acknowledgement that an objective truth is out of reach of a commander is more relativistic than constructivist in nature, and even reading Clausewitz as a relativist requires some interpretation. John Boyd's work on strategic theory was much more explicitly relativistic, even bordering on constructivist, in its foundations. While Boyd never wrote most of his most profound insights in any single collection or work, detailed research performed by Frans Osinga reveals that scholars who questioned absolute knowledge influenced much of Boyd's thinking.[270] For example, Osinga noted that Boyd drew from Godel and Heisenberg's work to conclude that "we cannot determine the character and nature of a system within itself and efforts to do so will only generate confusion and disorder."[271] Boyd also found inspiration in the social sciences for his constructivist views, with works by Clifford Geertz and Edward Hall enabling an appreciation for the local nature of knowledge and

[269] Sun-Tzu and Clausewitz, *The Book of War*, 354.
[270] Osinga, *Science, Strategy and War*, 18.
[271] Osinga, 27.

influence of culture to produce that knowledge.[272] The importance of considering context and values when assessing truth and knowledge plays a prominent role in Boyd's theories, but his theories were designed to inform action, not understand change and innovation within militaries. More recently, the cultural school of military innovation has employed the concept of "theory of victory" to account for the social influences on military innovation.

Rosen introduced "theory of victory" in 1988 as a conceptual tool to account for how the way people thought about war could spur induce innovation in militaries.[273] The framing that a new theory of victory can supplant an old one in such a way to create a slow-moving change recognizes that the new theory of victory cannot be verified as an objective truth, yet by Rosen's account, militaries still take concrete actions based on these theories. His theoretical tool has even earned a place in formal U.S. Army doctrine in the form of "concepts," which the U.S. Army defines as "ideas for a significant change based on proposed new approaches to the conduct of operations or technology."[274] As a way to explain competing ideas within a military, theory of victory is a helpful tool, but it falls short of the reality constructing function that marital knowledge performs for a military. The original use of theory of victory is future-focused. It describes "what war will look like and how it will be won."[275] This future orientation of Rosen's theory of victory implies a level of uncertainty about the theory's validity that is unavoidable when discussing the unknowable future. Martial knowledge is a much stronger statement about truth and reality as far as the military in question is concerned. One could consider

[272] Osinga, 77.
[273] Rosen, "New Ways of War."
[274] "ADP 1-01 Doctrine Primer," 1–2.
[275] Rosen, "New Ways of War."

martial knowledge as a theory of victory that has been validated and reinforced by the technology triad to attain the mantle of "truth." Contemporary scholars who employ the term "theory of victory" use it in a way that is much closer to marital knowledge.

The cultural school of military innovation relies heavily on a theory of victory, or culturally influenced ideas, to explain how militaries determine the correct way to act, but they still stop short of fully embracing a constructed reality. Dima Adamsky's use of theory of victory was an exemplar in this line of thinking when he said a "'[n]ew theory of victory' is a quintessentially cultural-ideational endeavor."[276] His focus on a military's culture as the source and driver of new ideas related to the best way to fight is similar to, but not the same as, a military knowledge system producing martial knowledge. Griffin noted that Adamsky explicitly denies cultural considerations the "independent causal power" to induce innovation within a military.[277] In Adamsky's words, "[s]tructural factors and emerging technologies represent the independent starting point of military transformation."[278] Adamsky demonstrated this logic in his book, *The Culture of Military Innovation,* when he analyzed how the cultures of several different militaries influenced the changes within that military to the information technology revolution, which he treated as a common independent variable across each of the militaries.[279] Griffin also noted that the leading scholars in the cultural school of military innovation all share a similar view that there is an objective reality that induces change within a military, and that once the change is forced on the military, then cultural factors determine the

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[276] Adamsky, *The Culture of Military Innovation*, 11.
[277] Griffin, "Military Innovation Studies," 204.
[278] Adamsky, *The Culture of Military Innovation*, 10.
[279] Adamsky, *The Culture of Military Innovation*.

direction that change will take.[280] The technology triad ascribes no such primacy to materiel and doctrine. If anything, there is a slight bias within the technology triad for martial knowledge, as the military's understanding of reality with the quickest possible rate of change of the three elements, to be the preeminent element within the triad.

However, the bias is only slight; martial knowledge is not the prime mover that generates all change. Benjamin Jensen, in his research on doctrinal change within the U.S. Army after the Vietnam War, fully embraced the dominant role of a theory of victory when he argued that all doctrinal changes start from a new theory of victory.[281] He started with a definition for theory of victory that was the most similar to martial knowledge as the articulation of "solutions to a particular operational problem that are based on 'frames' and function as a schema of interpretation that organizes how military professionals understand events and interactions."[282] Then, Jensen explained how the U.S. Army leveraged advocacy networks to grow new ways of understanding into full doctrines, which he defined as what would be a mixture of martial knowledge and doctrine, using the language of the technology triad.[283] While Jensen's framework highlights important aspects of the cases that he studied, it is still a partial explanation for the purposes of this dissertation because the focus on a theory of victory to doctrine transition minimizes the influence that materiel and doctrine have on the development of knowledge. Each of the elements within the technology triad are best understood as equal parts of a single complex system that are linked in reciprocal relationships. These

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280 Griffin, "Military Innovation Studies," 204–5.
281 Benjamin M. Jensen, *Forging the Sword: Doctrinal Change in the U.S. Army* (Stanford, California: Stanford Security Studies, an imprint of Stanford University Press, 2016).
282 Jensen, 16–17.
283 Jensen, *Forging the Sword*.

relationships define reality in totality for the military in question, not some perception of an objective reality that is influenced by a military's culture, in a way that a theory of victory alone cannot. One has to depart the military innovation literature to find research that has embraced constructivism to the degree that the logic of the technology triad dictates, which necessitates the generation of a new concept distinct from a theory of victory.

In his research on the relationship between the development of computing technologies and Cold War strategy, the science and technology studies scholar Paul Edwards introduced the concept of discourses to illustrate how complex military sociotechnical systems can define reality for the members of a military.[284] Edwards' use of discourses is a challenging concept that incorporates many of the same concepts and shares a common philosophical grounding as the technology triad, but there are some important distinctions related to the objectives of the two framings and the ultimate insights one can draw from each of them. In *The Closed World,* Edwards defined discourses as "the entire field of signifying or meaningful practices."[285] From this simple definition, he constructs an eloquent, flowing concept of an "intricately woven, discursively connected whole" where strategy, technology, and culture are connected by discourses which are "self-elaborating 'heterogeneous ensemble[s]'" that define a "closed world," which was intentionally opposed to the USSR.[286] In contrast, the technology triad is a discrete system with nodes, artificial as they may be, delineated by the idealized rate of change possible for a node in a real organization that as a whole produce a reality that

[284] Edwards, *The Closed World*.
[285] Edwards, 34.
[286] Edwards, 125, 120, 34, 40, 10.

those within the system accept applies to the whole of humanity, regardless of what those outside the system might think. The distinction between the construction of a recognized closed world in Edwards' research and the definition of reality in the technology triad will become important in Chapter 6 when the generalizability of the concept is tested. The differences between these two framings are a product of their differing objectives. Edwards' discourses were a concept he used to describe in great detail the interactions within a single system, the U.S. Government, for a limited period of time, The Cold War. The technology triad is meant to be a conceptual tool to describe the relationship between technology and military innovation in a way that is practically useful for the management of future technologies and innovations. The technology triad and Edwards' work share a common commitment to the social creation of reality as a result of their philosophical grounding in constructivist science and technology studies.

The technology triad is similar to many other framings of technology and society within science and technology studies as well, which is to be expected because common amongst models to enhance understanding of sociotechnical systems is a focus on the nexus between the material and the social worlds. Some theories place more emphasis on the social influences of change in the system, such as the Social Construction of Technology.[287] Other theories give more power to material objects in the system, such as technological momentum and Winner's unintended consequences, although it is worth noting that no serious sociotechnical systems theory ever gives full credit to technical artifacts as the drivers of change in the system.[288] Yet still, other theories either defy

[287] Bijker, Hughes, and Pinch, *The Social Construction of Technological Systems*.
[288] Hughes, "Technological Momentum"; Roland, *War and Technology*, 32; Winner, *Autonomous Technology*.

classification, such as Actor Network Theory and military technique, or treat the social and the material as two equals that move and change together, as in co-production and socio-technical imaginaries.[289] Each of these models has their own strengths and weaknesses and are most appropriate for different applications. For example, Bijker's technological frames and Jasanoff's co-production are more flowing, open-ended concepts, like Edwards' discourses, that can provide important insights about the totality of a system.[290] But they can also be so high level that it can be difficult to use them to discern concrete actions one can take to apply their insights. In contrast, Actor Network Theory can be so consumed by the fine details of a system that it can be difficult to bring the insights up to a level where they are useful for real organizations.[291] As a model that also aims to understand the nexus between the social and material worlds, the technology triad draws inspiration from each of these theories and incorporates portions of them in the triad, when useful for the aims of the technology triad.

Despite the similarities between the technology triad and other sociotechnical systems framings, the technology triad stands alone in that it is designed specifically to explore the relationship between technology and innovation in militaries and provide the understanding necessary to help manage that relationship in practice. The technology triad introduces the concept of martial knowledge to the world of constructivist lexicon to specifically address the truth produced by social processes within militaries. Martial knowledge is a special kind of knowledge related to warfighting that provides the logical base from which to create the rest of the technology triad, which employs philosophy

[289] Latour, *Reassembling the Social*; Jasanoff, *States of Knowledge*; Jasanoff and Kim, "Sociotechnical Imaginaries and National Energy Policies"; Ellul, *The Technological Society*.
[290] Bijker, *Of Bicycles, Bakelites, and Bulbs*; Jasanoff, *States of Knowledge*.
[291] Latour, *Reassembling the Social*.

from STS but is derived specifically for application to militaries. The distinction between war and peace produces a dynamic where martial knowledge is both reified by material and social influences and impossible to test with some sort of experiment. Few other competitive social activities exist in a space where new concepts cannot be immediately tested. For example, business innovation literature and thinking are commonly applied to military matters, but this is inappropriate because a civilian business always has ready access to the environment in which they are going to compete to test their knowledge directly.[292] Martial knowledge, as a separate node in a simple system delineated by physical differences, makes the whole technology triad a useful conceptual tool to help identify and understand assumptions about the realities that militaries construct for themselves.

Together with doctrine and materiel, martial knowledge defines the reality within which a military exists. This is a much bolder acceptance of social constructivism than is present in the existing military innovation literature and the critical insight of the technology triad.[293] Even Boyd did not go as far as to argue that reality is constructed; he stopped at acknowledging that there is no objective truth.[294] The technology triad accounts for the physical artifacts with which the members of a military interact, how those members act, and what they believe is true. Each of these elements of the technology triad influence and reinforce each other through the interactions described above. Equipment and doctrine reflect earlier versions of martial knowledge due to their slower rate of change, relative to martial knowledge, and provide a means of

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[292] Pierce, *Warfighting and Disruptive Technologies*; Brose, *The Kill Chain*; Blank, "Teaching Technology, Innovation, and Modern War at Stanford, Part 1."
[293] Griffin, "Military Innovation Studies," 204.
[294] Osinga, *Science, Strategy and War*, 274.

communication and interaction between members of the military that is at least as strong as formal debate and perhaps even stronger owing to the implicit nature of that communication. As that reality shifts over time, the complex interactions between the elements induced by differing rates of change produce an emergent reality for a military.

In peacetime and certain wartime situations, this reality is not some culturally influenced impression of an objective reality. It is the reality that the military has constructed for itself. If the assumptions that undergird that reality are never tested in combat, then they retain their status as truth defined by the epistemologies employed by that military. Even in wartime situations, those truths are rarely put to the test in the same situation envisioned by those who originally made them. Once two militaries engage in combat, war becomes a competition between two realities to determine which reality is most appropriate for the objectives of each military within the new reality created by the presence of violence. This conceptualization of war as a competition between realities will be explored at length in Chapter 5 when the implications of adopting this constructivist worldview related to military technology are addressed.

### *The Technology Triad as a Conceptual Tool*

It is important to return once again to the goals and limits of the intellectual approach employed within this research. The technology triad does not aim to produce a predictive theory of military change and innovation as it related to technology. Such a goal would be inappropriate given the degree to which the philosophical grounding of the technology is reliant on constructivism as a way to understand reality. Rather, the technology triad is meant to be a way to think about and frame major concepts related to military technology to produce useful insights for the management of real organizations. By embracing a pure constructivist framing of reality, it becomes possible to employ what could be termed 'extreme empathy' to help understand the lessons of the past.

Once one accepts that militaries construct the reality within which they exist, actions by previous militaries regarding technology that may seem ill-considered start to make much more sense. For example, the French military in the 1930s did not yet exist in a reality where maneuver was more important than fixed defenses. Even once the Germans demonstrated the effectiveness of a new way of fighting in Poland, the French military did not exist in a reality that made their national defenses inadequate for the coming war. Poland lacked the massive fortifications that the French believed would prevent a similar outcome if Germany attacked.[295] Only with the aid of hindsight can one adopt the role of an outside observer with knowledge of the relative strengths and weaknesses of the two militaries. This is the reality that was shared between the French and the Germans prior to the war. However, as far as the French were concerned, it did not exist until the Germans attacked. Only the reality that the French constructed for themselves existed. Had the Germans never attacked, the shared reality between Germany and France would have never existed. Military historians could still speculate who would have been victorious, but there would be no way to know for sure, any more than there was for the French before the fighting started. The technology triad embraces this idea that the only reality for a military is the one that they construct for themselves and draws artificial but useful boundaries within the comprehensive whole of military technology to help understand how militaries craft that reality.

[295] Clark, *Blitzkrieg*, 74–76.

The complexities of military technology can be overwhelming. Each element within the technology triad is not a singular node that extends to the other two nodes uniformly. Each node is actually its own system, with its own complex relationships with other elements of adjacent technology triads within the system. For example, any one piece of equipment does not exist in isolation but as a piece in a larger system of other equipment designed to complement it. Some links may be more obvious, such as the one between trucks and trailers. But other links, such as the one between radio design and tents, may be difficult to discern. These links in the materiel node extend temporally as well, where new versions of some equipment must be compatible with older versions of closely related pieces of equipment. Each interaction between the elements of the technology triad happens across the full breadth of each node. Furthermore, the nodes themselves are artificial constructs of a complex and tightly coupled system of social and material elements. In order to reduce the complexity of the way these webs of people, practices, and artifacts are linked together, the technology triad makes some gross simplifications to bring out the relevant aspects of the interactions. This allows one to view the full system from different aspects that highlight different orientations of the mix of social and material to enhance understanding of the system.

Each of the elements of the technology triad are a form of technology in their own right but are conceptually distinct enough to produce non-arbitrary nodes. By breaking the whole of military technology into materiel, doctrine, and martial knowledge, relevant influences and differing rates of change between the elements comes into focus. These relationships, influential and temporal, help describe how a military constructs and maintains its reality as each of the nodes change over time. These two actions, reality construction and reality maintenance, are not always complimentary. There are times when the construction of reality produces a significant departure from the version of reality that preceded. While the maintenance function described by the technology triad is strong, it is not unsurmountable. The technology triad, as a conceptual tool, provides a framing to help understand these periods of discontinuous change as shifts in reality and the relationship between these shifts and military technology.

### Innovation and the Technology Triad

The development of the technology triad above necessarily focused on military change, rather than innovation, as an intermediate step towards addressing the inquiry at the core of this dissertation's research: What is the relationship between technology and military innovation? However, now that the technology triad is fully developed, employing the broader category of military change as a conceptual tool, the focus can shift from change to innovation. Specifically, the focus will shift to military innovation. This is important because there are many different types of innovation and there are aspects of military innovation that make it unique in the manner that martial knowledge is a unique type of knowledge. Just as the definition of technology was a useful first step to explore its relationship with military change, the definition of innovation must precede any detailed discussion of the relationship between technology and military innovation. Even in colloquial use, innovation has a wider range of possible definitions than technology does, but it often means something along the lines of the definition given by Matt Ridley, the controversial popular author and member of the British House of Lords, as "finding new ways to apply energy to create improbable things and see them catch on...[T]he word implies developing an invention to the point where it catches on because it is sufficiently practical, affordable, reliable and ubiquitous to be worth using."[296] This definition focuses on novelty and adoption, which are important features to definitions of innovation, but the technology triad can help build off these concepts to produce a more comprehensive framing of innovation that is specifically tailored to military technology. The various definitions for innovation from different human endeavors can provide a foundation upon which to develop this definition of innovation that is compatible with and leverages the logic of the technology triad.

Recognizing that innovation is critical to success in competitive ventures, a robust body of literature exists that is related to innovation and how it affects competition between people exists complete with a wide range of definitions. A full review of this literature is both beyond the scope of this dissertation and not necessary to demonstrate some of the key ideas bound up in the concept of innovation to understand the relationship between military innovation and the technology triad. In research that focuses on how groups of people change over time, innovation can mean anything from invention, the mental process of producing something new, to commercialization, the adoption of inventions by bringing them to market, and everything in between.[297] Invention as a way to understand innovation comes from anthropological and sociological studies of change within groups of people and stresses the novelty of some new way of thinking.[298] Economists often distinguish between invention and

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[296] Matt Ridley, *How Innovation Works: Serendipity, Energy and the Saving of Time.* (Place of publication not identified: Harper Collins, 2020), 4.
[297] Godin, *Models of Innovation*, 34–35.
[298] Benoît Godin, *The Idea of Technological Innovation: A Brief Alternative History* (Cheltenham, UK ; Northampton, MA: Edward Elgar Publishing, 2020), 20.

commercialization of those inventions when they address innovation.[299] The definition of innovation in the previous paragraph is a good example of this distinction. However, economists do not necessarily hold that the innovator is also the originator of an idea, as the definition in the previous paragraph implies.[300] Representing full use of these concepts, one of the most influential works on innovation in the business world, Clayton Christensen's *Innovator's Dilemma,* adopts a functional definition of innovation that is best characterized as effectively combining invention and adoption of new technologies, which include both artifacts and techniques, within an organization.[301] The presence of both a new idea and the adoption of that new idea is important to the relationship between the technology triad and military innovation. But without further refinement, novelty and adoption fail to indicate why a new idea is adopted.

Concepts related to environmental fitness in evolutionary biology build off of simpler definitions of innovation and can help explain why a military may adopt a new idea, piece of equipment, or practice despite the apparent stabilizing effect of prior knowledge and slow-changing material solutions. Framings of innovation derived from biological research build on the requirement for novelty and adoption to add a consideration for how the adopted changes of a phenotypic trait describe the interaction of organisms and their environment. In this space, innovation generally means a significant change to more than one member of a population that confers an increased fitness on those members that lead to a significant impact on the community or

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[299] Godin, *Models of Innovation*, 27.
[300] Godin, 35.
[301] Clayton M. Christensen, *The Innovator's Dilemma: The Revolutionary Book That Will Change the Way You Do Business*, 1. Collins Business Essential ed., [25. Nachdr.] (New York, NY: Harper Business, 2010).

environment.[302] The increased fitness qualification for biological innovation implies that change must positively increase some desired trait to qualify as innovation. This increase in capability, in turn, has an impact on the larger system.

Andrew Maynard used a similar qualification in his work on responsible innovation to distinguish between simple novelty and the “focused, targeted, purposeful change” that “provide sufficient value to others that they are willing to invest in them” to create truly innovative changes.[303] The requirement for an innovation to be a positive change along some spectrum of value, presumably the ability to win wars for a military, provides an explanation for why a military would overcome the structural barriers to change. If a military believes that the innovation will increase its ability to perform its core function, it will change. In the language of the technology triad, the military that adopts an innovation holds as truth, as verified by its knowledge system and reinforced by its material and doctrine, that the innovation brings the military more in line with the best way to fight a war.

The technology triad introduces a way to think about military change that can account for the basic elements that define an innovation in general and clarify ambiguous points within the existing literature specifically focused on military innovation. Thomas Mahnken defined defense innovation as “the transformation of ideas and knowledge into new or improved products, processes, and services for military and dual-use applications.”[304] Mahnken’s use of ‘defense’ innovation is an important distinction.

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[302] Michael E. Hochberg et al., “Innovation: An Emerging Focus from Cells to Societies,” *Philosophical Transactions of the Royal Society B: Biological Sciences* 372, no. 1735 (December 5, 2017): 4, https://doi.org/10.1098/rstb.2016.0414.
[303] Andrew Maynard, *Future Rising* (Coral Gables: Mango Publishing, 2020), 118.
[304] Thomas G. Mahnken, “Innovation in the Interwar Years,” *SITC Research Briefs* Series 10, no. 2018–11 (May 30, 2018), https://escholarship.org/uc/item/1hw200dw.

Within military innovation literature, scholars refer to three levels of innovation. The highest level is strategic, which is the responsibility of civilian leadership and refers to all national efforts, military and civilian, related to fighting wars. The next level down is the previously mentioned defense innovation, which is the nexus between civilian activities, such as industry, and military operations. The lowest level in this construct is military innovation, which refers specifically to operational and tactical matters in the conduct of combat.[305] Distinguishing between these three levels may be helpful for specific inquiries, such as wartime mobilization and defense industrial capacity related applications, but they become less helpful when addressing innovation in warfighting writ large. The line between tactical actions and strategic actions is blurred in some of the most important military activities national leadership engages in, such as nuclear strikes or special operations raids. Additionally, the model is appropriate for the United States military, where the line between military and civilian is carefully managed through various civil-military norms, but this distinction is not universally applicable to the world's militaries. There are, however, obvious differences between the strategic actions a nation takes to compete with other nations and the tactical actions in which the militaries of those two nations might engage.

The technology triad's focus on the discontinuous nature of war and peace provides a framing that can address these differences. In strategic interactions, adversarial nations are constantly in competition with each other. This means they are in a position to test the fitness of their martial knowledge for the current reality shared between the two nations. Unless the nations are engaged in combat, the tactically oriented aspects of

[305] Cheung, Mahnken, and Ross, "Frameworks for Analyzing Chinese Defense and Military Innovation," 17.

martial knowledge remain true only within the confines of the reality constructed by that military in peacetime. By framing strategic and 'military' innovation as such, the technology triad can apply equally and evenly to each layer of Mahnken's hierarchy. As the focus of this dissertation is innovation within military aspects of strategy, while acknowledging the other elements of national power are vital as well, the term 'military innovation' remains appropriate, but with the broader view that it encompasses tactics, strategy, and everything in between.

The technology triad can also provide a means to address the inclusion of changes that are either new *or* improved. Mahnken's use of innovation is broad enough to include any change at all as an innovation. Grissom's definition of innovation from the previous chapter as "a change in operational praxis that produces a significant increase in military effectiveness" specifies that innovation must be an increase in military effectiveness.[306] Between these two definitions, the technology triad would support Mahnken's broader conception, but not because any change at all should be considered innovation. Clarity on this point can come from the literature on responsible innovation, where the direction of innovation is intended to increase value for some person or group of people. As the technology triad is a way to describe how a military constructs, maintains, and changes its local reality, any deliberate changes that it makes, as long as they are consistent with the martial knowledge that it holds as true, are improvements in the reality within which it resides. This removes the requirement of hindsight from the identification of innovations that would otherwise be necessary if one would consider military

[306] Grissom, "The Future of Military Innovation Studies," 907.

effectiveness absolute. The only way one could determine that would be looking back on the outcome of a war.

Grissom's consensus definition of military innovation introduced another point of ambiguity when he specified that an innovation must produce a *significant* increase in military performance. This leaves the precise definition of "significant" up to the observer to apply their judgment. Some increases are clearly more significant than others, but there are many changes that a military could make that would fall somewhere in between insignificant and significant. Andrew Ross addressed this observation by articulating that military innovation is best thought of as a continuum with minor changes on one side and major changes on the other, and "innovation encompasses both…and spans the spectrum between the two."[307] In Ross's framing, revolutionary change occurs when a number of minor discontinuous changes in weapons and doctrine align and reinforce each other to produce a major discontinuous change on the full system.[308] By labeling all change as innovation, Ross successfully removes the subjectivity inferred in requiring 'significant' change for innovation, but the introduction of 'revolutionary change' more or less takes the place of innovation in the normal use of the word.

Terry Pierce's military application of Christensen's disruptive technologies framing from the civilian business literature addresses the level of change necessary to qualify as an innovation in much the same way the technology triad does. In Pierce's model, an innovation occurs when a new technology is developed and is successfully paired with doctrinal changes to incorporate that technology that changes the manner of fighting in a way that was not consistent with the military's previous judgments of

[307] Ross, "On Military Innovation," 2.
[308] Ross, 3.

worth.[309] Rosen lauded Pierce's work as an improvement on Rosen's own research and a significant development in the thinking regarding military innovation and its distinction from other types of change.[310] However, as Pierce's framing is more or less a direct application of a model developed for technology innovation in the civilian business environment, it fails to account for the differences between these two environments related to the continuous and discontinuous presence of competition.

Christensen's model of disruptive technologies was built specifically to be practically applicable for civilian business managers. He derived four principles of disruptive technology from the research upon which his model is built. These principles do not neatly transfer to military application. The first is that companies must keep their customers happy to succeed. From this observation, Christensen found that good management within companies focuses on those products that have met their customers' needs in the past. [311] Militaries do not have customers in the same sense that a company does. While a military may have a duty to serve a society, how the military performs this service is largely left up to the military as long as it continues to adhere to the values of the society which it serves. Second, Christensen built a portion of his model on the observation that companies need to continue to grow to serve their shareholders.[312] In contrast, many nations would prefer if their military would perform their function for society on a shrinking budget, especially when the perceived threat of war is low. Third, Christensen noted that companies often require quantitative analysis on the expected

[309] Pierce, *Warfighting and Disruptive Technologies*, 25–26.
[310] Pierce, vii.
[311] Christensen, *The Innovator's Dilemma*, 264.
[312] Christensen, 265.

return of new products, which is impossible for a disruptive technology.[313] This is similar to the idea that peacetime innovations in a military must be undertaken without foreknowledge of how that innovation will perform in combat, but militaries create complex knowledge systems to test concepts and produce martial knowledge. In contrast, Christensen found that companies will more often fail to take chances on new products because the outcome is too risky. Finally, Christensen's explicit belief in the general tendency of new technologies to "move toward [improvements in] reliability, convenience, and price" does not translate directly to a military technology where older technologies may be better suited for the strategic environment of some future war.[314] These foundational inconsistencies between the civilian business environment and military competition induced Pierce to draw a sharp distinction between doctrinal and materiel innovations to account for the historical record where some disruptive material changes did not translate to innovation.[315]

The technology triad illustrates how any change to materiel or doctrine will have some influence on the other owing to the complex relationship between these two nodes and how martial knowledge can account for those instances where changes did not produce innovation. Despite these foundational differences between the technology triad and Pierce's disruptive innovation model, the broad strokes of innovation happening outside of previous estimations of worth are complementary, and Pierce's insights are a

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[313] Christensen, 265.

[314] Christensen, 266; Bobby Sickler, "Elon Musk Says Drones Are the Future of War, but He Should Consider Horses," Medium, May 6, 2020, https://onezero.medium.com/elon-musk-says-drones-are-the-future-of-war-but-he-should-consider-horses-1176d9970b62.

[315] Pierce, *Warfighting and Disruptive Technologies*, 25.

useful point from which to build a technology triad derived formulation of military innovation.

Building off of the foundation provided by the technology triad, military innovation becomes the creation of a new martial knowledge, through the falsification of some previously held truth or generation of some previously unknown truth, along with the accompanying changes in materiel and doctrine to align with and support this new martial knowledge. In the discussion above related to Kuhn's critique of Popper's assertion that the conduct of science is a search for falsification, Kuhn demonstrated that, in practice, scientists do not actively seek to falsify existing truths.[316] Similarly, the idea that innovation is related to proving a previous martial knowledge false is not intended to imply that there is a deliberate effort to assault existing martial knowledge within militaries or that falsification is a necessary component to innovation. Rather, the key point is that the military in question's understanding of reality has shifted in some non-trivial way. This broader definition embraces the idea that reality for the military in question is locally constructed and not subject to some outside measure of effectiveness until the military engages in combat. As each instance of combat can be completely different, there is no way to determine the fitness of the locally defined reality of any one military compared to future adversaries, the way the evolutionary biology definition uses fitness for the environment as a measure of innovation. Similarly, the broader environmental impact of an innovation, which would be a change to the character of war, is not a necessary component in this framing of innovation, despite its presence in many

[316] Kuhn and Hacking, *The Structure of Scientific Revolutions*.

definitions of military innovation, because without the specific war, the innovation will be tested in, there is no way to determine its usefulness.

This definition of innovation does retain several aspects of the previously discussed framings of innovation. It fits Maynard's qualification that innovation requires a deliberate change to improve.[317] The military redefines its reality, and the rest of the triad adjusts to align with this new reality in a way that optimizes the likelihood of success in terms of the reality as it exists for the military in question. The innovation impacts more than just one person, which would be invention to an economist, because the reality creation is a social process that impacts every member of the military. Finally, in this definition, innovation is a significant departure from the previous state, just as in biological, Christensen's, Pierce's, and Grissom's definitions, because reality in its totality has been reframed. With its focus on changes in martial knowledge, this definition of military innovation may seem to contradict earlier sections that emphasize that the relationship between the three nodes is reciprocal. Approaches to business management informed by complex adaptive systems can help demonstrate how changes within the technology triad develop in militaries to the point where martial knowledge is redefined and a military innovates.

### ***Complexity Leadership Theory***

Discontinuous change is an important element of innovation, but it is difficult to identify with linear thinking. Linear thinking implies that changes, no matter how great they are, are a natural evolution of the past because it fails to account for the other

[317] Maynard, *Future Rising*, 118.

influences on a system that can induce change. In contrast, complexity thinking, with its emphasis on concepts like interconnectedness and critical points, can help bring the nature of discontinuous change into focus, even without the aid of hindsight. In his book, *Models of Innovation*, Benoit Godin identifies two general models for how people produce innovation. The first is a process that follows the development of a new technology or idea sequentially in time.[318] Some of the most recent works on military innovation use these sorts of models for the steps that an innovation takes from conception to adoption in a military.[319] However, as Godin explains in his book, temporal models of innovation have largely given way in current innovation research to structural models that emphasize large sociotechnical systems and the interactions within them that produce new ideas.[320] Despite the more comprehensive explanations possible with structural models of innovation, temporal models retain their popularity as rhetorical tools for the same reason they became popular in the first place; they are easy to understand and translate to concrete actions, like budgets, in organizations.[321] Complexity Leadership Theory (CLT) provides a framework that helps contextualize the interactions that produce innovations and the discontinuous changes they represent within an organization while still providing concrete actions leaders can take and without oversimplifying the system.

Complexity Leadership Theory draws extensively from the broad implications of complex adaptive systems science. There is no unifying "complexity theory." Rather, it is

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[318] Godin, *Models of Innovation*, 5.
[319] Tai Ming Cheung, ed., *Forging China's Military Might: A New Framework for Assessing Innovation* (Baltimore: Johns Hopkins University Press, 2014); Horowitz and Pindyck, "What Is Military Innovation? A Proposed Framework."
[320] Godin, *Models of Innovation*, 218.
[321] Godin, 78.

the general study of complex systems, which are "systems[s] that exhibit nontrivial emergent and self-organizing behaviors."[322] Importantly, the emergent behavior of a system can be difficult or impossible to predict based on the actions of the elements, or agents, within the system. Complex adaptive systems are a special class of complex systems that, when evaluated at the level of their emergent behaviors, process information about their environment and make changes in response to that information.[323] The study of complex adaptive systems has proven useful in a wide range of applications, from the biological sciences as a predictive tool to describe evolution to the study of international relations and military command theory as a metaphor for the behavior of social systems.[324] Many of the core concepts associated with science and technology studies, like sociotechnical systems, also benefit from an application of complexity thinking to social systems.[325]

Complexity Leadership Theory is the most prevalent of several similar frameworks that apply the concepts of complex adaptive systems science to the management of social systems.[326] Developed by Mary Uhl-Bien in 2007, CLT conceptualizes the role of leadership within organizations as either adaptive,

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322 Melanie Mitchell, *Complexity: A Guided Tour* (Oxford [England] ; New York: Oxford University Press, 2009), 13.
323 Mitchell, 13.
324 Stuart A. Kauffman, *The Origins of Order: Self-Organization and Selection in Evolution* (New York: Oxford University Press, 1993); David S. Alberts and Richard E. Hayes, *Power to the Edge: Command, Control in the Information Age*, Information Age Transformation Series (Washington, DC: CCRP Publication Series, 2003); Robert Maxfield, "Complexity and Organization Management," in *Complexity, Global Politics, and National Security*, First Printing (Washington, D.C.: National Defense University, 1997).
325 Allenby and Sarewitz, *The Techno-Human Condition*.
326 Jonathan Rosenhead et al., "Complexity Theory and Leadership Practice: A Review, a Critique, and Some Recommendations," *The Leadership Quarterly* 30, no. 5 (October 2019): 101304, https://doi.org/10.1016/j.leaqua.2019.07.002; Benyamin B. Lichtenstein and Donde Ashmos Plowman, "The Leadership of Emergence: A Complex Systems Leadership Theory of Emergence at Successive Organizational Levels," *The Leadership Quarterly* 20, no. 4 (August 2009): 617–30, https://doi.org/10.1016/j.leaqua.2009.04.006.

administrative, or enabling leadership. In her model, adaptive leadership represents the forces of emergent adaptation within a complex adaptive system, administrative leadership represents the force of bureaucratic "top down" management of organizations, and enabling leadership represents those actions that manage the relationship of the other two forces. Together, the three types of leadership provide a framework for organizations to achieve the efficiency of centralized management structures and the adaptability of less formal structures.[327]

Michael Arena, the former Chief Talent Officer at General Motors, worked with Uhl-Bien to develop an organizational model of innovation from the core concepts of CLT that described the practices he used at General Motors. This model, called "adaptive space," forms a synthesis of Godin's temporal process and spatial structure models of innovation by designating roles for leaders within organizations corresponding to portions of the lifespan of an innovation that emphasizes complex relationships between people.[328] The adaptive space is broken into four temporal steps of innovation: discovery, development, diffusion, and disruption. These steps are the product of interactions between specific leaders within an organization, or society at large, that perform the functions required for the step.[329] The ability to produce a usable model of innovation without sacrificing the messiness of complex systems demonstrates the potential

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[327] Mary Uhl-Bien, Russ Marion, and Bill McKelvey, "Complexity Leadership Theory: Shifting Leadership from the Industrial Age to the Knowledge Era," *The Leadership Quarterly* 18, no. 4 (August 2007): 298–318, https://doi.org/10.1016/j.leaqua.2007.04.002; James K. Hazy, Jeffrey Goldstein, and Benyamin B. Lichtenstein, eds., *Complex Systems Leadership Theory: New Perspectives from Complexity Science on Social and Organizational Effectiveness*, Exploring Organizational Complexity Series, v. 1 (Mansfield, MA: ISCE Pub, 2007).

[328] Michael J. Arena, *Adaptive Space: How GM and Other Companies Are Positively Disrupting Themselves and Transforming into Agile Organizations* (New York: McGraw-Hill, 2018); Mary Uhl-Bien and Michael Arena, "Complexity Leadership," *Organizational Dynamics* 46, no. 1 (January 2017): 9–20, https://doi.org/10.1016/j.orgdyn.2016.12.001.

[329] Arena, *Adaptive Space*, 101–2.

usefulness of a CLT approach to military innovation and a possible way forward to describe how the technology triad could undertake periods of significant change.

Recently, complexity science applications to organizational leadership have suffered harsh critiques that scholars who espouse frameworks like CLT oversell the power of complexity science to explain the behavior of social organizations compared to traditional management concepts and create a philosophical inconsistency in the process. This critique stems from CLT's explicit rejection of positivist management techniques as ill-fated attempts to control social complexity at the same time that CLT also appeals to the predictive power of the natural sciences to make strong claims about the potential of complexity applications to leadership.[330] Regardless if CLT is more appropriately used as a metaphor or as a predictive tool, it can still be a valid framing to provide useful insights about the relationship between technology and military innovation. In fact, the technology triad outlined above is at its core a modification and adaptation of several disparate academic theories combined in a way to address a weakness in the security studies body of research and say something useful about real organizations. In this regard, a broad range of options exists to leverage the explanatory power of CLT without creating philosophical inconsistencies within the technology triad.

### *Complexity, Innovation, and the Technology Triad*

Complexity Leadership Theory and the ideas that undergird it are useful lenses to explain how innovation progresses within the technology triad. Framing innovation within the technology triad capitalizes on the advantages of combining temporal process

[330] Rosenhead et al., "Complexity Theory and Leadership Practice."

and spatial structure models of innovation provided by CLT but also adds a new dimension related to the way changes to elements of the technology triad impact the creation of new realities within militaries. The resultant three-step model describes the way new realities start and spread within an organization both temporally and spatially. This produces a model of innovation that is consistent with the underlying logic of the technology triad, which is itself a combination of temporal, spatial, and epistemological dimensions.

*Autonomy*

Innovation starts with the ability to make some change to one of the elements of the technology triad outside the established reality. It is important to note that the spark of innovation can start in any one of the three elements of the technology triad. A new materiel solution, a new doctrinal approach, or just a new idea can each start a military on the path to innovation, and the ability to change one of these elements may take any number of forms in practice. It could refer to physical ability, such as access to the resources to design and build a new materiel solution, or ability could also represent the authority to change an element of the technology triad in militaries with more rigid command structures. The key consideration is that the person or people making the change have the autonomy to deliberately conduct their activity out of line with the established reality of the military.

Drawing inspiration from Uhl-Bien's concept of adaptive leadership, innovation can start at any level in the organization where there is autonomy to act.[331] It is neither a

[331] Mary Uhl-Bien and Russ Marion, "Paradigmatic Influence and Leadership: The Perspectives of Complexity Theopry and Bureaucracy Theory," in *Complex Systems Leadership Theory: New Perspectives*

top-down nor a bottom-up concept of innovation. This is consistent with the way innovations start in real organizations, where they may be the product of an inspired leader or the result of tinkering by those at the lowest levels in the organization. An autonomy-centered model for the genesis of innovations also accounts for both the formal and informal genesis of innovations. The historical record contains instances when new realities were the result of deliberate processes where autonomy was purposeful and those when it was the result of a loosely connected system. As a concept for innovation generation, autonomy differs from the discovery step in applications of CLT in *Adaptive Space* by allowing for innovation to be precipitated from changes in materiel and doctrine as well as in knowledge.[332]

Existing literature on innovation does normally account for aspects of autonomy, either formal or informal, but does not use the term "autonomy" specifically. In Law and Callon's study on the development of the Tactical Strike Reconnaissance aircraft in the Royal Air Force in the 1950s, they advocated for the establishment of complementary local and global organizational networks to develop new technology. In their formulation, the local network would have the authority to take actions free of the constraints of a global network, which would be responsible for ensuring the outputs of the local network meet the needs of the larger organization.[333] In another example of formally generated autonomy, the 2000 report on transforming the U.S. Navy stated that their "research has demonstrated that the best way to foster innovation in a large bureaucracy is to create

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*from Complexity Science on Social and Organzational Effectiveness*, vol. 1, Exploring Organizational Complexity Series (Mansfield, MA: ISCE Pub, 2007).
[332] Arena, *Adaptive Space*.
[333] Law and Callon, "The Life and Death of an Aircraft: A Network Analysis of Technical Change," 46.

enclaves that can operate as small organizations."[334] Informal autonomy is the central theme of a recent book by Matt Ridley, called *How Innovation Works,* where he stated that "the main ingredient in the secret sauce that leads to innovation is freedom."[335] Christensen's research on innovation in computer companies mirrored this conclusion when he observed that innovative designs were "almost always" the result of engineers experimenting with bootlegged components.[336]

Autonomy represents a point on the temporal path of innovation, an activity performed by those who innovate, and a challenge to the established reality of a military. Whether formal or informal, autonomy to take deliberate action outside the widely accepted reality of an organization is the first step of innovation. The presence of autonomy alone is not enough to spark innovation. Some person within the system must act to alter one of the elements of the technology triad. The alteration that the innovator makes to the technology triad must be outside of the established reality. If a person exercises their autonomy to alter an element of the technology triad within the established reality, they are simply improving performance within the existing reality. Only by challenging the established reality can the process of upending that reality begin.

*Development*

Once some change has been made to one of the elements of the technology triad, it cannot become innovation until it also influences changes within the other two

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[334] Brad Hayes et al., "Transforming the Navy" (Newport, RI: Naval War College, 2000), 13; Jensen built on this idea when he highlighted the important role that "incubators" play in the development of new theories of victory in Jensen, *Forging the Sword*.
[335] Ridley, *HOW INNOVATION WORKS*, 359.
[336] Christensen, *The Innovator's Dilemma*, 49.

elements of the triad. Once all three of the elements of the triad have been changed to conform to the new reality implied by the original change to a single element, the process shifts from the autonomy phase to the development phase. Autonomy is still required for development, but now the purpose of the ability to act outside the established reality is to take the nascent change to a single element of the technology triad and develop the reality that the change implies fully by aligning the other two elements of the triad. This creates a new technology triad within the original one. This new technology triad embodies its own understanding of reality. The whole process can be envisioned as fractal in nature, a common feature in complex systems.[337] Within the larger, dominant technology triad, smaller technology triads grow and develop.

Development is a nearly direct application of the second step with the same name in the version of CLT advocated in *Adaptive Space*.[338] Development in CLT focuses on taking new ideas and refining them. The technology triad model of innovation alters this by allowing changes to materiel and doctrine to also serve as the catalyst for innovation. This change may be irrelevant at the individual level because whatever person altered some aspect of materiel or doctrine must have initiated that change because of an idea that they had. However, shifting the focus from ideas alone to the other two elements of the technology triad allows the idea to scale to full organizations. Within the technology triad, a change to martial knowledge may be a collective effort undertaken at a school or in the professional journals before it takes the next step to development with the requisite

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[337] Geoffrey B. West, *Scale: The Universal Laws of Growth, Innovation, Sustainability, and the Pace of Life in Organisms, Cities, Economies, and Companies* (New York: Penguin Press, 2017), 130.
[338] Arena, *Adaptive Space*, 54.

changes to materiel or doctrine. Similarly, a change to doctrine or materiel alone does not constitute development until a complementary martial knowledge is also developed.

Similar to autonomy, development as a concept is present within the innovation literature, but it is rarely explicitly defined as it is in *Adaptive Space*.[339] Christensen highlighted the importance of development when he observed that organizations tend to under resource innovations that challenge the accepted manner of conducting business.[340] In his application of Christensen's ideas to the military, Pierce argues that successful innovations are the result of innovators disguising their new idea as simple enhancements to the existing paradigm.[341] Both of these approaches apply the implicit assumption that an established organization will resist change as a matter of course. The technology triad adopts a more neutral approach by observing that innovation simply requires the development of a new reality, whether that is enabled by manipulation of organizational systems or through a military's desire to explore new ways of achieving its organizational objectives.

The cost of failure is high in military affairs, and upending an established reality is not a task that militaries undertake without good reason to believe that this is the best action. The novelty of an idea, materiel solution, or technique is not enough to create innovation alone. Before an innovation can proceed to the final stage, those within the organization must be assured that fundamentally altering the truths that they hold creates value.[342] The perceived ability of the new reality to create value for the organization determines which innovations to continue to pursue and which ones to abandon. During

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[339] Arena, 54.
[340] Christensen, *The Innovator's Dilemma*, 50.
[341] Pierce, *Warfighting and Disruptive Technologies*, 31.
[342] Maynard and Garbee, "Responsible Innovation in a Culture of Entrepreneurship: A US Perspective."

this phase, militaries allocate resources to change each of the elements of the technology triad and build the initial idea into a full alternate reality within the military. At the end of the development phase of innovation, multiple competing realities exist within the military.

### *Disruption*

Innovation is complete when a new dominant reality emerges. This could be the result of the new reality overtaking the previous one, or the new reality could be a synthesis of the two competing realities. The key qualifier of innovation is that the previous reality no longer holds up to the challenges of the martial knowledge, materiel, and doctrine of the new technology triad. In theory, this transition is distinct and clean. In practice, the shift from one reality to another is messy and ill-defined. Elements of the old reality, whether aging materiel or traditions masquerading as prior knowledge, always remain in the new reality. However, the way the members of a military understand reality and its implications for warfighting will have shifted.

Disruption is a combination of the diffusion and disruption phases of CLT. This allows the technology triad to shift the focus from the actions of individuals within the organization to the scales necessary to describe the emergent epistemological and physical behavior of groups of people.[343] In peacetime, the transition tends to be slow and difficult to recognize, as the previous technology triad shifts at the pace of organizational processes. The tension between the new reality and old reality manifests itself in each of the elements of the technology triad simultaneously. For example, testing and

[343] Arena, *Adaptive Space*, 101–2.

experimentation are conducted with mixtures of old and new materiel solutions and doctrine. Over time, each element of the technology triad conforms to the new reality. The different rates of change of each element prevent a clean departure from one reality to another. In wartime, the transition can be almost immediate as one military demonstrates a superior reality for the specific environment in which the war takes place. The military experiencing a rapid shift in martial knowledge may have to find ways to use materiel and doctrine from the previous reality to operate as those elements lag, but over time the three elements of the technology triad align to produce an established reality.

This process draws inspiration from dialectic models of change. Hegelian dialectics tend to imply a progressive evolution towards some objectively ideal state owing to the complex logic Hegel used to develop his ideas.[344] The dialectic nature of innovation within the technology triad does not imply that the new reality is objectively better than the old one. Rather, it is important to note that the reality that emerges after the interaction of the old technology triad and the new one is the one that is most appropriate, or optimal, according to the members of the military in question. Sequentially, the process follows the general scheme where there is an existing reality, then a new technology triad challenges that reality, and an emergent reality that is a combination of the two realities forms. The process changes a military's perception of reality to the degree it is no longer compatible with the original reality similar to the way Kuhn described that science undergoes paradigm shifts.[345]

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[344] Frederick C. Beiser, *Hegel*, 1st ed, Routledge Philosophers (New York ; London: Routledge, 2005).
[345] Kuhn and Hacking, *The Structure of Scientific Revolutions*.

Dialectic models of change related to military affairs already exist in the literature; the technology triad adds the materiel element to these framings. Clausewitz's fundamental framing of war was a dialectic between states to impose their will through violence.[346] Berger and Luckman echoed Clausewitz when they explained how societies could impose the reality defined by their unique socially constructed knowledge through force.[347] When Osinga explained the development of doctrine, he leveraged the dialectic nature of deliberate change between new and existing ideas from structuration theory.[348] The technology triad builds on these ideas by recognizing the ability of materiel to influence each of these elements to produce an emergent reality. Materiel solutions from a new technology triad represent a dialectic relationship with old materiel solutions, just as knowledge and doctrine do because a specific martial knowledge and implied doctrine are embedded in the design and function of every materiel solution. Together all three elements of a new technology triad interact with the old technology triad to produce an emergent reality and the innovation that the shift represents.

### *Military Innovation Defined*

Previously, this dissertation defined innovation as the creation of a new martial knowledge, through the falsification of some previously held truth or generation of some previously unknown truth, along with the accompanying changes in materiel and doctrine to align with and support this new martial knowledge. This definition can be refined to incorporate the dialectic interplay of realities created by each technology triad. Thus

[346] Sun-Tzu and Clausewitz, *The Book of War*.
[347] Berger and Luckmann, *The Social Construction of Reality*, 125–27.
[348] Osinga, *Science, Strategy and War*, 108.

refined, military innovation becomes the emergence of a new reality from the dialectic interplay of competing technology triads.

This definition is distinct from definitions of innovation derived from systems that assume constant competition to evaluate the fitness of new innovations. For example, Christensen's model of innovation is a linear process defined by overlapping S curves of adoption over time.[349] This model requires constant competition to retain explanatory power because each step is "better" based on the performance of each new technology in relation to the environment. The technology triad model of innovation is complex and inwardly focused because the environment where the innovation will be tested, some future war, does not exist yet. Innovations are tested against a constructed reality within the military that is influenced and shaped by the previous elements of the technology triad. Only the crucible of combat can provide an outside reality against which to test new innovations. Even then, as discussed above, combat does not always present the conditions necessary to test certain aspects of constructed realities, depending on the assumptions that underpin the constructed realities; it must be what the military in question considered the "right kind of combat."

A definition of innovation as the creation of a new reality is practically useful for the management of innovations within militaries to achieve strategic objectives. This model embraces the general idea found in the preponderance of the literature that only major changes count as innovations.[350] Ross presented a strong critique of this approach when he said that "the emphasis on major, large-scale innovation, rather than viewing a

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349 Christensen, *The Innovator's Dilemma*, 45.

350 Grissom, "The Future of Military Innovation Studies."

spectrum from small- to large-scale, excludes much innovation."[351] The distinction between these two approaches depends on where the line between change and innovation is drawn. The technology triad does recognize that change is ever-present in militaries, but it only reaches the level of innovation when it creates a new reality. This new reality can provide a significant advantage to a military over its adversaries because they enable the ability to act outside the adversary's understanding of reality. When Bloch lamented that the Germans had redefined the concept of time in operations, he was expressing regret that the Germans were able to operate outside the French understanding of reality.[352] Secretary Carter expressed a similar idea when he said that changes in technology are producing an environment where "sometimes we don't realize we are being attacked when we are being attacked."[353] By framing innovation as those changes which enable the creation of a new reality exclusively, the technology triad provides a way forward for militaries to actively gain and maintain the position of relative advantage that a new reality provides.

**Conclusion**

Science and technology studies concepts, specifically ideas related to sociotechnical systems and socially constructed knowledge, provide a useful lens through which to reimagine the relationship between technology and military innovation. The application of these basic concepts to the conduct of militaries creates a model that describes how military socio-technical systems evolve. It is equally descriptive for cases

[351] Cheung, Mahnken, and Ross, "Frameworks for Analyzing Chinese Defense and Military Innovation," 21.
[352] Bloch, *Strange Defeat*, 37–38.
[353] *Technology, Innovation, and Modern War*.

of stasis and massive change and does not rely on imposing worldview to those inside the system that they may not hold themselves. In practice, each of the three elements of the technology triad, martial knowledge, materiel, and doctrine, change at different rates. The complex interactions of these elements changing at different rates produce an emergent understanding of reality for the military in question.

The autonomy to make a change to one of the three elements of the technology triad creates the conditions for the development of a new technology triad and the reality that it embodies. This new reality competes with the pre-existing reality to produce a new reality and subsequent technology triad. This process of reality creation, or disruption, creates a distinction between change and innovation. Distinguishing between changes that occur within pre-existing realities and innovations that create new realities allows for a more comprehensive analysis of military capabilities and can inform strategic choices. Many of the most horrific military events in history were the result of two militaries engaging in combat from two completely different realities. One cannot help but wonder if the French may have been better prepared to defend their families from aggression had they been able to appreciate the misalignment between their own technology triad than that of the Germans.

The ideas in this chapter were presented largely without historical references to focus on the ideas and their relation to existing research. However, the technology triad as a model and the concept of innovation within the technology triad emerged from careful study of the development of tanks and armor development in the U.S. Army prior to World War II. The next chapter will give an account of this innovation in terms of the technology triad to provide further context for the ideas with the model and demonstrate the application of the technology triad to a historical case.

"We must recognize that we are living in a machine age and in the interest of National Defense the Army must 'cut its cloth' accordingly."

-Proceedings of the War Department board to make recommendations for the development of a mechanical force, 1 October 1928[354]

# CHAPTER 4

# TANKS AND THE U.S. ARMY PRIOR TO WORLD WAR II

## Introduction

The development of armored warfare represented a fundamental shift in the conduct of ground combat. First developed to break the stalemate of trench warfare in World War I, tanks and the various doctrines that dictated their employment had altered basic considerations of space and time on the battlefield by the eve of World War II.[355] This well-documented transition over a relatively short period of time produces a useful case study to explore the relationship between technology and military innovation. As a framing for military innovation, the technology triad resulted from careful study of the development of armored warfare within the U.S. Army prior to World War II combined with the lessons and insights of previous research related to technology, knowledge systems, innovation, and military history. This chapter will serve as a tool to demonstrate the ability of the technology triad to provide novel insights and to further explain the

[354] Charles S. Lincoln, "A Mechanized Force" (Proceedings of a Board Officers convened by S.O. 110, W.D. 1928 re Mechanized Force, October 1, 1928), 5, 84-20, U.S. Army Heritage and Education Center, Carlisle Barracks.
[355] Fuller, *Tanks In the Great War*; Bloch, *Strange Defeat*.

concepts within the technology triad through application to the historical case of military innovation from which the model was originally derived.

The core of the data that informs this case study comes from the annual addresses of the US Army branch chiefs to the student body of the U.S. Army War College through the 1930s. Major General Lynch, the Infantry Branch Chief in 1938, explained that "it has become customary for Chief of Branches each year to appear before the War College class to outline the activities of their offices and the current developments within their respective branches. It is in no sense the purpose of these discussions to achieve instructional result but rather to present a picture of what is passing through our minds in our approach to the several problems confronting us."[356] As such, these speeches serve as an ideal record of the state of the U.S. Army and the official positions and views of its leaders related to events that happened nearly 100 years ago. Furthermore, the extensive question and answer transcripts at the end of most of the speeches provide more candid remarks by the U.S. Army leadership in response to the concerns of the mid-grade officers within the U.S. Army at the time. In order to fill in the gaps left by these formal addresses and paint a more comprehensive picture of the time period, this dissertation draws from published U.S. Army doctrine from the era, official U.S. Army histories, personal papers of the key players, extensive records of the U.S. Army Ordnance Board proceedings, military research conducted in the inter-war period, and a limited number of secondary sources.

[356] George Lynch, "The Infantry" (Transcript of lecture delivered at the Army War College and discussion with audience, September 20, 1938), G-3 Course No. 5, 1938-1939, U.S. Army Heritage and Education Center, Carlisle Barracks.

As this dissertation draws heavily from primary source data and strives to allow the actors to speak for themselves when able, many of the common fixtures in histories of inter-war tank development are not as prominent as they are normally in the secondary literature. For example, the ideas propagated by J.F.C. Fuller and Heinz Guderian in the 1920s and 1930s only enter this case study if those ideas were directly addressed by the officers in the U.S. Army contemporaneously.[357] The ideas propagated by Fuller and Guderian were important to the final form that armored warfare would assume, but this eventual outcome was far from obvious to the U.S. Army officers addressing these same questions prior to World War II. Rather than starting from a known outcome of a global shift to mechanized warfare and working back to find those aspects that influenced its development, this dissertation employed research methods common in STS that allow the actors to speak for themselves and seeks to explain failure as well as success.[358] This approach to historical research enables the development of a model that challenges some widely accepted themes in the historical record and has the potential to be practically applicable without the advantage of hindsight.

That the U.S. Army copied the German model of armored warfare, even in principle, is one such common narrative that breaks down under the interactions that the technology triad can illuminate.[359] The U.S. Army's approach to armored warfare was a distinctly American innovation, which becomes clear when one allows the actors within

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[357] Fuller, *Tanks In the Great War*; Heinz Guderian, *Achtung-Panzer! The Development of Tank Warfare*, Cassell Military Paperbacks (London: Cassell, 1999); Harold R. Winton, *To Change an Army: General Sir John Burnett-Stuart and British Armored Doctrine, 1927-1938*, Modern War Studies (Lawrence, Kan: University Press of Kansas, 1988); Mahnken, "Innovation in the Interwar Years"; Dale Wilson, *Treat 'em Rough: The Birth of American Armor, 1917-20* (Novato, CA: Presidio, 1989), 231.
[358] Latour, *Reassembling the Social*; Bijker, *Of Bicycles, Bakelites, and Bulbs*.
[359] Mark D. Sherry, "Armored Force Organization," in *A History of Innovation: U.S. Army Adaptation in War and Peace* (Washington, D.C.: Center of Military History, 2009), 51; Wilson, *Treat 'em Rough*, 231.

the system to speak for themselves and builds understanding from a position that accepts the locality of knowledge.[360] There are even indications in the historical record that the German Army may have borrowed some early ideas on armored warfare from failed U.S. Army experiments in the late 1920s.[361] There is little doubt that the German successes in Poland and France had a profound impact on the shift in thinking about tanks in the U.S. Army, but painting this shift as an innovation born in Germany and adopted in, or diffused to, the United States is missing the full complexity of the story. Only because there was already an American version of martial knowledge related to armored warfare developing did the lessons from Europe find fertile ground in the U.S. Army to enable such a bold shift in a short period of time. This is a different manner of understanding and framing the way innovations occur in militaries than assuming an objective truth that each military slowly moves towards as it becomes more clear through the demonstration of other nations' abilities. Similarly, application of the technology triad to this case allows one to move beyond the assertion that George Patton and others like him were the profits of armor and the few voices of reason regarding the promise of tanks within a community of suicidal traditionalists who valued the romanticism of horse bound combat above all else.[362] These leaders were important figures in the development of American armored warfare once the idea started to spread within the U.S. Army, but over-focusing

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360 Arthur R. Wilson, "A Critical Analysis of the C. & G.S. Pamphlet Cavalry Mechanized," Individual Research (Fort Leavenworth, Kansas: The Command and General Staff School, March 23, 1934), IR#118-1934, Combined Arms Research Library, Ft Leavenworth.

361 "History of the Armored Force, Command and Center" (Washington, D.C.: Historical Section, Army Ground Forces, 1946), 6, N-14787, Combined Arms Research Library, Ft Leavenworth, http://cgsc.contentdm.oclc.org/cdm/ref/collection/p4013coll8/id/4448.

362 Katzenbach, "Tradition and Technological Change"; James Kelly Morningstar, *Patton's Way: A Radical Theory of War* (Annapolis, Maryland: Naval Institute Press, 2017), 67–72; Jennifer Mcardle, "Simulating War: Three Enduring Lessons from the Louisiana Maneuvers," War on the Rocks, March 17, 2021, https://warontherocks.com/2021/03/simulating-war-three-enduring-lessons-from-the-louisiana-maneuvers/.

on their limited role in the genesis of the martial knowledge obscures important considerations.

The model that results from the study of changing technology and military innovation related to the development of armored warfare in the U.S. Army prior to World War II highlights relationships and developments that may prove valuable to the effective contemporary management of change in militaries. The importance of interactions between and within socio-technical systems becomes clear with this approach. This allows the model to move beyond simplistic or hindsight-oriented explanations and biographical histories to embraces the complexity of the entire system as it existed. Insights that can inform the management of complex relationships and uncertainty are more useful for those who must make important decisions with long-lasting consequences, even if it does shift the focus away from some of the most entertaining or successful figures in the historical record.

When viewed through the lens of the technology triad, the development of armored warfare in the U.S. Army prior to World War II can be separated into four distinct periods characterized by the predominant interactions within the technology triad of that period. The first period stretches from the invention of the first tank through the end of the 1920s. This period is defined by a stable doctrine and martial knowledge that overwhelmed attempts to develop novel materiel solutions. The second period starts in 1929 with the establishment of an experimental mechanized brigade. This attempted innovation also failed, but for reasons related to insufficient autonomy to develop the doctrine and materiel solutions to align with a new warfighting concept. Once the experimental unit disbanded in 1931, the U.S. Army entered the third period where the

Cavalry and Infantry branches within the Army made incremental changes to their own technology triads in parallel. During this period, the martial knowledge and the materiel remained largely stable, and a new doctrine emerged in the military colleges. Additionally, this period demonstrates the fractal nature of technology triads as both the Cavalry and the Infantry systems were nested within a larger one represented by the full U.S. Army. The final period starts with the establishment of the U.S. Armored Corps in 1940 and represents innovation as the reality of the U.S. Army makes a fundamental shift when martial knowledge and materiel solutions adjust to align with the doctrine that developed during the third period. This final form of the technology triad is what the U.S. Army took to the deserts of North Africa at the beginning of the war.

**World War I and Dominance of the Infantry Branch**

While militaries introduced tanks in World War I, they would fail to achieve the status of a military innovation for the U.S. Army until the very eve of the next global conflict more than 20 years later. The earliest tanks, those that militaries invented, designed, and produced during World War I, showed great promise but were little more than enhancements for the existing doctrine and martial knowledge by the end of World War I. Despite a failure to achieve a shift in reality for the U.S. Army, the tank was a new material solution, the influence of which would shift over time with various social changes within the U.S. Army to ultimately enable a true military innovation. The extended period from the invention of the tank to innovation provides a rich landscape against which to analyze the complex interactions within the socio-technical system, and the technology triad provides that necessary framework to organize these interactions.

The tank started out as the quintessential materiel solution to a specific problem defined by a military knowledge system. In October 1914, just months into World War I, a British officer named Edward Swinton proposed the use of so-called "landships" to overcome the challenges associated with trench warfare and reintroduce mobility to the battlefield.[363] The martial knowledge and doctrine of the time were characterized by the use of large infantry formations to seize and hold terrain, a task made near impossible by early 20th century advances in automatic weapons and quick-fire artillery.[364] Brigadier General Rockenbach, the U.S. Tank Corps commander in World War I, exemplified the original intended purpose of the tank when he noted that "the functions of tanks are to make a path through obstacles for the infantry and to protect them from the destructive losses from machine gun and rifle fire."[365] He framed the tank's role in terms of the specific problems it was designed to overcome: enemy-emplaced obstacles and casualties inflicted by machine gun and rifle fire. But, as the British discovered at Cambrai, there was also an unintended consequence associated when armies employed a large number of tanks at a single time. In this battle, the British did not just protect the infantry but created a local breakthrough of the German lines with the tanks that allowed the British armored force to penetrate four miles past the German lines.[366] Despite this initial glimpse into the future of armored warfare, early tanks had severe mechanical limitations that prevented militaries of the time from developing the kinds of massive armored units that would swarm across these same European fields in just a few decades.

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[363] Fuller, *Tanks In the Great War*, 18; Brodie and Brodie, *From Crossbow to H-Bomb*, 196.
[364] Kramer, *Dynamic of Destruction*, 36–39.
[365] S. D. Rockenbach, "'Remarks of Brigadier General S. D. Rockenbach, Chief of Tank Corps, U. S. Army, at Conference of Department and Division Commanders, Held in Washington, D. C.' in 'Tanks With Infantry'" (Transcript of lecture, January 12, 1920), UD541.1.T3, U.S. Army Heritage and Education Center, Carlisle Barracks.
[366] Brodie and Brodie, *From Crossbow to H-Bomb*, 198.

Early tanks were slow, had limited visibility, and required a significant amount of maintenance to employ in military operations. The World War I Mark VIII tanks could only travel at a top speed of 4 miles per hour cross country. Inside the machine, the crews' only visual cues from the outside world were a four-inch slit a quarter of an inch wide and a small periscope.[367] A tank study on the tactical and technical means to control tanks in World War I conducted by the US Army Tank School in 1932 noted that "the considerable difficulty of outside observation by either the slits or the telescope, renders the vehicle, a machine so to speak, one which is blind."[368] These early tanks also required a "major overhaul" after only 9 or 10 miles of operation.[369] These combined characteristics of the tank imposed severe restrictions on how the Army could employ them for combat, demonstrating the limiting influence materiel solutions can have on both doctrine and martial knowledge. The technology triad also helps frame the reciprocal manner in which the knowledge system influenced the design of tanks.

Less than two years after the conclusion of World War I, Brigadier General Rockenbach described the influence of the knowledge system on tank design when he said, "the first thing to be decided and the first thing to get clear in your minds is as to what are the functions of the tank?" and "having decided on the functions of tanks, then

[367] Rockenbach, "'Remarks of Brigadier General S. D. Rockenbach, Chief of Tank Corps, U. S. Army, at Conference of Department and Division Commanders, Held in Washington, D. C.' in 'Tanks With Infantry.'"

[368] G. G. Ferris, "Tank Study: Tactical and Technical Means to Control Tanks Before, During, and After Combat, in 'Tank Studies Prepared by the Field Officers of the 1932 Class of the Tank School,'" 1932, UE 159.T36, U.S. Army Heritage and Education Center, Carlisle Barracks.

[369] Adna Chaffee, "Mechanization In the Army" (Transcript of lecture delivered at the Army War College and discussion with audience, December 12, 1930), 84-58, U.S. Army Heritage and Education Center, Carlisle Barracks.

naturally comes the question of their design."[370] The official U.S. Army history of the Ordnance Department in World War II illustrated this relationship as well, with the addition of doctrine and in reverse chronological order, when its authors stated, "the circle was endless: doctrine depended on tactical use intended; tactical use depended on what tanks were capable of; what tanks were capable of depended on developing models for predetermined use."[371] In both of these accounts, the knowledge system produced the basis for both doctrine and materiel solutions.

Although each element of the technology triad is a different facet of technology, the distinction between the nodes of the technology triad, materiel, doctrine, and martial knowledge, becomes clear when one considers the speeds that they changed within the U.S. Army. Recounting a story from 1919, Brigadier General Rockenbach, the commander of the US Tank Corps in World War I, provided actual measures of the times it took to adjust each of the elements of the technology triad. He explained that it took 12 hours to decide to build a new tank on a specific gun carriage (update the martial knowledge), 2 to 12 months to train tank operators (update the doctrine), and 18 months to build a tank (update materiel).[372] Each element of the technology triad updated at a different rate, defined by the types of changes that would have to take place for the update to occur. The martial knowledge only required the recognition of a new idea and could update much faster than the materiel, which required physically producing new equipment. These sorts of minor shifts to the technology triad related to tanks, such as the

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[370] Rockenbach, "'Remarks of Brigadier General S. D. Rockenbach, Chief of Tank Corps, U. S. Army, at Conference of Department and Division Commanders, Held in Washington, D. C.' in 'Tanks With Infantry.'"
[371] McLaughlin Green, Thomson, and Roots, *The Ordnance Department: Planning Munitions for War*, 192.
[372] Rockenbach, "'Remarks of Brigadier General S. D. Rockenbach, Chief of Tank Corps, U. S. Army, at Conference of Department and Division Commanders, Held in Washington, D. C.' in 'Tanks With Infantry.'"

updated gun carriage to which Brigadier General Rockenbach referred rather than a totally new machine, that took place immediately after the conclusion of World War I indicate that the larger technology triad within the U.S. Army was relatively stable in regard to tanks.

Taking a broad view of the role of doctrine, methods of organization in the U.S. Army as branches, such as infantry or cavalry, with specific missions framed a certain way of thinking about tanks and their proper role on the battlefield and played a major stabilizing force on the development of, or lack thereof, armored warfare in the U.S. Army through the 1920s. The official history of the Ordinance Department in World War II noted that "as long as tanks were regarded solely as support for the riflemen in attack, infantry concepts of their use necessarily predominated."[373] The genesis for this conceptualization of the tank as support for infantry was doctrinal in nature, and this doctrine was itself a reflection of an earlier knowledge system informed by the lessons of World War I. Adopting organizational models based on successful theories of victory from World War I, the US Army was organized to fight as branches with separate missions after the war. Rather than reorganize to create a new branch for tanks, the United States chose to assign responsibility for this weapon to the Infantry in Section 17 of the 1920 National Defense Act.[374] This organizational doctrine bounded the appropriate uses for tanks by tying them to the infantry on foot.

Leaders at the time recognized that the organization of an army played an important role in the way that army conceptualized the correct way to fight. The same

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[373] McLaughlin Green, Thomson, and Roots, *The Ordnance Department: Planning Munitions for War*, 189.
[374] Wilson, *Treat 'em Rough*, 226; *National Defense Act, Approved June 3, 1916 as Amended* (Washington: Government Printing Office, 1926), 14, https://heinonline.org/HOL/P?h=hein.comprint/nldfsat0001&i=1.

year that tanks would become part of the infantry, Brigadier General Rockenbach, referring to organizing the U.S. Army to employ tanks, said that "We want to be sure that we are placing them correctly at the beginning, if that is possible, because once we have an organization it is difficult to change it."[375] Brigadier General Rockenbach could have simply been referring to the difficulty inherent in rearranging large organizations, but his statement would also prove prophetic on the direction the entire tank technology triad would move once the responsibility for tanks was assigned to the infantry. The inter-war U.S. Army infantry started from an intellectual position rooted in the primacy of the foot soldier over all other tactical arms, and the designs of early tanks reflected this martial knowledge.[376]

The infantry branch leadership exercised their institutional control over the tank as a materiel solution and produced machines that directly supported the branch's mission requirements. In 1922, the Secretary of War issued an order stating that "The primary mission of the tank is to facilitate the uninterrupted advance of the rifleman in the attack."[377] From this broad directive, the Chief of Infantry provided the Chief of Ordinance with the specifications and requirements for the development of future tanks.[378] Civilian engineers did assist with the development of new tanks but remained in a strictly advisory role, which made the production of the materiel a completely military

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[375] Rockenbach, "'Remarks of Brigadier General S. D. Rockenbach, Chief of Tank Corps, U. S. Army, at Conference of Department and Division Commanders, Held in Washington, D. C.' in 'Tanks With Infantry.'"

[376] S. O. Fuqua, "The Trend of Development of Infantry" (Transcript of lecture delivered at the Army War College and discussion with audience, September 18, 1930), G-3 Course No. 7, 1930-1931, U.S. Army Heritage and Education Center, Carlisle Barracks; "Minutes of the Ordnance Committee Meeting" (August 1, 1929), 7, Ordnance Board Minutes, Box 4, Folder 7573-9359, Rock Island Arsenal Museum, Rock Island Arsenal.

[377] "Minutes of the Ordnance Committee Meeting," August 1, 1929, 7.

[378] "Minutes of the Ordnance Committee Meeting," 8.

endeavor from start to finish.[379] Every step of the development of new tanks, from design changes to testing results, was subject to the approval of a "Tank Board" that included infantry and ordinance officers, which the U.S. Army intended to ensure that fielded equipment would meet the using branch's tactical needs.[380] This close coordination undoubtedly kept the infantry and the ordinance branches informed of new developments and provided opportunities for minor adjustments, but it was organizationally labor-intensive. The separation between the portion of the U.S. Army that defined the needs and requirements for the tanks, the martial knowledge and doctrine, from the portion of the organization that was designing and building the equipment, the materiel, became an impediment to rapid change. The Chief of Infantry in 1926 lamented that he could only shift the priority of tank development from medium tanks to light tanks after "numerous conferences."[381] While the U.S. Army struggled under the organizational burden of its boards and conferences to change and align the elements of the technology triad to create a new reality, civilian automotive technology made large advances in the 1920s.

Walter Christie was a civilian engineer who built his own tanks and thus enjoyed near-total autonomy to build the tanks that he thought best without the input or direction from the U.S. Army.[382] Beginning in 1920, Christie designed tank chassis with a novel suspension system where the track rested directly on the top of large road wheels, which eliminated many moving parts and imbued the vehicle with several desirable characteristics.[383] Christie's tanks could be driven with tracks in the normal fashion for

[379] "Minutes of the Ordnance Committee Meeting," 14, 28.
[380] "Minutes of the Ordnance Committee Meeting," 6.
[381] "Minutes of the Ordnance Committee Meeting," 16.
[382] Robert Stewart Cameron, *Mobility, Shock, and Firepower: The Emergence of The U.S. Army's Armor Branch, 1917-1945* (Washington, D.C.: Center of Military History, 2008), 27.
[383] George F. Hofmann, "The Troubled History of the Christie Tank," *Army*, 1986.

off-road traction, or their operators could remove the tracks and drive directly on the road wheels. This convertible design allowed the tanks to achieve speeds of up to 25 miles per hour in the off-road configuration at a time when the Mark VIII tanks still in service moved at just 4 miles per hour and other experimental tanks achieved speeds of just over 11 miles per hour.[384] Additionally, with the tracks removed, Christie's tanks could travel at up to 40 miles per hour on roads over great distances, which alleviated the requirement to transport tanks on trains or the backs of trucks as was necessary with World War I era tank designs.[385]

By the end of the 1920s, Christie had effectively leveraged his autonomy to design and build tanks that were superior to those designed and built by the U.S. Army in several important ways. But these tanks failed to meet the requirements established by the infantry branch's martial knowledge related to tanks. Testing that the U.S. Army performed on the Christie-designed tanks in 1924 found that "that the principle employed in the construction and arrangement of the driving elements of the Christie type track is basically wrong."[386] Further testing in 1929 on a later model tank similarly found that the Christie designed tanks were "capable of remarkable demonstrations and is some improvement over his previous vehicles. However, it still contains some of the original defects which would be greatly magnified in serious effect if there were added to the existing 6-ton chassis the approximately 10 additional tons necessary to make this vehicle

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[384] "Report on Acceptance Test of Christie Tank" (October 4, 1930), George S. Patton Papers, Box 2, Folder 23, University of North Dakota Elwyn B. Robinson Department of Special Collections; Rockenbach, "'Remarks of Brigadier General S. D. Rockenbach, Chief of Tank Corps, U. S. Army, at Conference of Department and Division Commanders, Held in Washington, D. C.' in 'Tanks With Infantry'"; "Minutes of the Ordnance Committee Meeting" (August 22, 1929), 23, Ordnance Board Minutes, Box 4, Folder 7573-9359, Rock Island Arsenal Museum, Rock Island Arsenal.
[385] "Report on Acceptance Test of Christie Tank."
[386] "Minutes of the Ordnance Committee Meeting" (March 14, 1929), 40, Ordnance Board Minutes, Box 3, Folder 7172-7572, Rock Island Arsenal Museum, Rock Island Arsenal.

into a complete fighting tank measuring up to the demands of the tank board."[387] The Christie-designed tanks achieved impressive advances in speed and range, but at the expense of other attributes which the infantry marital knowledge held were important. While Christie possessed the autonomy to create a materiel solution that was outside of the established reality, he lacked the authority to produce corresponding changes within the doctrine and martial knowledge of the infantry branch to produce an innovation.

Christie's tanks in the 1920s were a notable exception to the general stagnation that armored warfare experienced within the U.S. Army within the decade that followed World War I. Throughout this period, the martial knowledge and doctrine, primarily maintained within the infantry branch, remained the dominant forces in the technology triad. The materiel solutions designed and built by the U.S. Army Ordinance Branch were closely coupled with the Infantry branch reality, and thus, the few advances made in this element of the technology triad supported the existing reality rather than created the opportunity for innovation. When Christie introduced materiel solutions that were well outside the established reality, with their emphasis on speed above armor and armament, the testing that the U.S. Army conducted confirmed that these machines would not support the objectives of the established reality, and no doctrine or martial knowledge emerged to create a new reality. By 1929, after ten years of effort, the U.S. Army had only designed and purchased eight light tanks and three medium tanks.[388] Inspired by developments in foreign militaries, the U.S. Army would shift their approach to

[387] "Minutes of the Ordnance Committee Meeting," 41.
[388] "Minutes of the Ordnance Committee Meeting," August 1, 1929, 32; "Minutes of the Ordnance Committee Meeting," August 22, 1929, 26.

innovation as the 1920s drew to a close in an attempt to capitalize on the technological advances in mechanization first demonstrated by Christie's designs.

## The Mechanized Force

While the U.S. Army had struggled through the 1920s to adequately leverage the unintended consequences of the tank foreshadowed in the Cambrai breakthrough of 1917, the British Army was making great strides in doctrine development to achieve the same goal. In 1928, U.S. Secretary of War Dwight Davis observed a demonstration of the British Experimental Mechanised Force, which was the world's first mechanized combat brigade.[389] This demonstration impressed the Secretary of War, and he ordered a similar test unit to stand up in the U.S. Army upon his return to the United States.[390] In July 1928, the U.S. Army established an "Experimental Armored Force" at Camp Meade, Maryland as an initial proof of concept, which would attempt to develop the martial knowledge and the doctrine necessary to innovate with tanks.[391]

Viewed through the lens of the technology triad, the general outline of the U.S. Army's attempt at armored warfare innovation with this experimental unit becomes clear. In 1929, three officers, including an Infantry officer name Sereno Brett, drafted the outline for a completely new vision for what tank forces could be.[392] Brett was one of the very few officers who remained committed to developing a separate tank force in the 1920s after the War Department disbanded the Tank Corps and would go on to be a

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[389] Winton, *To Change an Army*, 72; "History of the Armored Force, Command and Center," 1.
[390] "History of the Armored Force, Command and Center," 1.
[391] "History of the Armored Force, Command and Center," 1.
[392] S. E. Brett, J.K. Parsons, and C.C. Benson, "Mechanized Force" (Study drafts and associated correspondences, December 26, 1929), George S. Patton Papers, Box 2, Folder 20, University of North Dakota Elwyn B. Robinson Department of Special Collections.

major influence in the eventual success of the U.S. Army's armored warfare innovation efforts.[393] The proposed force was a severe departure from the existing infantry martial knowledge and doctrine that foresaw tank divisions leveraging superior speed at the expense of armor to move across vast battlefields at the head of field armies in coordination with aviation units.[394] The officers conducting this initial study did not realize it at the time, but the ideas they developed would be nearly identical to the underlying martial knowledge and doctrine that characterized armored warfare in Europe more than a decade later. In fact, the officer charged with developing the Armored Force organization in 1940 remarked that had they been privy to the work Brett and his compatriots completed in 1930, it would have saved "untold hours of labor."[395] However, this new martial knowledge and doctrine surpassed the capabilities of the existing materiel solutions at the same time the U.S. Army was experiencing challenges adopting Walter Christie's new convertible tank designs.

Despite the failure of Christie's tanks to meet the requirements set by the infantry martial knowledge in the late 1920s, his convertible tank design continued to garner enthusiasm both within Congress and in the U.S. Army. Walter Christie possessed a special talent for generating public interest in his inventions. Christie leveraged his ability to generate publicity to convince the House Military Affairs Committee to direct the U.S. Army to buy seven model 1930 Christie tanks.[396] However, it is unclear how necessary this political pressure really was considering that enthusiasm within the U.S. Army was

[393] Wilson, *Treat 'em Rough*, 230–31; "History of the Armored Force, Command and Center," 4.
[394] J.K. Parsons, "Mechanized Force" (Working draft of memo for the Adjutant General sent to Brett for comments, January 9, 1930), George S. Patton Papers, Box 2, Folder 20, University of North Dakota Elwyn B. Robinson Department of Special Collections.
[395] "History of the Armored Force, Command and Center," 6.
[396] Hofmann, "The Troubled History of the Christie Tank."

already quite high for Christie's tanks, especially among those officers who were designing the experimental mechanized force. The year before congress would "force" the U.S. Army to purchase Christie tanks for experimentation, Major General Fuqua, the Chief of Infantry, described the Christie tank as "the most striking tank of the class yet to be developed."[397] George Patton himself kept a copy of the U.S. Army requisition for a Christie tank in 1929 in his personal papers and wrote "probably a very momentous paper" on it.[398] The officers who wrote the original concept for the experimental mechanized force in 1930 were especially interested in the promise of the Christie design to support their vision of a fast-moving tank force.[399]

Rather than the civilian leadership of the U.S. military forcing consideration of Christie tanks, as is the common framing of this episode of U.S. tank history, the technology triad produces a framing that is more consistent with the historical record.[400] As discussed in Chapter 2, civilian leadership forcing change on the military is a reflection of the assumption that militaries resist change as a matter of course. However, the words and actions of the leaders in the U.S. Army at this time demonstrate both a desire and a willingness to undertake change within the military. For example, the quote at the opening of this chapter demonstrates that the tank can be viewed as part of a larger shift within the United States as means of production transitioned through the 1920s from muscle power to mechanical power.[401] This was a reflection of the political and social

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[397] Fuqua, "The Trend of Development of Infantry," 3.
[398] Morningstar, *Patton's Way*, 67.
[399] Parsons, "Mechanized Force."
[400] Hofmann, "The Troubled History of the Christie Tank"; George F. Hofmann, "A Yankee Inventor and the Military Establishment: The Christie Tank Controversy," *Military Affairs* 39, no. 1 (1975): 12–18, https://doi.org/10.2307/1986717.
[401] Ronald Kline and Trevor Pinch, "Users as Agents of Technological Change: The Social Construction of the Automobile in the Rural United States," *Technology and Culture* 37, no. 4 (October 1996): 763, https://doi.org/10.2307/3107097; Lincoln, "A Mechanized Force," 5.

influences on the martial knowledge of the U.S. Army related to the development of tanks and armor doctrine. Furthermore, the core concepts that drove the vision of the mechanized force, when viewed through the lens of the technology triad, were an attempt to modify the martial knowledge of the U.S. Army to align with the unintended consequences, or opportunities, of the tank, especially Christie's light, fast designs.

Up until its deemed failure in late 1931, the Mechanized Force appeared as if it was going to be the first step in the creation of a new reality in armored warfare.[402] In practice, the U.S. Army declined to allocate the resources necessary to achieve the revolutionary ideas of independent tank divisions, which would lay the foundation for its eventual failure.[403] Absent the resources to field new material solutions to support this new martial knowledge, the U.S. Army collected tanks, armored cars, and trucks already fielded in the various branches and designed a regiment-sized unit around the already existing equipment.[404] The available materiel solutions of the day represented an earlier reality and were unable to support an appreciable departure from the existing martial knowledge and doctrine in the Infantry.

Hamstrung by materiel solutions from an earlier technology triad, the Mechanized Force never successfully validated a new martial knowledge and eventually was reorganized as a more traditional mechanized cavalry force.[405] One could charge the U.S. Army with resisting change that was too fast, but the future Chief of Cavalry, Colonel

[402] "History of the Armored Force, Command and Center," 3.
[403] J.K. Parsons, "Letter to Sereno Brett" (May 31, 1930), George S. Patton Papers, Box 4, Folder 9, University of North Dakota Elwyn B. Robinson Department of Special Collections, https://time.com/vault/issue/1940-07-08/page/21/; Van Voorhis, "Mechanization," October 13, 1937.
[404] Van Voorhis, "Mechanization," October 13, 1937, 2.
[405] Van Voorhis, 1–2.

Kromer, countered this very accusation in reference the Mechanized Force in 1933, saying

> "General Connor, used to refer to the military mind as being an extremely conservative one with regard to innovation, because the military man who is in charge and is responsible for the decisions as to what will be the means the United States entrusts its defense to, is very much in the position of the banker who is entrusted with the investment of the funds of a widow. In investing funds, you can invest in very conservative investiments [sic] which have tremendous amount of security and a rather limited amount of income, on the other hand go to the other extreme and look for a tremendous amount of income, but you lose in the amount of security you have. So that the military man is between the devil and the deep blue sea, like the investor, he wants as much as he can get for his money, but he wants security in the greatest degree, and the national defense of the country, like the widow's capital, is something for which security must be assured, and the dangers and perils of extreme views of organization must not be discounted. So it is with us in considering this question of mechanization or in any of the relatively new methods or means of warfare that have been introduced."[406]

In a U.S. Army War College seminar discussion three days earlier, Colonel Humphry, who helped lead the discussion, expressed the same sentiment that the mechanized force had failed to prove its validity when he said, "I don't believe we have progressed far enough in our country in actual demonstrations of the ability of the Mechanized Force to perform the functions they visualize it should perform."[407] These statements by senior officers and the assignment of traditional cavalry missions to the Mechanized Force were reflections of the strength of the knowledge system that supported the pre-existing martial knowledge.

Just as the U.S. Army was unable to successfully change the martial knowledge and doctrine related to tanks to align with the new materiel solutions Christie developed,

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[406] Oswald H. Saunders, "Status of Mechanization - 1933" (Transcript of lecture delivered at the Army War College and discussion with audience, Washington, D.C., September 18, 1933), 21, G-3 Course No. 5, 1933-1934, U.S. Army Heritage and Education Center, Carlisle Barracks.
[407] Saunders, 28.

the U.S. Army was unable to validate the nascent Mechanized Force concept with the materiel solutions available and create a new reality. Although the original concepts for the Mechanized Force called for a radical departure from existing military operations in the late 1920s, with independent tank divisions spearheading fast-moving assaults, the Mechanized Force that the U.S. Army built in 1930 was given traditional cavalry missions to test the validity of the organization.[408] This meant that the utility of the new unit was evaluated in testing against the capabilities of the types of units for which that doctrine was developed and within the constraints of the existing knowledge system.

The biggest challenge the Mechanized Force faced in these tests was the command and control of their units.[409] The mechanized units simply moved too fast and over too great of distances for the traditional methods of control encompassed in the existing cavalry doctrine. This created a situation where the Mechanized Force attempted to conduct missions that horse cavalry units were already conducting rather than focusing on those tasks that would specifically require a mechanized unit. Thus, there would have been little need to develop new doctrine and materiel solutions, as the Germans would over the next decade with radios, when the traditional units met the requirements of the existing martial knowledge already.[410] The conservative answer, such as Colonel Kromer referred to in the quote above, would have been to slowly integrate tanks and combat cars into the already existing horse cavalry structure to capitalize on the advantages the machines brought and leverage the command and control doctrines that were optimized for slower moving horse units. This is precisely what the U.S. Army did with the

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[408] Van Voorhis, “Mechanization,” October 13, 1937, 1–2.
[409] Saunders, “Status of Mechanization - 1933,” 28.
[410] Guderian, *Achtung-Panzer! The Development of Tank Warfare*, 11.

mechanized force. It became the "mechanized cavalry" with both horses and machines to accomplish traditional cavalry missions.[411] By framing this organizational stasis in terms of the technology triad, one can see how the decision to not innovate in relation to the Mechanized Force was less of an example of romantic traditionalism of horse cavalry units, as some have contended, and was more of a logical decision based on the outcome of internal epistemologies that were hampered by an inadequate alignment between the changing elements of the technology triad.[412]

Shortly after the U.S. Army abandoned its efforts of armored warfare innovation with the Mechanized Force, it also gave up on Walter Christie and his tank designs. Although Christie designed tanks did successfully complete several tests related to speed and range by the Tank Board in 1930, his designs remained prone to mechanical failure and were not strong enough to carry adequate armor for the traditional infantry tank missions.[413] The original concepts of the Mechanized Force accepted a degradation in armor to achieve greater overland speed and mobility, but the missions of the Mechanized Force shifted away from these revolutionary ideas over time.[414] At the same time that the U.S. Army was starting to see the speed that the convertible tank designs enabled as an impediment to effective command and control, Walter Christie's difficult personality posed additional challenges for the service to work with him. Throughout the time that Christie worked on tanks with the U.S. Army, he routinely demonstrated that he believed he was the only one qualified to determine what his tanks should be, not the

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[411] Van Voorhis, "Mechanization," October 13, 1937, 1–2.
[412] Katzenbach, "Tradition and Technological Change."
[413] "Report on Acceptance Test of Christie Tank."
[414] Parsons, "Mechanized Force."

users, and missed delivery deadlines for testing equipment.[415] The Ordinance Branch terminated their partnership with Christie in 1933 and eventually terminated all work on convertible style tanks in favor of vehicles that would meet the requirements dictated by the martial knowledge of the U.S. Army, which remained largely unchanged throughout the period that the Mechanized Force existed.[416]

The U.S. Army's decision to disband the Mechanized Force in October 1931 was grounded in sound logic given the way that the elements of the technology triad changed together.[417] The materiel solutions that the Mechanized Force employed were ill-suited for the traditional cavalry doctrine that the force employed within the bounds defined by the martial knowledge of the day. Similarly, the decision to abandon the Christie tanks was made based on considerations defined by the martial knowledge. Neither of these decisions was inevitable. The concept of fast-moving tank divisions supported by aircraft is strikingly similar to the "blitzkrieg" formations and doctrine that the Germans would use to collapse the Polish defenses less than a decade later. There are even some indications that the Germans may have first encountered these ideas in the initial study that Brett and Parsons produced for the Mechanized Force.[418] Likewise, the USSR adopted the Christie tank and became their famous T-34, which the German Panzer Generals would later claim was superior to their own tanks when the two armies fought during Operation Barbarossa.[419] Of course, it is only with the advantage of hindsight that

[415] "Minutes of the Ordnance Committee Meeting," March 14, 1929, 32; Hofmann, "The Troubled History of the Christie Tank"; Cameron, *Mobility, Shock, and Firepower: The Emergence of The U.S. Army's Armor Branch, 1917-1945,* 129–30.
[416] Hofmann, "The Troubled History of the Christie Tank"; Hofmann, "A Yankee Inventor and the Military Establishment."
[417] Cameron, *Mobility, Shock, and Firepower: The Emergence of The U.S. Army's Armor Branch, 1917-1945*, 45.
[418] "History of the Armored Force, Command and Center," 6.
[419] Hofmann, "The Troubled History of the Christie Tank."

one can know for certain that the tank did introduce a fundamentally new way of conducting ground warfare. The combination of speed, mobility, and firepower enabled the employment of the tank as the decisive arm by capitalizing on the shock value of the weapon, but the U.S. Army was poorly positioned to recognize and nurture this innovation. The interactions within the technology triad provide a way to frame how the U.S. Army changed, or failed to change, in relation to advancing tank technologies in the late 1920s without leveling charges of blind resistance to change.

**Decentralization and the Spark of Innovation**

Between World War I and World War II, the branches of the US Army were much more powerful than they are today.[420] Each of the branches maintained its own chains of command and legal authorities to perform their assigned missions within the Army. In May 1931, Army Chief of Staff General Douglas MacArthur delegated the responsibility for developing concepts and equipment for mechanized warfare to each of the various branches.[421] This was a significant departure from the organizational approach, or doctrine in terms of the technology triad, that had dominated the U.S. Army's efforts to innovate in armored warfare since 1920, where the infantry branch maintained the sole authority to develop tanks. In order to avoid the legal restrictions imposed by the War Department's 1920 directive, the U.S. Army called tanks in the cavalry "combat cars," but combat cars were practically indistinguishable from the machines that the infantry called "tanks."[422] Each branch's version of tank employment

[420] Robert Stewart Cameron, Interview, Armor Branch Historian., Telephone, April 23, 2019.
[421] Cameron, *Mobility, Shock, and Firepower: The Emergence of The U.S. Army's Armor Branch, 1917-1945*, 47.
[422] Cameron, 48.

was based on the local martial knowledge related to mechanized combat in that branch, and the development of tanks and doctrine effectively bifurcated between the infantry and the cavalry. The materiel solutions that each branch employed were very similar, but the different approaches to doctrine and slight differences in materiel solutions between the branches provide the opportunity to observe how martial knowledge influences the other two elements of the technology triad.

### ***The Infantry and Tanks***

The martial knowledge of the infantry branch was rooted in a strongly held truth that the soldier on foot was the most important component on the battlefield. The materiel solutions and doctrine employed by the infantry existed in a subordinate role with the sole purpose of supporting the advance of soldiers on foot. In 1935, Major General Croft, Chief of Infantry, demonstrated the values judgment inherent in this position when he said, "the machine without man is a most stupid thing; that in war of the future no matter how much we may employ the machine, the human being must still rank first and foremost in importance."[423] As with all complex systems, the influence of this point of view is indirect, and it is impossible to draw a causal relationship from it to tank design. However, one can see a strong reflection of the preeminence of the infantryman over the tank in the relative importance that the infantry placed on anti-tank guns over armored vehicles and its intellectual origins.

[423] Edward Croft, "Developments In Organization, Armament and Equipment of Infantry" (Transcript of lecture delivered at the Army War College and discussion with audience, September 12, 1935), G-3 Course No. 5, 1935-1936, U.S. Army Heritage and Education Center, Carlisle Barracks.

Major General Fuqua confidently claimed in 1930 that "the tank can never successfully enter into a gun versus armor race," and Major General Lynch echoed this sentiment seven years later when he said that "there is no use trying to neutralize the anti-tank gun with heavier armor."[424] Major General Croft's 1936 speech explains the logic driving the advantage that infantry leaders assigned to the anti-tank gun over the tank, despite a mobility advantage for the armored vehicle, when he said, "We learned from bitter experience in the last war that we cannot throw infantry against such a defense without adequate preparation and supporting fires. It will be just as suicidal to attempt an assault by tanks against a prepared defense."[425] Major General Croft, in this quote, was drawing a direct comparison between infantry assaulting on foot against machine-gun positions and tanks assaulting fixed positions. This pre-existing knowledge combined with the values judgment of the importance of the infantry on foot and the fundamental responsibilities of the infantry as a branch produced a preference for tank designs that could withstand machine-gun fire in support of advancing infantry but relied on other types of weapon systems to reduce enemy defenses as part of a combine arms team.[426] Major General Croft does acknowledge certain "special situations" where "tanks can and should operate independently and with boldness." [427] However, his qualification of "special circumstances" reinforced that the tank was subordinate to the infantry and not a separate force, as the original Mechanized Force envisioned. The influence of the

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[424] Fuqua, "The Trend of Development of Infantry"; George Lynch, "Current Infantry Weapons" (Transcript of lecture delivered at the Army War College and discussion with audience, October 4, 1937), G-3 Course No. 6, 1937-1938, U.S. Army Heritage and Education Center, Carlisle Barracks.
[425] Edward Croft, "Developments in Organization, Armament and Equipment of Infantry" (Transcript of lecture delivered at the Army War College and discussion with audience, October 6, 1936), G-3 Course No 6, 1936-1937, U.S. Army Heritage and Education Center, Carlisle Barracks.
[426] Lynch, "Current Infantry Weapons."
[427] Croft, "Developments in Organization, Armament and Equipment of Infantry."

infantry's martial knowledge on the design of tanks was stronger than the production of a general preference for a type of tank. Consideration of the interactions between all three elements of the technology triad help illustrates the complex relationship.

The example of protection against machine-gun fire can demonstrate how doctrine is linked to martial knowledge through materiel solutions and how internal experimentation depends on other parts of the knowledge system that produce martial knowledge. Enough armor to provide immunity from machine-gun fire was a base requirement for tanks in the 1930s. But against what type of machine gun should the Army test the armor plate? As late as 1935, senior officers considered both the .30 and .50 caliber machine guns adequate anti-armor weapons.[428] The capabilities of these two weapons are very different. A single infantryman could employ the .30 caliber machine, but 7/8" of armor would stop the round. The .50 caliber machine gun, on the other hand, required a crew to fire but would penetrate at least 1¼" of armor. The U.S. Army could have simply made the armor thick enough to stop any machine gun, but then they would have paid the price in the tanks' speed.[429] The U.S. Army had to make decisions about the most likely ways the tanks would be employed in combat and the types of threats they would encounter based on this determination to design the tank. Any testing carried out after that could only validate the materiel solution adequately addressed the problem as defined by the knowledge system because larger caliber guns were beyond the capabilities deliberately designed into the tank. The definition of the problem, the testing, and the resulting optimum doctrine are all interconnected and reliant on the knowledge system and the martial knowledge it generates for their initial orientation. Furthermore,

[428] Croft, "Developments In Organization, Armament and Equipment of Infantry."
[429] Lynch, "Current Infantry Weapons"; Lynch, "The Infantry," September 20, 1939.

the consideration of martial knowledge relative to both materiel and doctrine as a new dimension of analysis in this case helps explain their interdependence more fully than simply doctrine and materiel alone.

While martial knowledge exerted significant influence on materiel, the materiel solutions available also exerted a limiting influence on martial knowledge and doctrine. In 1935, the chief of infantry said, “I hope to avoid getting the cart before the horse as is done when we try to reorganize purely along theoretical lines which, in the absence of full knowledge of the powers and limitations of available materiel, leads to useless and costly mistakes.”[430] Later in this same speech Major General Croft did say “it is certain that the greatly increased speed of the new tanks will have a marked influence on tank tactics,” then he suppresses his initial enthusiasm by saying “but positive statements as to the new tactics must be deferred until there has been more practical work with units as large as a battalion.”[431] There does appear to be a recognition on Major General Croft’s part that the new materiel solutions might open up new ways of operating. However, he falls back on the internal epistemologies of the knowledge system to guard against adopting a doctrine that the tank could not support. The direct influence of tanks on the doctrine of the U.S. Army through the mid-1930s was largely one of limiting what was possible because their martial knowledge changed much slower than the materiel development. The knowledge system placed too high a value on internal testing to validate knowledge generation and pre-existing knowledge from a time when tanks were slow and unreliable. As a result, the infantry missed another opportunity to align their

[430] Croft, “Developments In Organization, Armament and Equipment of Infantry.”
[431] Croft.

martial knowledge and doctrine with “the greatly increased speed of the new tanks” that the contemporary materiel was able to provide.

By 1936, the tank had become much more capable as a materiel solution to address the problems defined by the existing martial knowledge, and U.S. Army leadership started wrestling with what this meant for ground combat in general. In this same year, Major General Croft of the infantry demonstrated the challenges that the infantry experienced adapting its reality to the new capability when he said, “Too much should not be expected from the tanks” followed by “our tactics must exploit the speed of the new tank.”[432] This contradictory interpretation of the influence of materiel solutions on the knowledge system is characteristic of the transition period as the Army’s knowledge system slowly adapted to the new capabilities of the tank.

The U.S. Army conducted numerous experimental maneuvers throughout the 1930s to determine the best method of employment for tanks as the materiel solutions changed over time. These maneuvers take on the appearance of objective tests because the opposing forces were free to develop their own courses of action to achieve their assigned missions. Major General Lynch believed in these tests so much that he claimed in 1937 that they “lead to definite answers” and are superior to “excessive reliance upon the conceptions of the imagination.”[433] However, just as with the discussion above related to the thickness of armor, the standards by which the U.S. Army evaluated the tests were rooted in previous versions of the martial knowledge related to tanks. During the 1930s, this meant that the lessons from the last large war, World War I, always loomed in the background.

[432] Croft, “Developments in Organization, Armament and Equipment of Infantry.”
[433] Lynch, “Current Infantry Weapons.”

The martial knowledge of the infantry in the 1930s was largely built on top of pre-existing institutional knowledge and the experiences of the people who made up the organization. Lecture after lecture delivered at both the War College and the Command and Staff College started with a recounting of the application of the topic of the lecture from World War I.[434] This aspect of knowledge systems can take on the appearance of institutional conservatism, and certainly, the relative importance an organization places on pre-existing knowledge can stabilize an organization's knowledge production. However, the tenants of ANT, specifically allowing the actors to speak for themselves, provide a guardrail to avoid inappropriately ascribing intent to actors. For example, an alternate explanation for the focus on World War I lessons well after the war could be that in the military, where the cost of failure is measured in human lives, there is good reason to emphasize knowledge that has proven itself in combat. Major General Lynch, the Infantry Branch Chief in 1938, exemplified this point when he lamented that "The farther we get from the World War, the dimmer its lesson become."[435] The strong influence of the lessons from World War I through even the late 1930s, along with deeply held values propositions, produced a stable martial knowledge within the Infantry branch.

After nearly 20 years of development and testing with armored forces, Major General Lynch proclaimed that "The infantry tank has just one mission: the neutralization of resistance in the advance of foot troops."[436] The strength of Major General Lynch's conviction on this matter supports the idea that the doctrine of a military can have a

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[434] Herr, "The Cavalry," September 19, 1938; Leon Kromer, "The Role and Development of Modern Cavalry" (Transcript of lecture delivered at the Army War College and discussion with audience, September 10, 1935), G-3 Course No. 4, 1935-1936, U.S. Army Heritage and Education Center, Carlisle Barracks.
[435] Lynch, "Current Infantry Weapons."
[436] Lynch.

profound impact on the way that the military understands reality, because the U.S. Army's organization into branches framed the way that the infantry officers understood how the tank might be most useful. Despite advances in materiel solutions and frequent testing, a stable martial knowledge ensured that any future advances simply helped the infantry better perform their mission in accordance with the larger U.S. Army doctrine.

### *The Cavalry and Combat Cars*

In the cavalry branch, especially after the U.S. Army disbanded the Mechanized Force, the doctrine of splitting the responsibility for the development of the tank between the branches followed a parallel track as in the infantry. The cavalry conceptualized the combat car as a materiel solution intended to complete traditional cavalry roles. Major General Chaffee, a future commanding general of the U.S. Armored Force, demonstrated this when he said, "this directive of 1931 has been constantly kept in mind by successive chiefs of cavalry and successive commander of the force in the field over the past eight years. Every change in organization, every improvement in equipment has been measured by it."[437] The presence of this U.S. Army level doctrine defined the reality within which Major General Chaffee understood the combat car and strengthened the influence of the cavalry martial knowledge over the design of the materiel. Just as the infantry saw the tank as a tool to perform infantry tasks, the cavalry conceptualized the tank to perform cavalry missions.

[437] Adna Chaffee, "Mechanized Cavalry" (Transcript of lecture delivered at the Army War College and discussion with audience, September 29, 1939), G-3 Course No. 12, 1939-1940, U.S. Army Heritage and Education Center, Carlisle Barracks.

The organizational values and value judgments were slightly different within the cavalry compared to the infantry. In the cavalry, values such as mobility and versatility defined the "cavalry spirit," which was defined in a War Department policy from 1 May 1931 as "an asset which, while intangible, is none the less a vital factor in combat."[438] These values defined the lens through which the cavalry defined the function of tanks, the design of experimental tests on those tanks, and the interpretation of results from the same tests. This influence created a preferred tank design that was light, fast, and intended to work in tandem with horses, which held a clear advantage over machines in these areas over very rough terrain.[439]

As in the infantry, the limits of the tank to perform the missions dictated by the cavalry martial knowledge exerted a limiting function on the development of doctrine. In 1935, Major General Kromer explained that "the inherent limitations for machines for proper battle reconnaissance of a strange terrain were brought out very forcibly during the maneuvers…to launch an attack of mechanized vehicles over unknown terrain will be extremely hazardous."[440] Major General Kromer was comparing the ability of scouts on horseback to conduct reconnaissance against scouts inside a cavalry combat car. The framing of this comparison illustrates how the knowledge system and the limits of materiel solutions combine to exert a limiting function on doctrine. In this case, Major General Kromer was explaining why horse cavalry combined with mechanized cavalry model adopted after the dissolution of the Mechanized Force was the best of both worlds.

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[438] Kromer, "The Role and Development of Modern Cavalry"; Bruce Palmer, "The Cavalry" (Transcript of lecture delivered at the Army War College and discussion with audience, October 12, 1936), G-3 Course No. 10, 1936-1937, U.S. Army Heritage and Education Center, Carlisle Barracks; Herr, "The Cavalry," September 19, 1938.
[439] Herr, "The Cavalry," September 19, 1938.
[440] Kromer, "The Role and Development of Modern Cavalry."

The local truth inherent in Major General Kromer's statement relative to the success of mixed units was an outcome of the interactions between all three elements of the technology triad to create the cavalry martial knowledge. For example, the cavalry favored certain types of machines that fit with their model of horse cavalry employment because the knowledge system was structured in such a way to define the problems the same way they were defined with horses. An emphasis on mobility over all possible terrain reflected a knowledge system that developed within the horse cavalry. When machines were tested against horses by this metric, the horse came out on top every time. For example, in 1935, Major General Kromer explained that "from our experience in these maneuvers, and work since that time, it has been concluded that mechanized units are more sensitive to the incidents of terrain than are any other units."[441] These tests were not "rigged" for the tanks to fail on purpose; the knowledge system relied on its previous knowledge with horse units and values associated with the cavalry culture to frame the internal tests in a manner that was not favorable to early tanks. The knowledge system produced a reality that defined the superiority of the horse over tanks as truth. Adopting a doctrine and materiel solutions, the horse in this case, that reflected this truth was the most appropriate action for the cavalry to take.

Around the same time that tanks started to advance to the point where they were challenging aspects of the infantry martial knowledge, they were producing similar influence within the cavalry. Like the infantry, the strength of the cavalry martial knowledge in the 1930s made it difficult for the officers responsible to appreciate the emerging unintended consequences of the combat car. In 1937, Brigadier General Van

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[441] Kromer.

Voorhis said, “the attack of an organized position by mechanized cavalry is to be avoided if it is possible” right before he recounted a story from a training exercise where a mechanized cavalry unit was decisively victorious doing that exact thing.[442] Even though the armored unit was capable of conducting this sort of attack, the mission was outside the reality that the existing knowledge system created for cavalry units, so the Army had a hard time understanding what it meant.

Despite these early indicators that combat cars might be able to perform missions outside the established martial knowledge of the cavalry, the U.S. Army’s doctrine continued to play an important role in the design of tanks and inhibited opportunities for innovation. Major General Kromer exemplified this in 1937 when he said, “the American doctrine is that modern means must be utilized to increase the effectiveness of all arms in carrying out their roles which remain unchanged.”[443] In 1938, Major General Herr, the chief of cavalry who followed Major General Kromer, continued his predecessor’s adherence to the existing martial knowledge and doctrine, saying that “the organization and equipment [of the mechanized cavalry] is designed solely for the furtherance of cavalry roles. Our combat car has been kept light and fast with no attempt to encroach on the role of the heavier infantry tank.”[444] These quotes illustrate that the logic behind the design of weapons in the U.S. Army during the 1930s was to create weapons that met the pre-existing doctrinal requirements of the branches. The cavalry’s missions required mobility rather than the ability to stand and fight against a stronger force.

[442] Van Voorhis, “Mechanization,” October 13, 1937.
[443] Leon Kromer, “Cavalry” (Transcript of lecture delivered at the Army War College and discussion with audience, October 1, 1937), G-3 Course No. 5, 1937-1938, U.S. Army Heritage and Education Center, Carlisle Barracks.
[444] Herr, “The Cavalry,” September 19, 1938.

Differences between infantry and cavalry tank design considerations indicate the strength of the influence of doctrine on the materiel solutions the two branches sought. In a discussion following an address to the Army War College in 1939, a major in the audience articulated that the infantry had recently changed its tactics and was designing heavier tanks. The major asked the chief of cavalry, Major General Herr, if the cavalry would likewise transition to heavier armor. Major General Herr's response that "if we need anything heavier, as long as it has the cavalry mobility necessary to execute our missions, we propose to take it" illustrates that the primary consideration for the design of cavalry tanks in his mind was the assigned cavalry missions.[445] Even though Major General Herr was aware that heavier tanks were being developed within the U.S. Army and that there may be a need for a heavier tank, these were secondary considerations to the assigned mission of the cavalry. Major General Herr's framing of cavalry requirements in terms of 'mobility,' a value statement, additionally illustrates the state of the cavalry's knowledge system and the influence this held over the design of materiel solutions. In 1939, Major General Chaffee further demonstrated this point when he said, "if any one thought can be said to have guided the design and construction of the vehicular equipment of our mechanized cavalry, it was the requirement that the vehicle be built to fit the mission."[446] Thus, the intended use for the combat car continued to dictate the desired aspects of its design above all other considerations.

Strong and static martial knowledges that originated in the infantry and the cavalry were the predominant interactions within the technology triad during this period of tank development. This produced slow but steady improvement along established

[445] Herr.
[446] Chaffee, "Mechanized Cavalry."

realities rather than an innovation through the creation of a new reality. Major General Van Voorhis, then the commanding general of V Corps, explained in 1938 that "the employment of mechanized cavalry differs very little, if any, from the employment of horse cavalry, except as might be expected to result from the substitution of the machine for the horse."[447] From the point of view of the infantry, Major General Lynch, the infantry branch chief, argued that the infantry had "adopted a tank policy which makes these tanks…infantry auxiliaries, on the theory that it is the rifleman, the infantry, that is going to execute the act of decision in battle."[448] Each branches' unique martial knowledge exerted a powerful influence on the doctrine of tank employment within that branch. Subsequently, those doctrines influenced the preferred design and function of tanks.

### *A New Doctrine, the Spark of Armored Innovation*

Even though the predominant interactions within the technology triad were characterized by relatively stable martial knowledge and minor shifts in tank design through the 1930s, the first step of what would become a shift in reality within the U.S. Army related to tanks was unfolding in doctrine development. The formal educational facilities in the Army, the Army War College and the Command and Staff School, served as especially powerful nodes of knowledge generation within the Army of the 1930s compared to tacit knowledge that may have been generated by field units conducting training. These institutions derived their influence within the knowledge system through

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[447] Daniel Van Voorhis, "Mechanization" (Transcript of lecture delivered at the Army War College and discussion with audience, September 29, 1938), G-3 Course No. 10, 1938-1939, U.S. Army Heritage and Education Center, Carlisle Barracks.
[448] Lynch, "The Infantry," September 20, 1939.

their formal authority to create and disseminate knowledge as part of their mission. One can picture the landscape of knowledge production within an organization as a heat map with links that represent lines of authority. The development of new doctrine was one of the responsibilities of the formal education facilities in the inter-war period.[449]

Incorporating institutional lessons learned from the Mechanized Force, the U.S. Army Command and Staff College issued a new formal doctrine for the cavalry in 1933.[450] "Organization and Employment of Mechanized Units in a Cavalry Division and Cavalry (Mechanized)" outlined doctrine for tactical level operations of units that were comprised of both horse bound and combat car equipped troops with special emphasis on the collective and collaborative employment of the two types of units. While the document did outline the differences in speed and mobility between the two means of travel for cavalry troopers, the proposed combat march formations depicted horses in the middle of large formations with combat cars protecting the front, flanks, and rear of the horse formation.[451] This general concept of closely tying the combat cars to the horses within the mechanized cavalry persisted throughout the document. In the same year this doctrine was published, the Command and Staff College sent drafts to senior leaders within the U.S. Army for their feedback. Field commanding generals and branch commanding generals alike agreed that the doctrine was conceptually sound but needed minor adjustments in the details.[452] Major General Henry's comments were typical of the responses the Command and Staff College received when he said, "I think the pamphlet,

449 "History of the Armored Force, Command and Center," 4.
450 "Cavalry (Mechanized)" (The Command and General Staff School, October 4, 1933), Special Collections, M 506-K, 53879, Combined Arms Research Library, Ft Leavenworth.
451 "Cavalry (Mechanized)," 26.
452 Wilson, "A Critical Analysis of the C. & G.S. Pamphlet Cavalry Mechanized," March 23, 1934.

in general, is sound, well arranged, and fairly written."[453] This sort of positive feedback on the general ideas in the doctrine is best understood as an indication of their alignment with the martial knowledge related to the employment of mechanized units after the lessons learned from the Mechanized Force. However, those with the ability to act outside the established reality within the formal education centers of the U.S. Army found fault with the doctrine almost immediately and took the first tentative steps towards innovation in the process.

The most stinging critique of the 1933 mechanized doctrine would come from Captain Arthur Wilson, a young field artillery officer who would later become a general officer in World War II and a major contributor to the success of the D-day invasion.[454] As part of a student paper for his studies at the Command and General Staff College in 1934, Captain Wilson disagreed with the basic concept that horses and combat cars should be employed as a team and took it upon himself to totally rewrite the doctrine from scratch.[455] Citing his experiences as a junior officer in the Mechanized Force, Captain Wilson argued that tying horses too closely with combat cars did not help the unit leverage the advantages of each type of cavalry; it had the opposite impact by slowing the combat cars to the speed of the horses and forcing the horses to stay close to the roads.[456] Further exercising his student's privilege of academic freedom, Captain Wilson proposed a series of "General Principles" for the employment of mechanized units that were absent from the 1933 doctrine.[457] These principles, such as "the maximum

[453] Wilson, Report D.
[454] Wilson, "A Critical Analysis of the C. & G.S. Pamphlet Cavalry Mechanized," March 23, 1934; Arthur R. Wilson, "Report of Operations in North Africa" (Operational Report, December 12, 1942), https://cgsc.contentdm.oclc.org/digital/collection/p4013coll8/id/61/rec/2.
[455] Wilson, "A Critical Analysis of the C. & G.S. Pamphlet Cavalry Mechanized," March 23, 1934, 1.
[456] Wilson, 1, 9.
[457] Wilson, 24; "Cavalry (Mechanized)."

of surprise obtained by mobility, boldness, speed of maneuver, and concentration on the objective," laid out a way of operating that capitalized on the unintended consequences of the tank and look very similar to the general characteristics that would guide U.S. Army armored operations in World War II.[458] Although Captain Wilson possessed the autonomy to introduce new doctrine, he lacked the formal authority to adopt it within the service or take any action beyond proposing the ideas. For this new doctrine to achieve a meaningful impact on the way the U.S. Army operated, it would have to further develop and align with a corresponding martial knowledge and materiel.

The same year that Captain Wilson proposed his new mechanized doctrine at the Command and General Staff College in Fort Leavenworth, Kansas, Major Alan Kingman authored a similar document at the Army War College in Washington, DC.[459] Major Kingman, along with Sereno Brett, would go on to become important figures in the development of the armored doctrine that the U.S. Army would employ at the beginning of World War II.[460] Major Kingman's war college paper was not a direct critique of the 1933 doctrine, but it did echo all of the key ideas from Captain Wilson's document related to the separation between horses and combat cars and building on the basic lessons from the Mechanized Force.[461] Importantly, Major Brett was a classmate of Major Kingman's at the war college, and Major Kingman cited Major Brett's 1928 original proposal for the Mechanized Force in his paper.[462] After graduating from the war college, Major Kingman would become the chief of tanks at the Command and Staff

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[458] Wilson, "A Critical Analysis of the C. & G.S. Pamphlet Cavalry Mechanized," March 23, 1934, 24; Morningstar, *Patton's Way*.
[459] A. F. Kingman, "Mechanized Units" (Student Report, U.S. Army War College, Washington, D.C., May 5, 1934), 407-46, U.S. Army Heritage and Education Center, Carlisle Barracks.
[460] "History of the Armored Force, Command and Center," 4.
[461] Kingman, "Mechanized Units."
[462] Kingman.

College, where he read Captain Wilson's proposed mechanized doctrine in the fall of 1934.[463]

In 1935, the Command and General Staff College released a revised Mechanized Cavalry doctrine.[464] It would be inappropriate to assign a direct causal link between Captain Wilson's and Major Kingman's papers and the revised 1935 doctrine. However, the ideas in their papers were very clearly present in the new doctrine.[465] The formatting and sections of the 1935 doctrine are much more similar to Captain Wilson's proposed draft than they were to the 1933 doctrine despite the feedback from senior U.S. Army leaders that the original document's layout was satisfactory.[466] The 1935 doctrine also conforms to Captain Wilson's critique of the 1933 doctrine when he argued for increasing the portion of the document that addresses marches and camps from five lines to a full chapter.[467] Most importantly, the 1935 doctrine represents a fundamental change from the 1933 doctrine by separating the horse units from the mechanized units in organization, tactics, and even within the document's layout.[468] The primary "principle of organization" in the 1935 doctrine described that "the doctrine of mechanized cavalry requires the organization of self-contained tactical units to meet cavalry missions. Independent operations, in addition to cooperation with other arms and with horse

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[463] Arthur R. Wilson, "A Critical Analysis of the C. & G.S. Pamphlet Cavalry Mechanized" (Library Card, Fort Leavenworth, Kansas, March 23, 1934), IR#118-1934, Combined Arms Research Library, Ft Leavenworth; "History of the Armored Force, Command and Center," 4.
[464] "The Tactical Employment of Cavalry (Tentative)" (The Command and General Staff School, 1935), Special Collections, Combined Arms Research Library, Ft Leavenworth.
[465] "The Tactical Employment of Cavalry (Tentative)."
[466] The sections in the 1935 doctrine from Marches to Special Operations are almost an identical format as Chapter 3, paragraphs 37-71 in Wilson's report. "Cavalry (Mechanized)"; Wilson, "A Critical Analysis of the C. & G.S. Pamphlet Cavalry Mechanized," March 23, 1934; "The Tactical Employment of Cavalry (Tentative)," 1935.
[467] Wilson, "A Critical Analysis of the C. & G.S. Pamphlet Cavalry Mechanized," March 23, 1934, 5; "The Tactical Employment of Cavalry (Tentative)," 1935.
[468] "The Tactical Employment of Cavalry (Tentative)," 1935.

cavalry demand self-contained administrative as well as tactical units."[469] This is exactly the change that both Captain Wilson and Major Kingman called for within their respective academic papers.[470] Captain Wilson's widely-read critique of the 1933 doctrine clearly served as inspiration for major portions of the new doctrine, and Major Kingman, in his role as the Command and General Staff School Tank Instructor, would have played an important part in the development of any new doctrine related to that subject within the school.[471] The shift from combined units to separate units represents the exercise of autonomy within the Command and Staff College to change the doctrine outside the accepted reality then present in the U.S. Army.

By 1937 the U.S. Army had released yet another doctrine for the employment of all cavalry.[472] This doctrine retained many of the key concepts from the 1935 doctrine, including the explicit separation between mounted and mechanized units. Specifically, the 1937 version of "The Tactical Employment of Cavalry" outlined the advantages and disadvantages of horse and mechanized cavalry in relation to each other in an effort to help commanders decide which type of unit might be more important for specific missions.[473] This same year, the U.S. Army circulated an "experimental" doctrine that addressed mechanized units at the divisional level.[474] Mechanized divisions did not exist

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[469] "The Tactical Employment of Cavalry (Tentative)," 71.
[470] Wilson, "A Critical Analysis of the C. & G.S. Pamphlet Cavalry Mechanized," March 23, 1934; Kingman, "Mechanized Units."
[471] Wilson, "A Critical Analysis of the C. & G.S. Pamphlet Cavalry Mechanized," March 23, 1934; A. F. Kingman, "Tactics and Techniques of Infantry, Tactical Employment of Tanks" (Illustrative Problem with Solution, November 9, 1934), The Command and General Staff School Second Year Class, Command Course Discussion of Problems 1934-1935, p 120, Combined Arms Research Library, Ft Leavenworth; "History of the Armored Force, Command and Center," 4.
[472] "The Tactical Employment of Cavalry (Tentative)" (The Command and General Staff School, 1937), Special Collections, Combined Arms Research Library, Ft Leavenworth.
[473] "The Tactical Employment of Cavalry (Tentative)," 4–5.
[474] "The Tactical Employment of the Mechanized Division (Tentative)" (The Command and General Staff School, 1937), 2, Special Collections, Combined Arms Research Library, Ft Leavenworth.

in the U.S. Army yet, the largest mechanized unit was a brigade, but the service had already started building the doctrine for these future organizational structures once the materiel became available.[475] Despite the apparent advances in doctrine to achieve innovation in armored warfare, the other two elements of the technology triad were slow to catch up due to how the elements interact with each other.

In 1938, Lieutenant Colonel Ladd, an infantry officer, conducted a thorough review on tank doctrine within the U.S. Army as part of his course of study at the Army War College.[476] In this report, Lieutenant Colonel Ladd explained how the continued divided responsibility between the cavalry and the infantry impeded the U.S. Army's ability to achieve the full potential of armored units. He argued that the cavalry combat cars were too light to effectively conduct attacks across long distances and that the infantry was retaining their tanks to support slower-paced infantry assaults.[477] Lieutenant Colonel Ladd recommended that the U.S. Army reorganize to give the responsibility of this mission to one branch or the other, effectively a new martial knowledge at the U.S. Army level.[478] Further complicating the U.S. Army's ability to adopt the doctrine of 1937, there were not enough tanks.

In the spring of 1940, the U.S. Army conducted a series of corps and field army level exercises to train the massive influx of new troops in the service as the chances of the nation being pulled into the ongoing World War increased.[479] An observer with the

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[475] Van Voorhis, "Mechanization," October 13, 1937, 3, 7, 10; Herr, "The Cavalry," September 19, 1938, 11.
[476] J. A. Ladd, "Tank Doctrine" (Student Report, U.S. Army War College, Washington, D.C., May 1, 1938), 7-1938-50, U.S. Army Heritage and Education Center, Carlisle Barracks.
[477] Ladd.
[478] Ladd, 4.
[479] Office of the Army Commander, HQ Third Army, "Third Army Maneuvers" (Operations Order for training maneuvers, Sabine Area, May 1940), 1939-1940, Regular Course Misc Vol 2, Combined Arms Research Library, Ft Leavenworth; Mildred Hanson Gillie, *Forging the Thunderbolt: History of the U.S.*

IV Corps headquarters during these exercises noted that the new mechanized cavalry doctrine was inadequate because it was not accomplishing its goals in these maneuvers.[480] The U.S. Army lacked sufficient numbers of combat cars and tanks to field the required numbers of mechanized units for the exercises, so they mixed mechanized units with traditional horse cavalry units. As one would expect, when the commanders tried to push the horses as fast and as far as their mechanized doctrine stipulated, the animals could not keep up.[481] This unfortunate situation resulted in horse units littering the side of the roads as they allowed their mounts to rest and adversely impacted the outcome of the entire operation.[482] The new doctrine that the U.S. Army developed in its formal educational facilities held great promise, but it was incapable of achieving its potential with the martial knowledge and materiel solutions from an earlier reality. International events were unfolding in 1940 that would alter the martial knowledge of the U.S. Army related to armored warfare and allow the service to progress into the development of what would become the U.S. Army's innovation in armored warfare.

**The Dawn of Armored Warfare and a New Reality**

To this point, the discussion of the influence of the knowledge system on tank and doctrine development in the U.S. Army prior to World War II has focused primarily on the internal production of knowledge. But information related to the development of

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*Army's Armored Forces, 1917-45*, 1st ed, Stackpole Military History Series (Mechanicsburg, PA: Stackpole Books, 2006), 157; Gabel, *The US Army GHQ Maneuvers of 1941*.

[480] H. E. Dager, "Report of Temporary Duty with Third Army and IV Corps Maneuvers--1940" (Manuscript Observer's Report, Fort Leavenworth, Kansas, June 1, 1940), 7, 1939-1940, Regular Course Misc Vol 2, Combined Arms Research Library, Ft Leavenworth.

[481] Dager, 7; Office of the Army Commander, HQ Third Army, "Third Army Maneuvers," Scenario Blue p5.

[482] Dager, "Report of Temporary Duty with Third Army and IV Corps Maneuvers--1940," 7; Office of the Army Commander, HQ Third Army, "Third Army Maneuvers," Mobile Defense p3.

materiel and doctrine in other countries also entered the system from militaries abroad. The knowledge system played a critical role in the way that U.S. Army officers understood these developments to develop a theory of victory appropriate to their reality. New information was filtered and understood through the existing knowledge system to create as full of an understanding of reality as Army leadership could create with the information at hand. Major General Herr, chief of cavalry in 1938, exemplified this when he claimed that the reason both Germany and England had removed horses from their cavalry in favor of armored vehicles was because both countries lacked the national supply of horses that the United States maintained and that these countries believed any future war they fought would be in the confined spaces of Western Europe.[483] It would be inappropriate to assume Major General Herr was incorrect in his assertion without careful study of German and British historical records, but he does not have to be wrong to illustrate how the knowledge system could have brought him to this conclusion. Major General Herr was aware that these armies removed horses from their units and that the United States possessed a much more accessible supply of inexpensive horse stock. Additionally, officers in the United States Army at this time believed that they had to be prepared to fight a war in the vast expanses of the American West as well as foreign battlefields.[484] These facts, combined with an understanding of cavalry doctrine, which necessitated maximum mobility over even the most treacherous terrain, could have led him to conclude that if the German and British armies could maintain horses and believed they needed them, then they would have. The United States, on the other hand, both had the resources to maintain horses in the cavalry and believed they were necessary for the

[483] Herr, "The Cavalry," September 19, 1938.
[484] Kromer, "Cavalry"; Herr, "The Cavalry," September 19, 1938.

full range of environments in which the cavalry may have needed to fight; therefore, it only made sense for the US Cavalry to maintain horses as well as develop tanks.

The U.S. Army's knowledge system in the 1930s created a local reality from the complex interactions of organizational structures, values, prior knowledge, and epistemologies. This framing of reality defined the martial knowledge that directly influenced both the design of tanks and the way that the Army employed them. Major General Van Voorhis illustrated the local nature of this reality in 1938 when he explained that the US Army developed methods of "practice which are distinctly American and not copies of foreign ways."[485] But the U.S. Army's knowledge system was not a completely closed system. Information from other nations' efforts to innovate related to armored warfare would maintain constant pressure on the U.S. Army's martial knowledge.

While the US Army was slowly realizing the new capabilities that the tank brought to the fight, the German army had reorganized its forces to capitalize on those very same capabilities. In the same 1937 speech where he recounted the successful mechanized cavalry attack, Brigadier General Van Voorhis noted the development of the German Panzer Divisions and advocated for a similar force in the US Army that was separate from the cavalry.[486] That he did not advocate for a transition of the existing cavalry organization to capitalize on the demonstrated capabilities of the tank indicates that the materiel to martial knowledge link was still too weak to fully appreciate these new developments and create a reality where such a transition was appropriate.

In the first two weeks of September 1939, a German tank force invaded Poland and overran the Polish army with a decisiveness that provided an external cue to the

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[485] Van Voorhis, "Mechanization," September 29, 1938.
[486] Van Voorhis, "Mechanization," October 13, 1937.

potential of tanks strong enough to transform the knowledge system in the US Army. There were still some officers that held on to their preexisting reality for a short time. For example, just weeks after the invasion of Poland, when the Polish army was still fighting, Major General Herr defended the cavalry as a relevant arm on the contemporary battlefield when he said, "I don't believe you can single out any arm as being responsible for that [the defeat of Poland]. I think they [the Polish army] were just inadequately placed and armed and were completely surprised."[487] Brigadier General Chaffee's judgments on the events in Poland just ten days after Major General Herr's comments are more representative of the U.S. Army's shifting martial knowledge when he said, "there is no longer any shadow of a doubt as to the efficiency of well trained and boldly led mechanized forces in any war of movement that they cannot be combatted by infantry and horse cavalry alone."[488] Brigadier General Chaffee illustrated the full transition of at least his reality, updated by the potential of tanks as a decisive arm, in this same speech when he advocated for the formation of a Mechanized Cavalry Division that would be roughly modeled on the German Panzer Divisions that had just defeated the Polish army.

Almost immediately after the invasion of Poland, every aspect of the knowledge system within the U.S. Army started reacting to the demonstrated effectiveness of large armored formations. This is where the external epistemologies within the knowledge system started overcoming the influence of prior knowledge to create a martial knowledge to align with the doctrine that the U.S. Army created through the second half of the 1930s. Observers from the October 1939 First Army maneuvers in New York

[487] John Herr, "The Cavalry" (Transcript of lecture delivered at the Army War College and discussion with audience, September 19, 1939), G-3 Course No. 5, 1939-1940, U.S. Army Heritage and Education Center, Carlisle Barracks.
[488] Chaffee, "Mechanized Cavalry."

noted that horses continued to provide the most valuable intelligence reports but also that mechanized cavalry was virtually unstoppable.[489] Major Ramey noted that "the extreme difficulty of defense against fast moving, wide swinging mechanized columns was one of the important lessons left with me by the First Army Maneuvers – confirmed by recent developments in Poland."[490] By the winter of 1939-1940, the U.S. Army had developed the core doctrine that would be necessary to build massive armored units, and the martial knowledge was starting to shift. The previous martial knowledge that posited that the most effective means of employing tanks in combat was within the traditional cavalry and infantry organization in support of their traditional missions gave way to one that embraced an independent tank force that could more fully capitalize on the capabilities of the tank.

On 10 May 1940, the German Army executed *Fall Gelb* and invaded France with a force characterized by large, independent tank formations supported by attack aircraft.[491] The German Panzer divisions were strikingly similar to the original concepts for the U.S. Army Mechanized Force that the U.S. Army failed to build in the ensuing decade. When these nascent concepts first emerged in the late 1920s, the U.S. Army technology triad related to tanks was not in a position to achieve innovation through the realization of independent tank divisions. The U.S. Army doctrine remained grounded in a branch division between cavalry and infantry missions, and the materiel solutions available, or perceived likely to be available in the near future, were inadequate

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[489] R. S. Ramey, "First Army Maneuvers (Plattsburg, New York, Aug 13-27th 1939)" (Manuscript Observer's Report, Fort Leavenworth, Kansas, October 2, 1939), 10, 1939-1940, Regular Course Misc Vol 2, Combined Arms Research Library, Ft Leavenworth.
[490] Ramey, 10.
[491] Clark, *Blitzkrieg*, 102.

according to a martial knowledge which retained many of the values inherent in the preferred organization of the U.S. Army. The gradual changes that took place within the materiel and doctrine through the last half of the 1930s and within the knowledge system after the invasion of Poland produced fertile ground for a drastic shift in the martial knowledge to take place. If there was any serious doubt within the U.S. Army about what massive, independent tank units could do remaining after the invasion of Poland, the German success in France in May and June of 1940 removed that doubt. The U.S. Army took this new information and aligned the doctrine that had been produced in the schoolhouses in the late 1930s to create a distinctly American version of armored warfare rather than a simple copy of the German Panzer divisions.

Two weeks after the invasion of France, on 25 May 1940, a group of officers met in the auditorium of a local high school at the conclusion of a series of large exercises in Louisiana to discuss the role of tanks in ground combat in light of the German invasion**.** General Chaffee and Colonel George Patton were present at this meeting, but the conspirators specifically excluded the chiefs of infantry and cavalry from the discussion that would result in a formal proposal to the War Department to create an independent tank force.[492] The influence of the tank as a materiel solution on the martial knowledge and doctrine of the entire U.S. Army was complete on 10 July 1940, when the U.S. Army created a separate branch for tanks called the U.S. Armored Force.[493] The name of this unit, the Armored Force, was a deliberate decision to distinguish the new branch from

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[492] "History of the Armored Force, Command and Center," 7; Gabel, *The US Army GHQ Maneuvers of 1941*, 23; Gillie, *Forging the Thunderbolt*, 158.
[493] "Hard Pan," *Time*, July 8, 1940, George S. Patton Papers, Box 2, Folder 20, University of North Dakota Elwyn B. Robinson Department of Special Collections.

both the mechanized units of the cavalry and the tank units of the infantry.[494] Even though the knowledge system had changed, the tank as a materiel solution still performed a limiting function on the doctrine of this new force until the rest of the technology triad could catch up to the knowledge system.

When the U.S. Army formed the Armored Force, the new organization inherited the tanks from the infantry and cavalry that had been designed to address the problems framed by the prior knowledge system. These tanks were too light to address the new reality because the infantry had never intended tanks to fight other tanks and the cavalry had favored designs that traded armor for mobility.[495] The War Department began planning for the thousands of new tanks that the new Armored Force would need in June 1940. By August 1940, General Chaffee, then the commanding general of the Armored Force, pleaded with the tank board to "go into production now at all three plants as rapidly as possible on this [new] Medium Tank M3."[496] Chrysler constructed a factory to build the new tanks and delivered the first M3 medium tank in mid-April 1941.[497] With the fielding of the M3 tank and the subsequent M4 Sherman, which would become the workhorse of the U.S. Army in World War II, the U.S. Army aligned all three elements of the technology triad and achieved innovation in armored warfare.

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494 Gabel, *The US Army GHQ Maneuvers of 1941*, 24.
495 Gillie, *Forging the Thunderbolt*, 170.
496 "Minutes of the Ordnance Technical Committee Meeting" (August 29, 1940), 26, Ordnance Board Minutes, Box 7, Folder 15845-16373, Rock Island Arsenal Museum, Rock Island Arsenal.
497 Harry Thomson and Lida Mayo, *The Ordnance Department: Procurement and Supply*, United States Army in World War II, The Technical Services (Washington, D.C.: Office Of the Chief of Military History, Department of the Army, 1960).

**Analysis and Insights**

The development of armored warfare in the U.S. Army was a complex endeavor with the clean lines of causation at the grand scale giving way to an ever more complicated network of interactions as one examines the details. That the shift from horses to tanks took place over more than 20 years in a time of massive technological change makes parsing out the relationship between the changing technology and the military innovation even more challenging. Existing popular narratives of this shift within the U.S. Army tend to focus on the lack of development of an armored force similar to the German Panzer divisions as evidence of a traditional service that was resistant to change with a handful of prophets who valiantly fought an unmoving bureaucracy with varying levels of success.[498] The technology triad is an analytical model within which to move between high-level observations, such as relative stasis in a military, and more detailed accounts. This helps scope the complexity of the full system and produce possible framings for why the officers in the 1930s might have taken deliberate steps to avoid changes that seem obvious with the benefit of hindsight.

World War I saw the introduction of the tank as a materiel solution, but the militaries that employed it did so as a tool to improve their ability to achieve the goals of the pre-existing martial knowledge and its corresponding doctrine. While there were indicators that the tank could enable a new means of waging ground combat, the war ended before any military could fully realize the unintended consequences of the machine. In the U.S. Army, the strength of the martial knowledge and doctrine that reinforced organization along traditional branches minimized the strength of the link

[498] Katzenbach, "Tradition and Technological Change"; Wilson, *Treat 'em Rough*, 231; Morningstar, *Patton's Way*, 69; Johnson, *Fast Tanks and Heavy Bombers*, 135.

from the materiel to the martial knowledge and doctrine and ensured that the dominant influence flowed the opposite direction to relegate the tank to a supporting role in the technology triad. Walter Christie did exercise his autonomy to design and build tanks that were immune from the influence of the U.S. Army's martial knowledge, but he lacked the autonomy, in the form of authority, to make corresponding changes to the martial knowledge and doctrine that would have been required to employ his tanks effectively. The strength of the martial knowledge and doctrine within the U.S. Army likewise prevented the service from building a new technology triad around Christie's tanks the way that the USSR would with their T34 before the end of the 1920s.

The Mechanized Force can be viewed as both an external epistemology and an attempt to generate a new martial knowledge and doctrine to correspond with the materiel solutions that Christie created. As an external epistemology, the Mechanized Force was the U.S. Army's effort to test the ideas that they witnessed the British Army exploring with their own mechanized force. The way that the U.S. Army explicitly adjusted the British model to fit within the perceived local circumstances of the U.S. Army is the defining attribute of an external epistemology that fits the historical record more accurately than the idea that any army would try to copy another military's methods directly, as the diffusion literature would suggest.[499] The initial proposal of a Mechanized Force consisting of tank divisions supported by aircraft sought to leverage the increased speed promised by Christie's designs and could have potentially created a new reality within the U.S. Army. However, the War Department allocated insufficient resources to grant the Mechanized Force the autonomy it would have needed to create a new martial

[499] Horowitz, *The Diffusion of Military Power*.

knowledge and doctrine. In practice, the experimental force became a conglomeration of existing materiel solutions executing existing cavalry doctrine. The inability of the U.S. Army to effectively change all the three elements of the technology triad in a complementary way prevented innovation. The U.S. Army determined that the Mechanized Force would not be able to produce a sufficiently superior unit to traditional horse cavalry supported with combat cars and granted each of the branches the authority to employ tanks to achieve their own objectives. Splitting the responsibility for the development of tanks between the services subjected the direction of the materiel development to the martial knowledge and doctrine resident within the cavalry and the infantry.

While the technology triads within the cavalry and the infantry slowly evolved along a path determined by their own realties defined by the greater technology triad that defined the reality of the entire U.S. Army, innovative change started taking hold as officers in the academic centers of the service exercised their autonomy to challenge the existing reality. A combination of the increasing capabilities of the tank and knowledge generated during the Mechanized Force experiments inspired these nascent changes to the martial knowledge which were expressed in the formal doctrine of the mechanized cavalry. There is a difference between the formal doctrine of a military and its doctrine within the technology triad. The former is closer to the martial knowledge of the military, or how it believes it should operate, and the latter is the actions that the military actually takes to achieve its objectives. This overlap in concepts demonstrates the close link between the two elements and can make it difficult to parse them for analysis. In the case of armored warfare development in the U.S. Army, the service's formal doctrine expressed a slowly changing martial knowledge within a small portion of a single branch that impacted the way the force carried out its missions in training. Therefore, it is more appropriate to consider that the changes that occurred prior to the reorganization of the U.S. Army were primarily isolated within the doctrinal element of the technology triad.

Once the German Army overran the French defenses in 1940, the martial knowledge of the U.S. Military shifted relatively quickly and manifested itself first as a doctrinal change with the formation of the Armored Force. As a material solution, tanks served a dual role in late 1939 and early 1940 by simultaneously exerting an enabling function for the knowledge system, through demonstrated capabilities, and a limiting function on the doctrine of the Army, based on the fielding of earlier tank designs and the limited production capacity for new tanks. This illustrates the complex interactions that the technology triad brings into focus and the effect that different rates of change have on the emergent behavior of the system when framed in terms of the technology triad. Had the Army been forced to deploy the Armored Force prior to the fielding of the new tanks, it would have had to do so with materiel solutions that were completely misaligned with the reality it was operating in at that time due to the relatively fast pace of change of the knowledge system at that time and the structural limits of how fast the US could build new tanks.

By conceptually framing the military socio-technical system related to tanks in the U.S. Army prior to World War II in terms of the three elements of the technology triad, the relationship between the tank and the way the U.S. Army innovated over time breaks into periods of dominant interactions. The four distinct periods defined by the interactions within the technology triad allow the analysis of the development of armored warfare in the U.S. Army to move beyond overly simple accounts that may focus solely on the relative statis of the system. For example, Sereno Brett's ideas for the Mechanized Force could get lost in existing definitions of doctrine that include portions of what the technology triad refers to as martial knowledge within the definition of doctrine.[500] This would hide the way that members of the U.S. Army were attempting to produce an armored warfare innovation years before other countries successfully completed that task.

For militaries who are looking to history to try to actively manage technology and innovation today, a more nuanced understanding of how the Mechanized Force failed and why can provide valuable insights. An explanation that draws from an inherent resistance to change and charges that the cavalry-focused U.S. Army canceled the experiment because it threatened horses would induce a modern observer to take steps to avoid undue traditionalism. But this explanation fails to illustrate how one should draw the line between undue traditionalism and appropriate adherence to proven methods. When framed in terms of the technology triad, the Mechanized Force’s failure becomes an illustration of the inability to produce a full technology triad that could compete with the pre-existing technology triad. Two fully formed technology triads can compete with each other on equal grounds to help distinguish between helpful and unhelpful traditionalism. By isolating the knowledge generation and operational activities of a military, as the technology triad does, a new dimension to understand how materiel interacts with changing ways of war emerges.

Additionally, the local nature of martial knowledge accounts for the information that the actors in the system did not have at the time and helps to understand their

[500] Hoiback, “What Is Doctrine?”; Jensen, *Forging the Sword*, 5.

decisions in context. Without the explicit acknowledgment that martial knowledge is a locally generated and validated form of truth, it is tempting to assume that actors who made decisions that ended up being incorrect did so in spite of some “obvious” truth. By focusing on the generation of knowledge and the way that the materiel and doctrine of the U.S. Army influenced that process, the technology triad can provide an alternate explanation that does not have to assume incompetence on the part of those involved. Those officers who believed that horses should continue to play a key role in cavalry operations through the late 1930s almost certainly believed that this was the correct course of action, just as any decision that a modern military leader may make is the correct one in their mind. With this parallel drawn, modern military leaders can start to question the ways that current doctrine and fielded materiel might be influencing a martial knowledge that could be inappropriate for a war in the near future. This could allow the technology triad to provide useful insights in the contemporary management of technology, where hindsight is unavailable.

For this model to inform any case of military innovation beyond this one from which it was developed, much less a contemporary case, the technology triad must be generalizable to some degree. Applicability beyond this specific case is far from assured, as the technology triad was developed through careful study of the development of armored warfare in the U.S. Army prior to World War II, which is a specific instance bounded by time in a single service of one military. On the other hand, it would be near impossible to test the technology triad against every possible military innovation to determine the degree to which it is applicable. To assess the ability of the technology triad to provide insights beyond this one example, a more deliberate approach to testing is required. The next chapter will present a roadmap to explore the generalizability of the technology triad as an analytical tool.

“He who has the bigger stick has the
better chance of imposing his
definitions of reality.”

-Peter Berger and
Thomas Luckmann,
*The Social Construction of Reality*[501]

# CHAPTER 5

# EXTENDING THE MODEL

## Dreadnoughts and U-boats

Throughout the 19th century, the United Kingdom created the world’s greatest naval power to support and defend the vast British Empire. However, as the century drew to a close, many in the British government became concerned that without deliberate effort the British Royal Navy might lose its position of preeminence, and the British Parliament passed the 1889 Naval Defense Act.[502] This new law instituted the “two-power standard,” which stipulated that the Royal Navy must maintain more battleships than the next two largest fleets combined.[503] According to the prevailing martial knowledge of the day, which held that the number and strength of battleships would determine the outcome of naval battles, this would ensure a British victory even if two nations combined their fleets to threaten the Royal Navy.[504] As the events of World War I would demonstrate, this martial knowledge reflected a peacetime military knowledge

[501] Berger and Luckmann, *The Social Construction of Reality*, 127.
[502] Nicholas A. Lambert, “Righting the Scholarship: The Battle-Cruiser in History and Historiography,” *The Historical Journal* 58, no. 1 (March 2015): 275–76, https://doi.org/10.1017/S0018246X14000314.
[503] Angus K. Ross, “Four Lessons That the U.s. Navy Must Learn from the Dreadnought Revolution,” *Naval War College Review* 63, no. 4 (September 2010): 121.
[504] Lambert, “RIGHTING THE SCHOLARSHIP,” 275–76; Ross, “Four Lessons That the U.s. Navy Must Learn from the Dreadnought Revolution,” 121.

system and did not perform as intended in the wartime reality comprised of a determined enemy and submarines, a fundamentally different materiel solution for naval combat.

The Royal Navy's martial knowledge at the turn of the 20th century was firmly rooted in the preeminence of battleships in contemporary naval combat. Advances in propulsion systems, gun size and range, and armored hulls moved rapidly at this time in history, and the naval powers of the world engaged in a naval arms race to build bigger and better-armed battleships.[505] The HMS Dreadnought, launched in 1906, was one of the most famous ships of this era and combined steam turbines with a cutting-edge armament of ten 12-inch deck guns to produce the standard by which all subsequent battleships would be compared.[506] Maintaining such a large number of battleships in the Royal Navy was extraordinarily expensive. By 1905, the year before the HMS Dreadnaught was completed, the Royal Navy accounted for 37 million pounds out of a total governmental budget of just 121 million pounds.[507] To reduce the British government's financial strain and enable the purchase of the faster but equally as well-armed battle cruisers, the British Admiralty interpreted the Naval Defense Act to include both battleships and battle cruisers against the two-power standard.[508] Today, contemporary actors and historians have debated at great length the degree to which the battle cruiser and the Dreadnought class battleship represent innovative technologies.[509] But framed in terms of the

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[505] John Brooks, "Dreadnought: Blunder, or Stroke of Genius?," *War in History* 14, no. 2 (April 2007): 159–61, https://doi.org/10.1177/0968344507075875.
[506] Brooks, 58, 163–66.
[507] Lambert, "RIGHTING THE SCHOLARSHIP," 275–76.
[508] Lambert, 277.
[509] Lambert, "RIGHTING THE SCHOLARSHIP"; Brooks, "Dreadnought"; Ross, "Four Lessons That the U.s. Navy Must Learn from the Dreadnought Revolution"; David G Morgan-Owen, "Continuity and Change: Strategy and Technology in the Royal Navy, 1890–1918*," *The English Historical Review* 135, no. 575 (November 6, 2020): 892–930, https://doi.org/10.1093/ehr/ceaa194; Gautam Mukunda, "We Cannot Go On: Disruptive Innovation and the First World War Royal Navy," *Security Studies*, February 23, 2010, https://doi.org/10.1080/09636410903546731.

technology triad, both of these designs were improvements to the British Navy's existing materiel solutions to support the previous technology triad in that service. They still supported the same goals and represented the same basic assumptions that defined the reality of a battleship-dominant martial knowledge.[510] At the same time that naval engineers were designing bigger and bigger battleships, a fundamentally different material solution was emerging that challenged this pre-existing martial knowledge.

Robert Fulton built the first practical submarine more than 100 years before British engineers laid the keel for the HMS Dreadnought, but the strength of the battleship-focused martial knowledge in the Royal Navy would inhibit its adoption.[511] As early as 1904, Admiral Fisher, the architect of the Royal Navy that would fight World War I, questioned the ability of the battleship to survive against a force armed with torpedoes, but he maintained that as long as other countries continued to build battleships, that it was too dangerous to forego their manufacture.[512] Submarines would have been one of the machines that would have launched the torpedoes about which Admiral Fisher was concerned. In 1906, the British Royal Navy maintained a fleet of more than 50 submarines, which was a substantial number compared to Germany's one submarine at the time.[513] By 1914, civilian observers opined that the submarine had made the battleship obsolete.[514] Despite the presence of torpedoes and the submarines to launch them, the British navy maintained a battleship-centric martial knowledge. Exemplary of the general sentiment towards submarines in the Royal Navy, the British Admiral Arthur

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[510] Morgan-Owen, "Continuity and Change," 927, 898.
[511] Willis Fletcher Johnson, "Submarine and Dreadnought," *Scientific American* 78, no. 2016supp (August 22, 1914): 118–19, https://doi.org/10.1038/scientificamerican08221914-118supp.
[512] Brooks, "Dreadnought," 162.
[513] Mukunda, "We Cannot Go On," 144.
[514] Johnson, "Submarine and Dreadnought."

Wilson said in 1902 that submarines were "underhanded, unfair, and damned unEnglish."[515]

Sharing the martial knowledge that battleships defined a naval force, the Germans undertook a massive ship-building campaign around the same time that the British launched the HMS Dreadnought.[516] However, the Germans started out at a disadvantage with only four armored cruisers to the British Navy's 17 in 1907 and abandoned their attempt to outbuild the British Navy by 1912.[517] By the martial knowledge of the two countries, the British navy held a severe advantage over the German navy on the eve of World War I with over two million tons combined displacement in the British Royal Navy and less than half that amount in the German navy.[518] Furthermore, the British government had developed the industrial capacity to build 13 ships in the first 18 months of the war compared to Germany's two ships in that same time period.[519] It seemed that the British Navy's ability to protect their homeland, their empire, and the trade routes that connected them would be near impregnable once the war started.

Almost immediately after the onset of hostilities, the martial knowledge that held the supremacy of battleships and the technology triad that aligned with these beliefs failed to perform as desired in the presence of German U-boat submarines. While the Germans had yet to build their submarine fleet to the size that it would be at the end of the war, the few that they did employ was enough to force the British Navy to reposition

[515] Quoted in Beatrice Heuser, *The Evolution of Strategy: Thinking War from Antiquity to the Present* (Cambridge, UK ; New York: Cambridge University Press, 2010), 225; Holger H. Herwig, "The Submarine Problem: Germany, Britain, and the United States, 1919-1939," in *Military Innovation in the Interwar Period* (New York: Cambridge University Press, 1996), 247.
[516] Brooks, "Dreadnought," 159–61.
[517] Morgan-Owen, "Continuity and Change," 914, 926.
[518] Niall Ferguson, *The Pity of War* (London: Allen Lane, Penguin Press, 1998), 85.
[519] Morgan-Owen, "Continuity and Change," 899–900.

their fleet of capital ships out of reach of the German U-boats and far afield of the main action of the naval war.[520] Further challenging the pre-war martial knowledge, the Germans attempted a blockade of the British Islands by targeting merchant ships with U-boats in 1915.[521] The Dreadnought and Super-Dreadnought class battleships that the British Navy had spent so much money on before the war proved so ineffective in the war in which the British government would rely on them that in March 1916 the Commander of the British Grand Fleet, Admiral Sir John Jellicoe said, "I only wish I could exchange half a dozen battleships for half their value in light cruisers and destroyers."[522] Despite the early successes of the German U-boats, both sides continued to maintain a martial knowledge that posited the war on the sea would be won or lost in a massive fleet on fleet battle of the type envisioned before the war.[523] In May 1916, the fleets clashed near the Jutland Peninsula in the only major naval battle of the war and without the employment of submarines on either side.[524] The Battle of Jutland, far from the British triumph that the Royal Navy would have predicted with their larger fleet, ended in a draw.[525]

Shortly after the Battle of Jutland, the German navy shifted their martial knowledge and started aligning their technology triad to complement the new martial knowledge. Open engagement with the British fleet was a dangerous doctrine for the Germans. Without the ability to produce ships as fast as the British, they could not afford to risk losing their entire fleet and the threat that it posed to the British. Furthermore, the U-boat campaign of 1915 had demonstrated that the submarine, as a material solution,

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[520] Brodie and Brodie, *From Crossbow to H-Bomb*, 182.
[521] Victoria Carolan, *World War 1 at Sea* (Harpenden: Pocket Essentials, an imprint of Oldcastle Books, 2014), 92, http://public.ebookcentral.proquest.com/choice/publicfullrecord.aspx?p=1708746.
[522] Quoted in Morgan-Owen, "Continuity and Change," 898.
[523] Donald A Yerxa, "Remembering World War I at Sea," *Fides et Historia* 50, no. 1 (2018): 116,118.
[524] Carolan, *World War 1 at Sea*, 99.
[525] Heuser, *The Evolution of Strategy*, 251.

enabled a different kind of naval warfare. The Germans updated their martial knowledge that held the importance of battleships above all else and stopped the production of capital ships to focus on fielding more U-boats.[526] By February 1917, the Germans possessed more than four times as many submarines as they had employed in their 1915 campaign against merchant ships and undertook the most successful submarine campaign in history, as measured by tonnage sank vs. losses. The Germans sank more than twice as much shipping than the United States did in the Pacific theater during the entirety of World War II.[527] By the end of World War I, German submarines accounted for 11 out of every 12.5 tons that the German navy sunk during the war, demonstrating the superiority of the submarine technology triad within the German Navy compared to the surface ship grounded technology triad.[528]

The British Navy was slow to react to this new reality that the Germans were imposing on them. Not until the threat of losing the entire war loomed did the British Navy adopt a new doctrine with ship convoys that would allow them to employ their existing materiel within a new technology triad.[529] The British won the war, so it is difficult to critique their methods and approach to naval technology before and during the war without the obvious counter that it eventually worked. However, the technology triad demonstrates how the martial knowledge the British Navy held prior to the war, with its corresponding expensive capital ships and emphasis on fleet engagements, failed to achieve its desired effects once hostilities commenced. The Germans entered the war with the same general technology triad but at a disadvantage with their fleet size

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[526] Yerxa, “Remembering World War I at Sea,” 125.
[527] Yerxa, 126.
[528] Heuser, *The Evolution of Strategy*, 249.
[529] Heuser, 249; Mukunda, “We Cannot Go On,” 140; Yerxa, “Remembering World War I at Sea,” 125.

according to the martial knowledge both countries shared. But the Germans were able to pivot off their experiences during the war with access to the laboratory of actual combat to produce a new technology triad that was superior to the British Navy's technology triad. This short vignette demonstrates how the technology triad not only holds the potential to explain how a military changes with technology in peacetime, but it can also start to highlight the complex relationship between adversaries with interacting technology triads. This capability of the technology triad as an analytical model will be important as a way to test the generalizability of the model beyond the original case from which it was derived.

## A Deductive Framework

The technology triad was the result of grounded theory development derived from careful study of a single historical case study, and, as the above vignette demonstrates, there are tentative indications that the technology triad might apply to other cases. However, this method of applying the technology triad to individual cases does not guarantee that the ability of the technology triad to provide insights related to the development of armored warfare can be duplicated in additional cases. If the technology triad is going to fulfill its intended purpose as a practical model that national defense leaders can use to actively manage the relationship between technology and military innovation, the framework will have to be able to provide useful insights for cases beyond the one from which it was derived and individual cases in the historical record. This chapter will explore the logical consequences of the technology triad to establish a deductive framework against which to test the generalizability of the model in subsequent cases. Successfully meeting the qualifications outlined below will not mean that the technology triad is universally generalizable, but it will be an indicator that framing the relationship between technology and military innovation in the manner prescribed by the model could have the potential to be a useful endeavor for a wider range of scenarios. Furthermore, the failure to fulfill one or more of the logical consequences of the technology triad could point to the types of cases where the model is not useful and enhance understanding of the relationship between technology and military innovation in general.

There are four key indicators that may be present in cases of military innovation beyond the development of armored warfare in the U.S. Army prior to World War II that could support claims of broader generalizability of the model. The first is the non-trivial influence of martial knowledge on the development of doctrine and materiel solutions. Martial knowledge is the new concept, compared to doctrine and materiel, that forms the technology triad; without it, the technology triad loses its basic structure. Second, different rates of change between the three elements within the technology triad should be present. The relative rates of change between the three elements provide the functional justification for the separation of three conceptually intertwined aspects of technology. Third, the three phases of innovation should provide a basic blueprint for the way that the military innovation in question unfolded. Specifically, the role of autonomy and the necessity of aligning all three elements of the technology triad to create a new reality should be present. Finally, the local nature of martial knowledge and the reality produced by individual militaries' technology triads should produce competing realities that interact with each other in important ways when the militaries engage in combat. All four of these indicators do not need to be present in every case for the technology triad to provide useful insights, but the more that are present, the stronger the likelihood that the model will prove useful in the future management of technology and innovation in uncertain environments.

**Influence of Martial Knowledge**

Martial knowledge emerges as a novel concept that underpins the technology triad and enables the model to provide new insights. An acceptance that martial knowledge is the product of local interactions between people and their environments, rather than a reflection of some universal truth, forms the philosophical base from which the entire model is constructed. If one can adequately understand changes within the military related to technology by considering materiel and doctrine alone, then the technology triad, with its addition of martial knowledge, is an unnecessarily complicated academic exercise. While generalizability to some degree may not require the presence of all four of the indicators listed above, martial knowledge must be present in any subsequent case study for which the technology triad is applicable. The presence of martial knowledge should manifest itself through interactions with the materiel and the doctrine of a military.

Interactions between a military's martial knowledge and the material solutions that military employs could flow from martial knowledge to materiel, materiel to martial knowledge, or some combination of the two reciprocal relationships. Indications of the link from marital knowledge to materiel solution alone in subsequent case studies would provide weak support for technology at most. Ideas related to how knowledge, especially scientific knowledge, relates to technology production are far from new, and their relationship is well represented in the STS scholarship.[530] To support the claim that a new concept, martial knowledge, should be introduced to better understand the relationship between technology and military innovation, the influence from martial knowledge to materiel should specifically highlight the locally constructed nature of martial knowledge. Concepts from STS, such as SCOT, where the social interactions between the people within the military that are producing the martial knowledge play an important role in the way that the martial knowledge shapes the materiel solutions, would be a stronger indicator of the value of martial knowledge as a concept than a simple knowledge to materiel influence.

The opposite influence could also present itself, depending on the context of the innovation. This link, the materiel to knowledge link, can manifest itself in one of two ways. The materiel a military employs could have a reifying effect on the martial knowledge by introducing or maintaining a certain way of thinking about the conduct of war. Shapin and Schaffer's description of Boyle’s air pump as a “reifying engine” that turned previously conceptual ideas into laws of nature is an apt analogy for the way that a military’s materiel can influence its martial knowledge.[531] Through the physical demonstration of capability, materiel “proves” something about nature that was previously only a “theory” of what could be. This reification is an important aspect of the technology triad. It is the process through which ideas and concepts become a reflection

[530] Bush, *Science, the Endless Frontier*; Donald A. MacKenzie and Judy Wajcman, eds., *The Social Shaping of Technology*, 2nd ed (Buckingham [Eng.] ; Philadelphia: Open University Press, 1999); Ulrike Felt et al., eds., *The Handbook of Science and Technology Studies*, Fourth edition (Cambridge, Massachusetts: The MIT Press, 2017).
[531] Shapin and Schaffer, *Leviathan and the Air-Pump*, 28; Berger and Luckmann, *The Social Construction of Reality*, 106.

of reality in the strongest sense of the term. There is little doubt to anyone who has witnessed the massive explosion of a Mine Clearing Line Charge, a rocket launched string of explosives, that clearly a viable option for producing a path through a minefield is with one of these weapons. The deep concussion of the high explosives and the accompanying wave of heat and light are tangible proof that it is possible to quickly clear a path through minefields and implies a wide range of possible uses and capabilities that accompany this new truth. Of course, the Mine Clearing Line Charge is a materiel solution that is itself a material reflection of certain kinds of knowledge and implicit assumptions that may or may not be most appropriate for some future scenario. In the presence of the physical embodiment of the knowledge and assumptions that undergird the Mince Clearing Line Charge, the uncertainty that may have existed before the demonstration gives way to a more certain way forward. In this manner, the materiel has reified a previously conceptual facet of clearing minefields with explosives.

One can explore this stronger influence on the martial knowledge of a military by asking the question, 'does the materiel influence the understanding of truth beyond explaining the way things currently are and delve into the realm of the way things ought to be?' This question can help prevent observing a military's acceptance of the resources available as a true reflection of the martial knowledge within that military because there is always the potential for a lag in materiel production to align with a new martial knowledge. Without looking for reflections of the influence of materiel on the way things ought to be, a researcher risks misidentifying interim materiel solutions as a reflection of the current martial knowledge of a military. The second way that materiel can influence martial knowledge is through recognition of unintended consequences. Weapons and equipment designed for one purpose, say overcoming machine gun nests in World War I, could hold great potential to create entirely new ways of fighting, such as the way militaries employed tanks in World War II. Timely recognition of unintended consequences of materiel solutions, through internal or external epistemologies, is critical for a military to maintain an advantage in situations where fielded materiel holds the potential to produce rapid innovations.

Situations where fielded materiel can produce rapid innovations occur because of the martial knowledge to doctrine link. Once a military adjusts its martial knowledge to accept that it can employ the already existing materiel in a new manner, then the martial knowledge exerts an influence on the military's doctrine by establishing the most appropriate actions for that military to take to achieve its objectives. The distinction between martial knowledge and doctrine, which is not present in existing models of military innovation or doctrine, allows one to distinguish between how a military acts and how it would prefer to act. This is related to the question posed above in reference to a military that may hold a certain truth about the best way to fight a war but lacks the resources to act in that manner. A lag between when a military decides a certain action is the correct way to operate and when they can allocate the necessary resources to operate in that manner should be present in a mismatch between stated, or formal, doctrine and the way the military actually operates. For example, the U.S. Army was unable to execute its cavalry division doctrine at first because it lacked enough tanks.

Doctrine can also have a noticeable influence on the development of martial knowledge through what was phrased “military technique” in Chapter 3. Similar to the way that materiel can act as a “reifying engine” to define the boundaries of reality and truth, doctrine can impart a specific way of thinking on a military. While formal colleges and educational institutions exist in many militaries, members of a military primarily learn their craft through the conduct of field training and active operations. For example, during the 7th Cavalry Regiment exercises in New York in 1939, the primary purpose of those exercises was the training of troops to the point where it inhibited the units' ability to test new doctrinal concepts.[532] These field training exercises, their existence alone is a reflection of a military's doctrine, serve as reifying engines themselves that impart an impression of the correct way to conduct war on the participating military. If there was a question before the exercise about the best way to move combat cars across a small creek, for example, the experience gained in the exercise where a creek was forded both by the people who conducted the fording and everybody who witnessed it created a new truth against which all other methods must be measured. The anchoring effect of seeing the outcome of a doctrine in training reifies the cause and effect of the action and outcome to the point where the soldiers in question have justification for their belief that this is a reflection of the way things are and ought to be. This same idea could apply to normal day-to-day operations that reinforce certain ways of thinking about how a military should organize for or conduct operations. Indications in subsequent cases that the way a military operates imparts a way of thinking on that military, or martial knowledge, that can then influence the rest of the technology triad would indicate that distinguishing martial knowledge from doctrine is useful to better understand the entire system and how it changes over time.

[532] Ramey, "First Army Maneuvers (Plattsburg, New York, Aug 13-27th 1939)."

Because the system is always changing, not all of these influences will be present at any one given time. Many of the above interactions between martial knowledge and the rest of the technology triad are conflicting. The reifying potential and unintended consequences of material, for example, are essentially opposite effects. If an analyst could ever know everything about a system, there is a chance that the degree to which the two influences exist and work against each other could become clear. However, in the real world, with real data, the apparent strength of one influence or the other may mask the impact of the opposite effect and make it appear that there is only one at any given time. Additionally, each of these influences could occur at different levels, similar to the U.S. Army in the 1930s, where there was a technology triad at the service level related to tanks and nested technology triads within each of the branches. A study of additional cases could uncover the same structure. This would support the technology triad's model of internal innovation, where a new reality emerges within an existing reality to produce innovation. The presence of these influences alone does not indicate that the full technology triad is universally generalizable. But their presence would indicate that separating out martial knowledge to understand the changing relationship between doctrine and materiel could be a useful exercise for a wider set of cases and set the conditions to further explore the other aspects of the technology triad that determine its usefulness for the management of technological change in militaries.

**Different Rates of Change**

Assuming that martial knowledge is present and useful, the next indicator that the technology triad might be generalizable to some degree is the different rates of change between the three elements in the model. If one can reduce the system to just two elements, doctrine and materiel, the resultant system would simply describe how the quicker moving element is pulling along the slower moving one. There must be three elements for the different rates of change to produce the complex interactions within the system. When testing other cases for differing rates of change, they can conform to their fastest possible rates, such as the development of tanks gun carriages at the end of World War I, or the specifics of the case could alter the ordering of which element changes the quickest. The key consideration is that each of the three elements changes at different rates. This would indicate that all three elements are distinct from each other in ways that are noteworthy for the management of a real organization.

One particular way that the rates of change might manifest themselves to demonstrate the usefulness of the technology triad would be if the military is unable to field a materiel solution fast enough to conform to a specific martial knowledge and this, in turn, induces a change to the doctrine of that military. Such a scenario would especially support the applicability of the technology triad to that case because it combines the presence of martial knowledge as a useful concept distinct from doctrine and differing rates of change in one scenario. Furthermore, this instance would demonstrate a situation where the three elements are essentially changing at their fastest rate, with martial knowledge far outpacing materiel and doctrine somewhere in between. Logically, one would expect this scenario to be more likely at higher levels of command because that is when fielding new materiel solutions would be the most difficult compared to adjusting a military’s understanding of truth.

In practice, it may be difficult to determine if or how the rates of change for the three elements are different. The larger the socio-technical system, or the slower it is changing, the more challenging it will be to break these major movements out of the noise of the smaller interactions within the system. However, different rates of change are a fundamental quality of the logic that underpins the technology triad, and their identification within the system must provide useful insights for the technology triad to apply to a specific situation. Absent differing rates of change, it becomes much more difficult to argue that the technology triad holds clear, practical applicability in the management of military technology.

**Three Phases of Innovation**

The three phases of innovation within the technology triad are quite general, and the basic construct of a new idea, followed by the development of that idea, followed ultimately by an innovation is well represented within the literature and common sense already.[533] The key indicators within the phases of innovation that would support the technology triad as a useful model have to do with the concept of autonomy and how a new idea develops into a new reality in relation to the three elements of the technology triad. Autonomy is a critical concept within the innovation process of the technology triad because it signals the point where an idea departs from the established reality defined by a current technology triad and starts progressing towards a new reality. As demonstrated in the tank case study, not every new idea that is outside the established reality will eventually form a new reality. However, if the technology triad's concepts related to how

[533] Horowitz and Pindyck, “What Is Military Innovation? A Proposed Framework.”

militaries create local realities are generalizable, then the genesis of every innovation should be related to a departure from a previous reality. This autonomy could be held at a high level, normally considered “top down” innovation, or it could come from within the military.

Once a new triad starts forming around some change to one of the elements, then all three elements must change before a successful innovation can occur within the technology triad framing of innovation. All three elements must change because innovation within the technology triad is the establishment of a new reality that is defined by the interactions of each of the three elements. If subsequent cases turn up instances where just one or two of the elements are changed, and yet an innovation occurs, then this could indicate that the technology triad does not provide a useful model to analyze innovation in that case. The absence of the three phases of innovation in other cases would not invalidate the technology triad completely. But it would demonstrate the types of cases for which the sequence of innovation presented in Chapter 3 provides little insight. This could help refine the technology triad to enhance its practical usefulness in uncertain environments.

**Shared Realities**

The final indicator of generalizability is the most fundamental and the one that holds the potential to open this research beyond its current scope if it is valid. At the end of the discussion related to temporal interactions within the technology triad in Chapter 3, it was stated that the ability of the interactions of the three elements of the triad to define reality might be the most important insight one can draw from this framing of military technology. If the elements of the technology triad do play a key role in the definition of reality for a military, then the differences between the technology triads of each military will effectively create separate realities. This presents the opportunity to extend conceptualizations of war beyond the Clausewitzian violent dialectic competition between armies and nation-states to include a broader dialectic interaction between competing realities.[534] Conceptualizing war as a competition between realities implies important considerations about the way belligerents interact with each other, and reflections of these considerations should be present in other cases if the technology triad is generalizable.

In chapter 3, this dissertation explained how the technology triad creates reality for the military in question. Social interactions with the military are the critical aspect of the technology triad that enables the creation of reality. Berger and Luckmann highlighted the importance of social interactions in the construction of reality when they said, "The reality of everyday life further presents itself to me as an intersubjective world, a world that I share with others. This intersubjectivity sharply differentiates everyday life from other realities of which I am conscious. I am alone in the world of my dreams, but I know that the world of everyday life is as real to others as it is to myself."[535] In other words, reality is defined by those aspects of it that are shared with other people. Lawrence Freedman established a similar, but distinct in one critical way, concept in his book *Strategy*.[536] Freedman argued that the practice of strategy, ranging from business to war, can be framed as the ability of leaders to "form compelling accounts of how to turn a

[534] Sun-Tzu and Clausewitz, *The Book of War*.
[535] Berger and Luckmann, *The Social Construction of Reality*, 37.
[536] Lawrence Freedman, *Strategy: A History* (Oxford ; New York: Oxford University Press, 2013).

developing situation into a desirable outcome."[537] The idea that strategy can be a sort of narrative that is both shaped by leaders and builds on itself over time to describe the relationship between an organization's current state and some future desired state is similar to the concept of shared realities in the way that those within the organization would subscribe to both the validity of the narrative and their collective shared reality. However, the addition of aspects of the physical world within the technology triad makes the concept of a shared reality much stronger. Through the influence of doctrine and materiel on the production and maintenance of martial knowledge, the reality that emerges is more than a shared narrative. There are physical artifacts that reflect the embodied knowledge of the military, which serve as reifying objects and a form of language with which to communicate about the nature of reality. The physical properties of doctrine and materiel provide the opportunities for stronger justification of beliefs than the world of narrative alone can. The reality defined by the technology triad of a military is a shared reality, in the strongest sense of this term, between those military members.

Taken to its logical conclusion, the idea of shared realities can apply equally as well to the physical reality within which all humans exist as it does to the production of knowledge. Discussing perceptions of risk, Eugene Rosa developed a world view that argued for socially constructed epistemology and a realist ontology to address the concerns raised at the beginning of Chapter 3 related to the way that physical reality seems immune to our socially constructed notions of it.[538] Fundamentally different world views may help understand aspects of risk but are inappropriate for application to the technology triad because the three elements are intertwined and exist in both the physical

[537] Freedman, xiv.
[538] Rosa, "Metatheoretical Foundations for Post-Normal Risk."

and social worlds. Shared realities can address this inconsistency by applying the same logic to the social world as to the physical world. Socially constructed truths, or reality, are those that are shared between people, and physical reality is simply a set of truths that are shared by all humans in the four-dimensional world of physical things and time. It may be useful to think of realities as nested within each other, like Venn diagrams. There are aspects of socially constructed reality that one group may not share with another, so there is no overlap in that level of reality, but both groups share the physical world, a higher reality. In terms of the technology triad, militaries with different technology triads still share aspects of the higher reality that is the physical world.

War is the interaction between opposing realities within a higher shared reality. The plight of American prisoners of war (POWs) in the Vietnam War can help explain how this works. The North Vietnamese subjected the POWs to years of physical and psychological torture in an attempt to force the POWs to produce propaganda for the North Vietnamese.[539] The prisoners were totally isolated from the outside world, except for those instances where outside contact benefited the North Vietnamese.[540] To combat their exploitation, the POWs developed a closed society with their own means of communication and norms of behavior centered around faith in their fellow prisoners and a constant struggle against their captors.[541] If the North Vietnamese successfully forced a POW to provide a statement or some other action that could be detrimental to the

[539] John McCain, *Faith of My Fathers: A Family Memoir* (Random House Trade, 2016), 241.
[540] William Reeder, *Through the Valley: My Captivity in Vietnam* (Annapolis, Maryland: Naval Institute Press, 2016), 168–69.
[541] McCain, *Faith of My Fathers*, 211–12, 252–57.

American war effort, the other POWs would provide moral support and help that prisoner resume their resistance.[542]

In this example, the POWs and the North Vietnamese each existed within their own realities. The captors' reality was one where it was desirable for the prisoners to support the North Vietnamese war effort any way that they could. The prisoners' reality was defined by a truth that posited that any willing support of the North Vietnamese war effort was treasonous and immoral. If there was no difference between these two realities, then there would have been no conflict. One side or the other would have willingly carried out the request of the other. This same idea can scale up to entire wars. For example, had the French in 1940 lived in a reality where it was preferable to submit to German occupation without fighting, then there would have been no need for the Germans to wage war on France. The German Army would have simply moved into France and claimed their prize. This is a version of the often-quoted Sun Tzu's "to subdue the enemy without fighting is the acme of skill," if one could manage to intentionally bring an adversary's reality in alignment with their own without violence.[543]

When opposing realities of nations come in conflict with each other, those nations must appeal to a higher reality, one which is shared by both belligerents, to determine which reality will be dominant. Violence to force reality alignment is resorting to the ultimate shared reality, the one of flesh and blood, within which all humans exist. When the POWs maintained their own socially constructed reality in the face of North Vietnamese efforts to convince the prisoners to adopt the North Vietnamese reality, the guards employed violence, which existed in a reality that both the guards and the

[542] McCain, 244.
[543] Sun Tzu, *The Art of War*, trans. Samuel B. Griffith (New York: Oxford University Press, 1963), 77.

prisoners shared.[544] Unlike in combat, where killing is an option, perhaps even the goal, to convince others in a military to adopt a certain reality, the North Vietnamese could not just kill their prisoners because that was counter to their objective of using the prisoners to produce propaganda. This set up a protracted struggle for the definition of reality between the POWs and their captors that lasted until the prisoners were released. Controlling the level of shared reality that a war resorts to becomes an important consideration for combatants to achieve their political aims.

Conflict within this framing of war and peace does not have to resort to violence, just to the level of a reality that both sides share. The Chinese concept of "Lawfare" is a good example of a way that a nation can resort to a shared reality short of the ultimate shared reality, international law in this case, in an attempt to force their adversaries to conform to a desired reality.[545] Similarly, the Russian liminal warfare, or gray zone operations, mentioned in Chapter 3 is a doctrine that seeks to establish a dominant reality without resorting to large-scale combat.[546] Each of these examples would still fit within the same framing of war as a contest for the definition of reality within a shared reality; they are just at a lower shared reality than mass violence.

Acknowledging that conflict with levels of violence lower than would be expected in general war is a philosophically similar endeavor to Clausewitzian war, with its mass violence, extends the application of the logic upon which the constructed nature of martial knowledge relies. The discussion of violence as a requirement for war in

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[544] McCain, *Faith of My Fathers*.
[545] Stefan Halper, "China: The Three Warfares" (White paper prepared for Andy Marshall, Director of the Office of Net Assessment, Univeristy of Cambridge, May 2013), 46–70; Elsa B. Kania, "The PLA's Latest Strategic Thinking on the Three Warfares," The Jamestown Foundation, China Brief, August 22, 2016, https://jamestown.org/program/the-plas-latest-strategic-thinking-on-the-three-warfares/; Qiao Liang and Wang Xiangsui, *Unrestricted Warfare* (Beijing: PLA Literature and Arts Publishing House, 1999), 55.
[546] Kilcullen, *The Dragons and the Snakes*; McFate, *The New Rules of War*.

Chapter 3 was a simplification of more complex ideas to explain how martial knowledge is a purely social construction. Even in war, the conduct of violence is always, with good reason, subject to various elements of a socially constructed reality. From ancient ritual combat to the code of chivalry and even today's law of armed conflict, belligerents conform to a reality that is shared below the restrictions imposed by the physical world.[547] As long as combat remains within a socially constructed reality, anything short of Clausewitz's absolute war, then there is always a chance that some other reality will emerge that can challenge the constructed one, just as the dynamic of peacetime martial knowledge is tested in wartime.[548] The Clausewitzian distinction between war and peace characterized by the presence of violence is thus replaced by a framing where the relevant distinction becomes the level of shared reality within which the opposing realities compete.

Critically, the shared reality within which opposing realities compete does not exist until the conflict, or war, takes place. Militaries exist within their own realities, which are built and maintained by their individual technology triads. When militaries engage in war, a new shared reality forms between the belligerents. This shared reality does not exist until the war starts and may never exist if there is no conflict. If a specific war never breaks out between nations, then the individual realities within the militaries remain valid, as long as they are internally consistent, because events outside of the local reality never challenged them.[549] For example, had the British Navy in the vignette at the beginning of this chapter never engaged in combat with the German Navy, the

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[547] Martin Van Creveld, *Command in War* (Cambridge, Mass: Harvard University Press, 1985), 62–92; "FM 6-27 The Commander's Handbook on the Law of Land Warfare."
[548] Clausewitz, Howard, and Paret, *On War*, 87.
[549] Sickler, "Elon Musk Says Drones Are the Future of War, but He Should Consider Horses."

dreadnaughts would have maintained their preeminent position in the world of naval combat and fulfilled their intended purpose for the British Navy. It was only once the dreadnaughts were tested against the U-boats, mines, and torpedo boats, which were part of the new shared reality created by World War I, that the Dreadnought class battleships became inappropriate for their intended purpose. Just as internal innovation within the technology triad is a dialectic struggle for the most appropriate of competing realities, victory in war goes to the reality that is most appropriate for the shared reality between combatants. When the Germans' reality included weapons and doctrine that were more appropriate for naval combat in World War I, the British Navy was forced to adapt to this new reality. The Germans lost the war. However, in this one facet of the conflict, the German reality was superior, evidenced by the dramatic shift of British naval doctrine to protect merchant ships during the war.

If subsequent case studies demonstrate the development of unique realities and the ensuing competition between them, similar to the World War I naval example, then this is a positive indicator that the technology triad holds explanatory power beyond the development of U.S. armored warfare. Within these cases, it may be difficult to identify the competing realities because war is a dynamic struggle characterized by adaptation and change throughout its conduct. Militaries may be able to quickly adjust their martial knowledge as soon as it becomes apparent that their technology triad is misaligned for the war at hand. However, the lag in the time that it would take the materiel and doctrine to align with the new martial knowledge should be evident in the cases to help identify the competing realities.

**Testing for Generalizability**

The four indicators above form a test to apply to subsequent cases and determine the degree to which the technology triad might be generalizable. The presence of any or all of these indicators does not prove that the technology triad is universally generalizable. Such a goal is beyond the scope of this dissertation. However, their presence would help demonstrate that a model derived from careful study of a single case and informed by a wide range of academic fields can be a useful framing of the relationship between technology and military innovation for more than just the one case. This is a critical requirement for the technology triad to meet its stated goal of applicability in cases where hindsight or complete information is not available. The degree to which the model might provide useful insights will depend on its ability to highlight aspects of the subsequent cases that other approaches may not. The next two chapters will provide additional cases within which to test for the four indicators derived above by extending the technology triad's logic beyond the conditions of its genesis.

"If, despite Allied use of substantial non-nuclear forces, the Soviets continue to encroach upon our vital interests, then the Allies should use nuclear weapons."

-Secretary of Defense McGeorge Bundy
U.S. Policy on Military Actions in a Berlin Conflict
Memo to the President, 23 October 1961[550]

# CHAPTER 6

# NUCLEAR WEAPONS AND COMPETING REALITIES

## Introduction

The terrifying destructive potential of nuclear weapons distinguishes them from all other materiel solutions yet devised by humans to wage war. Their development and subsequent use changed the conduct of war in ways that induced many at the time to question if any knowledge about the conduct of war could survive the transition from the pre-nuclear world.[551] In many ways, the true impact of the existence of nuclear weapons is very much still an open question because no nation has employed the weapons in combat since they were first developed.[552] Stephen Rosen considered nuclear weapons so unique that he claimed any explanation of military innovation related to that materiel could not adequately apply to other cases.[553] The difficulty of devising a model of military innovation that applies to nuclear weapons as well as other materiel solutions makes nuclear weapons a good case study to test the limits of generalizability of the

[550] McGeorge Bundy, "National Security Action Memorandum NO. 109: U.S. Policy on Military Actions in a Berlin Conflict" (Declassified document, October 23, 1961), Presidential Papers, National Security Files, box 332, John F. Kennedy Library, Boston, MA.
[551] James Gavin M, *War and Peace in the Space Age* (New York: Harper and Brothers, 1958), 92.
[552] Francis J. Gavin, *Nuclear Weapons and American Grand Strategy* (Washington: Brookings Institution Press, 2020).
[553] Rosen, *Winning the next War*, 21–22.

technology triad. This chapter will explore the ways that the technology triad might enable an enhanced understanding of the relationship between the most important military technology of the 20th century and military innovation.

The exploration of nuclear weapons will start with an Italian military theorist from the 1920s and end with a bicycle in Cambodia as the Vietnam War drew to a close. The scale of this case necessitates a much higher level of analysis than was possible with the armored warfare chapter, but the broad inclusion of relevant material will enable the analysis of important developments to test the generalizability of the technology triad. Tracing the evolution of strategic thought from before the development of the atomic bomb to the conclusion of the United States' involvement in the Vietnam War through the lens of the technology triad will help determine the model's usefulness beyond just a single tactical case in a peacetime environment. Furthermore, the events within this case can enable the exploration of the important philosophical and strategic questions that such a framework implies as militaries move from peace to war.

Temporally, this case is bounded by Guilio Douhet's theories about the impact of airplanes on the conduct of war in the 1920s through the end of the U.S. military's Operation Rolling Thunder in 1968. Douhet is a logical starting point for the exploration of nuclear strategy because he is widely considered the first airpower theorist, and the framing of how nuclear weapons can achieve strategic outcomes owes its intellectual roots the conduct of strategic bombing in World War II, which employed some of Douhet's key ideas.[554] Between Douhet and the Vietnam War lays a rich landscape of interactions between materiel solutions and doctrine against which to test the ideas in the

[554] Edward Warner, "Douhet, Mitchell, Seversky: Theories of Air Warfare," in *Makers of Modern Strategy: Military Thought from Machiavelli to Hitler* (Princeton: Princeton Univ. Press, 1943), 485–503.

technology triad. Operation Rolling Thunder serves as the conclusion for this line of inquiry because that is when the United States was forced to accept that the strategy its military was pursuing in Vietnam could not achieve the United States' objectives in the war. This time period covers a wide swath of technological and social developments that could distract from the intended analysis, but a broader view is necessary given the strategic nature of nuclear weapons.

To help narrow the amount of information that could influence this case and to test generalizability above the tactical level, the case will focus on the strategic level interactions within the technology triad. For this analysis, strategic level actions will be distinguished from tactical by the set of available options to those making decisions. Strategy is defined by an open environment with unclear bounds on actions, and tactics are bounded within strategy to a narrower set of available options as defined by the applicable strategy.[555] In current U.S. military doctrine, there is a third level of military actions, the operational level, which will be difficult to avoid at times owing to both the interconnectedness of the concepts and perhaps even their artificiality. However, when able, the following analysis will error on the side of strategic level considerations, even at the expense of detail, to keep the case more focused on its objectives.

The final bounding of this case is organizational in nature with a focus on developments within the United States alone. The story of the development of nuclear strategy is impossible to separate from the influence of the Cold War between the United States and the USSR. Undoubtedly, activities that took place in the USSR and in other countries play a critical role in understanding the full picture of how nuclear weapons

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[555] Sun-Tzu and Clausewitz, *The Book of War*, 354; Edward Luttwak, *Strategy: The Logic of War and Peace* (Cambridge, Mass.: Belknap Press, 1987), 239.

related to the innovation of military strategy in the decades that followed World War II. However, the local nature of knowledge is a key concept within the technology triad and critical for its application in uncertain environments, so the model must be able to produce useful insights with only the information that would have been available to the United States at that time. Out of necessity, strategic intentions of the North Vietnamese will be addressed so far as it will help establish the degree to which local shared realities between the United States and North Vietnam played a role in the outcome of the war. Thus delineated temporally, conceptually, and organizationally this case will provide enough information at an appropriate level to test for the presence of the indicators from the previous chapter and potentially highlight aspects of the relationship between nuclear weapons and military innovation in the U.S. military through 1968.

It is important to note at the beginning what this case study is not. Despite the goal of producing novel insights, it is not a history of the development of U.S. nuclear strategy that leverages new primary source data to provide those novel insights. The history of nuclear weapons in the United States is well-trodden territory, and contributions to the historical record on this matter are beyond the scope of this dissertation. As such, the data that informs this case study is largely gathered from the existing histories of this period and augmented with well-known primary source information, where appropriate. Even the structure of this case study will be familiar to the informed reader with its path from early air power theorists through the Vietnam War. Instead, the goal of this case is to tell a well-known story of innovation through the lens of the technology triad to see what new insights, if any, might emerge. This will facilitate testing the generalizability of the technology triad within the structure developed in the last chapter to further asses the model's usefulness in uncertain environments.

As a test of generalizability, the structure of this case presents at least two possible critiques. The first critique is related to a common assertion in security studies literature that the Cold War period and its corresponding bi-polar international structure were unique in human history and that the influence of this unique period is so strong that lessons from it may poorly correspond to other time periods.[556] Rosen's assertion that no theory of military innovation can adequately address nuclear weapons and conventional weapons is tangentially related to this idea.[557] It is true that the decades following the introduction of the nuclear weapon were distinct from previous periods because, for the first time since the war of 1812, the full U.S. population was directly at risk of attack.[558] Far from being a detriment to the intent of this analysis, the uniqueness of the Cold War period makes this case a strong candidate against which to test how varied the cases can be for which the technology triad is valid. If the technology triad is valid in this case that is significantly different from other cases of technology and military innovation, then this strengthens the argument that the model might be useful in some unknown future case.

Second, the bounds of this case study could invite the criticism that the role of civilian society is under-represented in the analysis. While the technology triad does account for social, political, and economic influences in the production of knowledge, the final decision on weapons within the technology triad generally belongs to the military. Nuclear weapons transcended simple military application in every aspect, from their

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[556] Campbell Craig, *Destroying the Village: Eisenhower and Thermonuclear War* (New York: Columbia University Press, 1998), 3.
[557] Rosen, *Winning the next War*, 21–22.
[558] Craig, *Destroying the Village*, 3–4; Edwards, *The Closed World*, 57.

testing to their intended use, because of the terrible consequences that the population could suffer owing to their presence alone.[559] This case does not seek to diminish these important considerations, but they are not within the scope of the intent of the technology triad. The technology triad aims to help understand the relationship between technology and military innovation. In this case, that means that the military aspects of nuclear weapons are the important consideration. As the case will show, civilian scientists and political leaders played critical roles in the development of nuclear weapons and strategy, but they did so largely within a militaristic framing that blurred the lines between "civilian" and "military." It is possible that the technology triad might provide future insights on the roles of civilian and military personnel in the management of military technology, but fully exploring those implications is beyond the scope of this dissertation.

The development of nuclear weapons and their influence on military innovation will be a strong test of the generalizability of the technology triad. This case is specifically designed to test numerous dimensions of military affairs that are different from the original armored warfare case study to see how far the model might be useful. Analysis of the two decades following the first use of the atomic bomb through the lens of the technology triad will show how this materiel solution, designed to test disputed concepts of the character of war, came to fundamentally alter the bounds of what war was and could be for the U.S. military. However, this understanding of war was designed for a certain shared reality with the USSR that never occurred. When the U.S. military employed the doctrine and materiel that aligned with this martial knowledge in the Vietnam War, they failed to enable the achievement of the United States' strategic

[559] "Fallout and Disarmament: A Debate between Linus Pauling and Edward Teller," *Daedalus*, 1958.

objectives. The North Vietnamese reality, created by their own technology triad, proved more appropriate for the shared reality that existed between the United States and North Vietnam.

**The Character of War and Early Airpower Concepts**

Much like the tank, the airplane provided an early glimpse of its potential in World War I but materiel solutions of the day fell far short of that potential by the time the armistice was signed. Officers who had recognized the unintended consequences of a machine originally designed as an observation platform spent the decades following World War I producing new concepts and the corresponding doctrine and materiel to create local technology triads within the world's militaries.[560] Guilio Douhet has the distinction of being the first such airpower theorist, writing the bulk of his works from 1921 to 1927.[561] He was soon joined by others such as William "Billy" Mitchell and Alexander De Servisky in the United States and Hugh Trenchard and John Slessor in the British Royal Air Force.[562] Each military held their own martial knowledge related to the best way to employ aircraft, with the focus shifting between industrial centers, populations centers, or the enemy ground forces, but shared by all of these early thinkers was a firm belief that airpower could and would prove the decisive military arm in any future war.[563]

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[560] Brodie and Brodie, *From Crossbow to H-Bomb*, 177.
[561] Bernard Brodie, "Strategy In the Missile Age" (Santa Monica, CA: RAND, January 15, 1959), 22; Phillip S Meilinger et al., *The Paths of Heaven: The Evolution of Airpower Theory* (Maxwell Air Force Base (Alabama): Air University Press, 2010), 17–18.
[562] John Cotesworth Slessor, *Air Power and Armies* (Tuscaloosa: University of Alabama Press, 2009); Alexander De Seversky, *Victory Through Air Power* (New York: Simon and Schuster, 1942); Meilinger et al., *The Paths of Heaven*, 28.
[563] Meilinger et al., *The Paths of Heaven*; Slessor, *Air Power and Armies*; Warner, "Douhet, Mitchell, Seversky: Theories of Air Warfare."

Within the air arms of these militaries, the methods of aviation employment were held as martial knowledge that had been tested and validated through internal epistemologies. However, at the strategic scale of whole militaries, these ideas are more appropriately considered theories of victory or concepts that had yet to achieve the status of truth. Strategic airpower ideas were exemplar theories of victory within Rosen's definition of a theory of victory.[564] These theories had produced full career paths and organizational structures within the various militaries of the world, but they remained statements about the future and maintenance of large ground forces in all militaries demonstrates that no nation had accepted these ideas completely. Pre-World War II airpower realities, with complete technology triads, were competing with pre-existing realities centered on ground combat at the strategic level in between the second and third stages of innovation. World War II would provide the laboratory within which militaries would test these theories.[565]

Moral questions surrounding the bombardment of cities presented one of the challenges to full acceptance of the early airpower theories prior to the onset of hostilities. Douhet, the most extreme example, envisioned depopulating entire cities through the use of gas bombs that would kill all inhabitants indiscriminately.[566] The U.S. airpower theorists advocated the destruction of military targets, which more closely aligned with the values of the U.S. military knowledge system.[567] Once the war started in Europe, President Roosevelt wrote a letter on 1 September 1939 in an attempt to secure

[564] Rosen, "New Ways of War."
[565] De Seversky, *Victory Through Air Power*, 75.
[566] Meilinger et al., *The Paths of Heaven*, 22.
[567] De Seversky, *Victory Through Air Power*; Warner, "Douhet, Mitchell, Seversky: Theories of Air Warfare."

promises from European nations to refrain from bombing cities.[568] In his seminal work on the atomic bomb development, Richard Rohdes explained that "Great Britain agreed to the President's terms the same day. Germany, busy bombing Warsaw, concurred on September 18."[569]

Despite promises to avoid bombing population centers, all belligerents drifted towards doctrines that did just that through the course of the war. The air war between Great Britain and Germany started with both sides initially limiting their bomber raids to military and industrial targets.[570] However, a disoriented German bomber flight overflew their intended targets and dropped their ordinance in central London on 24 August 1940. Churchill retaliated in kind against Berlin within days, which invited an even more concentrated bombing of English cities by the Germans, and events soon overtook the pre-war notions of avoiding the destruction of population centers.[571] The British doctrine of targeting population centers was partly a reflection of shifting norms of behavior in the early years of the war and partly a doctrinal limitation imposed by the materiel solutions available at the time.[572] Referring to targeting decisions in 1941, Sir Arthur Harris, later to become the chief of Bomber Command, explained in his memoirs that "the targets were chosen in congested industrial areas and were carefully picked so that bombs which overshot or undershot the actual railway centers under attack should fall on these areas, thereby affecting morale."[573] Thus, the doctrine that the British air force employed early in the war was a compromise between their martial knowledge that it was preferable to

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[568] Richard Rhodes, ed., *The Making of the Atomic Bomb*, 25th anniversary ed., [with a new foreword], paperback ed (New York, NY: Simon & Schuster Paperbacks, 2012), 309–10.
[569] Rhodes, 310.
[570] Rhodes, 341.
[571] Rhodes, 341.
[572] Rhodes, 469.
[573] Rhodes, 469.

attack industrial targets, yet acceptable to destroy population centers, and the limiting influence of their materiel solutions that prohibited precision strikes on industrial targets alone.

By the end of World War II, the transition from precision attacks on industrial targets to deliberate destruction of enemy populations was complete as Douhet originally advocated. Under the command of General Curtis LeMay, U.S. Army Air Forces conducted bombing raids throughout 1945, employing tactics intended to produce massive fire storms.[574] These firestorms occurred when bombers dropped high explosives followed by incendiary bombs to create connected fires within a city. The fires would get so hot that they produced their own air currents that pulled the surrounding air into the fire and combusted all available materiel. One survivor of the Dresden fire bombing recounted, “A fire storm is an amazing thing. It doesn’t occur in nature. It’s fed by the tornadoes that occur in the midst of it and there isn’t a damned thing to breath.”[575] Japan, with its wooden cities, was even more susceptible to these tactics.[576]

With the ability to deliberately induce fire storms and destroy entire cities in a matter of hours, the earliest air power theorists’ visions were finally achieved. Curtis LeMay himself remarked in April 1945 that “strategic air bombardment faces a situation in which its strength is proportionate to the magnitude of its task.”[577] Post-war analysis of the impact of conventional strategic bombing on the outcome of the war, however, was undecided on just to what degree this doctrine was contributing to the eventual Japanese

[574] Rhodes, 591–600.
[575] Rhodes, 593.
[576] Rhodes, 591.
[577] Rhodes, 600.

surrender.[578] Effective or not, the bombing campaign required massive amounts of equipment and vast systems stretching from the South Pacific to the United States to support that equipment.[579] After a successful bombing raid against Nagoyan on 18 March 1945, LeMay's forces "ran out of bombs. Literally."[580] It was clear at the time, and confirmed by hindsight, that the bombing was having some effect, even if it was not total, but that the massive amounts of resources needed to do it with conventional weapons were limiting the doctrine's potential. Throughout the war, a team of military and civilian researchers in the United States had been working on a materiel solution that would finally push contested theories of airpower's ability to play the dominant role in the conclusion of a war from concept to validated knowledge.

**Building an Atomic Bomb**

The very idea of an atomic bomb was itself the initiative of civilian scientists who possessed the autonomy to convince the U.S. government to pursue the weapon. On 12 September 1933, as the story goes, while watching a traffic light switch from red to green, Hungarian physicist Leo Szilard first conceived of the potential for a sustained chain reaction of splitting atoms.[581] Five years later, radiochemists Otto Hanz and Fritz Strassman published a paper relaying the first experimental results that confirmed

[578] Gian P. Gentile, "Advocacy or Assessment? The United States Strategic Bombing Survey of Germany and Japan," *Pacific Historical Review* 66, no. 1 (February 1, 1997): 53–79, https://doi.org/10.2307/4492295; *The United States Strategic Bombing Surveys (European War) (Pacific War).* (Maxwell AFB: Air University Press, 1987); Conrad C. Crane, *American Airpower Strategy in World War II: Bombs, Cities, Civilians, and Oil*, Revised edition, Modern War Studies (Lawrence, Kansas: University Press of Kansas, 2016); Brodie, "Strategy In the Missile Age," 107.
[579] Edward Kaplan, *To Kill Nations: American Strategy in the Air-Atomic Age and the Rise of Mutually Assured Destruction* (Ithaca: Cornell University, 2015), 15.
[580] Rhodes, *The Making of the Atomic Bomb*, 600.
[581] Rhodes, 28.

Szilard's intuition.[582] Within weeks of Hanz and Fritz's discovery, Szilard made the logical leap from sustained fission and the ability to produce weapons of unimaginable destructive capabilities.[583] Similarly, the physicist Robert Oppenheimer made the connection between a splitting atom and a bomb almost immediately.[584] The immediate and independent conclusion of both of these scientists that a bomb was the best use of fission demonstrates that, from the very beginning, atomic power was envisioned by those who would bring it into this world as a means of conducting war. Concern that the Germans, who had forced many of the leading scientists involved in the early discovery of atomic power to flee their homelands, might develop an atomic bomb before the allies prompted Szilard to enlist the assistance of Albert Einstein in 1939 to convince the President that the United States must undertake an immediate effort to develop atomic weapons fully.[585]

The proposal to develop scientific knowledge related to atomic weapons was highly technical, uncertain in its feasibility, expensive, and advocated by civilians outside of the system, and the U.S. Army initially balked at the proposition to allocate resources to the bomb's development with the specter of war looming ever closer for the United States.[586] In May 1940, research conducted at Columbia University related to the viability of a sustained chain reaction convinced many in the government that the chances of producing an atomic weapon were likely enough that it warranted at least the resources required to test feasibility further.[587] That same year, the U.S. Government established the

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[582] Vincent C. Jones, *MANHATTAN: The Army and the Atomic Bomb*, United States Army in World War II (Washington, D.C.: Center of Military History, 1985), 7.
[583] Rhodes, *The Making of the Atomic Bomb*, 268.
[584] Rhodes, 275.
[585] Rhodes, 305.
[586] Jones, *MANHATTAN: The Army and the Atomic Bomb*, 21.
[587] Jones, 24.

National Defense Research Council (NDRC) to formally coordinate the efforts of American scientists in support of war preparations, including the development of the atomic bomb.[588] Despite initial misgivings about the likelihood of success by the NDRC chairman, Vannevar Bush, the U.S. Government had allocated $500,000 across several universities to conduct research on the atomic bomb, which soon proved Bush's pessimism misplaced.[589]

### *Autonomy and the Manhattan Project*

Scientific knowledge that atomic weapons were possible was not enough to ensure that the United States would build them. To achieve innovation, the U.S. government would have to grant an organization the authority, give it the resources, and staff it with the right people to create a materiel solution that was as far outside the pre-existing technology triad as atomic weapons were. Without a high level of autonomy, well-intentioned leaders could have reallocated resources of all types to support other efforts to wage World War II. Efforts to build the atomic bomb would achieve a level of autonomy that would inspire one observer would note that "the Manhattan district bore no relation to the industrial or social life of our country; it was separate, with its own airplanes and its own factories and its thousands of secrets. It had a particular sovereignty, one that could bring about the end, peacefully or violently, of all other sovereignties."[590]

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[588] Jones, 26.
[589] Jones, 27.
[590] Rhodes, *The Making of the Atomic Bomb*, 277.

By October 1941, enough evidence had been collected to convince the President that efforts to develop an atomic bomb required more deliberate organization than the government had employed thus far, and he created the Top Policy Group with himself as chair to direct efforts towards a bomb.[591] This organization is important to the development of the atomic bomb because it ensured that the program had access to the highest level of authority possible within the United States on a wartime footing. Despite support from the White House, the Manhattan Project, the name adopted in August 1942 to disguise research efforts as a military engineering district, struggled under the byzantine War Department requirements to secure resources.[592] Newly promoted Brigadier General Leslie Groves assumed command of the project with near-unlimited institutional authority in September 1942 against the wishes of Vannevar Bush, who was now the director of the Office of Scientific Research and Development (ORSD) above the NDRC organizationally.[593] General Groves's first challenge was to more effectively wield the authority vested in the Manhattan Project and secure the necessary resources to complete the bomb's development.[594] Bush quickly changed his mind about the new commander officer of the Manhattan Project when the general leveraged his direct line to the President to cut through bureaucratic red tape and secure a AAA priority rating, the very highest available in the War Department and essentially a blank check to acquire resources, that the previous leaders of the research project had unsuccessfully pursued for months.[595] Over the next several years, the organizational autonomy of the Manhattan

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[591] Jones, *MANHATTAN: The Army and the Atomic Bomb*, 31.
[592] Rhodes, *The Making of the Atomic Bomb*, 424–25; Jones, *MANHATTAN: The Army and the Atomic Bomb*, 43,57.
[593] Jones, *MANHATTAN: The Army and the Atomic Bomb*, 75.
[594] Jones, 75; Rhodes, *The Making of the Atomic Bomb*, 426–27.
[595] Jones, *MANHATTAN: The Army and the Atomic Bomb*, 81; Rhodes, *The Making of the Atomic Bomb*, 427.

Project would become so complete that its leaders could even prevent the drafting of its young engineers without explicit reference to the highly secret project.[596]

Organizational authority to secure materials and talented people is just one possible source of the autonomy to change an element of the technology triad. As the defining feature of autonomy is the ability to take actions outside the established reality, those creating change must also be able to exercise adequate epistemological autonomy, which the scientists working on the bomb possessed almost to a fault. As early as 1939, Szilard fought what he viewed as excessive centralization and control on the part of the government over the research that scientists associated with the production of the bomb were conducting.[597] Vannevar Bush agreed, at least tacitly, ensuring that the guiding philosophy of the NDRC and later the OSRD embraced a culture of freedom for scientists to conduct their research unimpeded.[598] This aversion to authority amongst the researchers manifested itself to the organizationally rigid military as "scientists of doubtful discretion and uncertain loyalty," which would continue to plague the project through the end of 1945.[599] Despite the military's cultural aversion to a group of researchers who possessed varying levels of respect for the chain of command, this environment produced an epistemological autonomy to compliment the organizational autonomy that would enable the production of a materiel solution that was unlike any that proceeded it.

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[596] Jones, *MANHATTAN: The Army and the Atomic Bomb*, 367.
[597] Rhodes, *The Making of the Atomic Bomb*, 413.
[598] Bush, *Science, the Endless Frontier*; Zachary, *Endless Frontier*.
[599] R. Gordon Arneson, "Notes of the Interim Committee Meeting Thursday, 31 May 1945, 10:00 A.M. to 1:15 P.M. - 2:15 P.M. to 4:15 P.M." (Declassified document, May 31, 1945), 14, Record Group 77, Manhattan Engineering District Records (RG 77), H-B files, folder no. 100 (copy from microfilm), National Archives and Records Administration, College Park, MD, https://nsarchive2.gwu.edu/nukevault/special/index.htm.

***What was the bomb "for"?***

The atomic bomb was more than just a big explosion that represented the next step along a path of ever power powerful weapons, and those responsible for its creation realized this from the very beginning.[600] This chapter argues that the introduction of the atomic bomb represented a change in the materiel that then induced changes to the martial knowledge and doctrine of the U.S. military. At face value, and even implicit in the structure of this chapter that starts with early airpower theories, this sequence contradicts the common narrative that the bomb was an evolutionary increase to the capabilities of strategic bombing.[601] It is only with the advantage of hindsight that the eventual role of the atomic bomb in the conduct of war becomes so clear. Certainly, the atomic bomb would eventually validate aspects of the contested theories of victory through airpower, but the people responsible for the development of this weapon were not certain this would be the case once the weapon was created.

The bomb's first advocate originally intended the weapon to be a tool for the establishment of an eternal peace. Betraying an implicit bias towards technological determinism, Szilard said of his early ambitions for the bomb,

> "should atomic weapons be developed, no two nations would be able to live in peace with each other unless their military forces were controlled by a common higher authority. We expected that these controls, if they were effective enough to abolish atomic warfare, would be effective enough to abolish also all other forms of war. This hope was almost as

[600] Dupuy, *The Evolution of Weapons and Warfare*.
[601] *The United States Strategic Bombing Surveys (European War) (Pacific War).*; Kaplan, *To Kill Nations*, 2; Lawrence Freedman, "The First Two Generations of Nuclear Strategists," in *Makers of Modern Strategy from Machiavelli to the Nuclear Age* (Princeton, N.J: Princeton University Press, 1986), 736.

> strong a spur to our endeavors as was our fear of becoming the victims of the enemy's atomic bombings."[602]

Throughout the entire project, civilian scientists continued to press their positions on how and why the United States should employ the atomic bomb.[603] In December 1944, Niels Bohr successfully convinced Secretary of War Stimson that the United States should adopt a position related to the secrecy of the atomic weapons program with the USSR that enabled totally transparent communication between the two nations.[604] The Secretary of War took this proposition so seriously that in one of his first communications with the newly appointed President Truman, he wrote that the bomb "has such a bearing on our present foreign relations and has such an important effect upon all my thinking in this field that I think you ought to know about it without much further delay."[605] On the eve of its first tactical employment, the leaders within the U.S. government were still unsure exactly what role atomic weapons should play in the conduct of strategy, but they were clearly envisioning that the bomb would have a more important impact than simply a large explosion.

Even the way the U.S. Army Air Forces determined the most appropriate tactical employment of the first atomic bombs demonstrates that they were not exactly sure what the bomb might do. By the summer of 1945, LeMay's bombing campaign was proving so destructive that General Groves was concerned that there might not be adequate targets remaining for his new weapon. However, the targeting committee held sufficient

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[602] Rhodes, *The Making of the Atomic Bomb*, 308.
[603] Jones, *MANHATTAN: The Army and the Atomic Bomb*, 531.
[604] Rhodes, *The Making of the Atomic Bomb*, 621.
[605] Henry Stimson, "Letter from Secretary of War Henry Stimson to President Harry S. Truman," Declassified Document, April 24, 1945, War Department [1 of 5, 1945]; Confidential Subject Files, 1945 - 1953; Collection HST-CF: Confidential Files (Truman Administration), Harry S. Truman Library, Independence, MO, https://www.docsteach.org/documents/document/stimson-letter.

organizational authority to remove cities from LeMay's target cities. They did just that, selecting the eventual targets, not for their operational importance alone but also for their ability to provide valuable information on the performance of the atomic bomb.[606] Even the manner in which the two cities were attacked was determined to ensure maximum results in this laboratory of war.[607] Each step of the way, from tactical employment to strategic considerations, military and civilian personnel worked hand in hand to shape the type of martial knowledge the atomic bomb would eventually produce. This blurring of lines between military and civilian and concurrent influence from the tactical to the strategic level demonstrates how viewing the atomic bomb as a materiel solution in relation to the martial knowledge it would produce starts to challenge accepted frameworks within defense analysis.

**World War II and Atomic War**

As late as June 1945, General George Marshal had not adopted the position that strategic bombing could achieve the United States' strategic objectives in the Pacific. He told the president, "airpower alone was not sufficient to put the Japanese out of the war. It was unable alone to put the Germans out."[608] In August 1945, the United States dropped atomic bombs on Hiroshima and Nagasaki, which was followed almost immediately by the Japanese surrender.[609] At the time, observers believed that the atomic bomb, coupled with the Soviet declaration of war against Japan and a promise to leave the Japanese legal

606 Rhodes, *The Making of the Atomic Bomb*, 627.
607 Arneson, "Notes of the Interim Committee Meeting Thursday, 31 May 1945, 10:00 A.M. to 1:15 P.M. - 2:15 P.M. to 4:15 P.M.," 13–14.
608 Rhodes, *The Making of the Atomic Bomb*, 687.
609 Brodie and Brodie, *From Crossbow to H-Bomb*, 261.

structure in place, precipitate the Japanese surrender.[610] That the judgment of those involved could shift so drastically from a belief that ground invasion was necessary to acknowledgment that the bomb "knocked the Japanese out of the war" supports the idea that the materiel solution and its demonstrated capabilities played a major role in the confirmation of theories of airpower that had remained disputed through the entire war rather than a simple extension of a previous truth. Later scholarship would show that the Japanese were very close to surrendering prior to the introduction of atomic weapons, but leaders in the United States did not know this at the time.[611] As far as the United States was aware, the bomb had created a new truth.

Almost immediately after the conclusion of the war, the United States conducted a post-war United States Strategic Bombing Survey (USSBS) to determine the extent to which airpower contributed to the outcome of the war.[612] The survey's authors asserted that "the capacity to destroy, given control of the air and an adequate supply of atomic bombs, is beyond question."[613] But then they qualified this statement by explaining that control of the air and adequate supply of atomic bombs was far from assured and that absent those conditions, "any attempt to produce war-decisive results through atomic bombing may encounter problems similar to those encountered in conventional bombing."[614] This theme of "similar to conventional bombing," but with larger weapons, would cause some controversy within the Army Air Forces leadership.[615]

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[610] Jones, *MANHATTAN: The Army and the Atomic Bomb*, 541–42.
[611] Jones, 541–42.
[612] *The United States Strategic Bombing Surveys (European War) (Pacific War).*
[613] *The United States Strategic Bombing Surveys (European War) (Pacific War).*, 113.
[614] *The United States Strategic Bombing Surveys (European War) (Pacific War).*, 113.
[615] Gian P. Gentile, *How Effective Is Strategic Bombing? Lessons Learned from World War II to Kosovo*, World of War (New York: New York University Press, 2001), 114.

The survey's lead investigator, Paul Nitze, wrote the summary report in such a manner that it was clear that Japan would have surrendered under the pressure of fire-bombing alone without the additional destruction wrought by the atomic bombs.[616] The USSBS is itself a fascinating study in the social influence on the production of knowledge. There is reason to believe that the ulterior motives of the USSBS authors were to use research to support a fore-drawn conclusion that the U.S. Army Air Forces should be a separate service.[617] This would support theories of military innovation related to inter-service rivalry, but the technology triad can paint the apparent bias of the USSBS in a different light. Alexander DeServski, famous for his pre-war writings and Walt Disney cartoons advocating for an increased role of airpower, was one of the most strident defenders of conventional bombing on the USSBS team.[618] Prior knowledge plays a key role in the production of knowledge within the technology triad, and DeSeverski's pre-war writings demonstrate that he firmly believed the most appropriate use of aircraft in combat required massive fleets to cause as much destruction as possible.[619] His dogged adherence to conventional bombing could just be a reflection of the importance of prior knowledge within the military knowledge system. Ultimately, that the USSBS could unambiguously claim the success of airpower theories and that the controversial point was whether or not the bombs needed to be atomic or conventional shows how the bomb, which was the product of a materiel solution developed and built at great expense outside of the pre-existing system, created a new truth about the conduct of war, in other words, a new martial knowledge.

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[616] Gentile, 115; *The United States Strategic Bombing Surveys (European War) (Pacific War).*, 107.
[617] Gentile, "Advocacy or Assessment?"; Gentile, *How Effective Is Strategic Bombing?*, 114.
[618] Jones, *MANHATTAN: The Army and the Atomic Bomb*, 548–49.
[619] De Seversky, *Victory Through Air Power*.

**Influence of a New Martial Knowledge**

The influence of martial knowledge created after the surrender of Japan extended beyond simply affirming pre-war ideas to altering the fundamental understanding of war within the United States in a way that would have drastic consequences at every level of defense from that point forward. In a book published in 1958, Lieutenant General James Gavin lamented that in the years following World War II, there was a common belief in defense circles that every aspect of war must be reconsidered, that "it was time to 'throw the books out the window,'" and that any lessons from World War II were invalid in the atomic age.[620] Clearly, General Gavin did not believe this to be the truth, going on to say, "this was nonsense."[621] However, he was, ironically, discrediting the idea that the atomic bomb had shifted the fundamentals of war in a book titled *War and Peace in the Space Age* that was meant to discuss how the recent proliferation of more capable nuclear missiles might shift the character of war. While General Gavin's hyperbole might have been a bit exaggerated, the martial knowledge created after the demonstrated abilities of the atomic bomb had reoriented the fundamental understanding of what war was and what it could be by redefining the boundaries of its existence.

Vannevar Bush's 1945 report "Science the Endless Frontier" summed up the shift succinctly when he quoted a joint letter by the Secretaries of Navy and Army in which they claimed that "war is increasingly total war."[622] The atom bomb, with its destructive capabilities and the mobilization of previously untapped national resources to create it,

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[620] Gavin, *War and Peace in the Space Age*, 92.
[621] Gavin, 92.
[622] Bush, *Science, the Endless Frontier*, 15.

had taken Clausewitz's once purely theoretical concept of total war and, for the first time, demonstrated to humanity that this terrible practice was not only possible but also the likely outcome of future wars. The strategic martial knowledge introduced after the bomb defined war on a line. On one end of that line, peace existed. The opposite end of that line represented nuclear war. In between were graduations of war that differed only in the level of violence inflicted and the amount of resources marshaled by the belligerents. This martial knowledge would influence the materiel fielded and the doctrine employed by the United States at every level from the tactical to the strategic.

A total reorganization of the armed forces was the first major influence of the new martial knowledge. In 1947, the Unites States created the United States Air Force to align its organizational doctrine with the new martial knowledge that airpower was a decisive factor in modern war.[623] This shift towards preparation for the possibility of nuclear was strengthened even further in 1948 when General Curtis LeMay was assigned as commander of the Strategic Air Command (SAC).[624] Under LeMay's leadership, SAC restructured their entire training program to focus on building the capability to conduct nuclear war at a moment's notice through strict standardization within the command.[625] Eventually, SAC would become the premier unit within the new Air Force, dominating everything from service culture with "the SAC way" to budget allocations.[626]

By the end of the 1940s the U.S. military's martial knowledge had become firmly rooted in the proposition that if a major war were to start, it would be a "general war," or

[623] Fred M. Kaplan, *The Bomb: Presidents, Generals, and the Secret History of Nuclear War*, First Simon&Schuster hardcover edition (New York: Simon & Schuster, 2020), 5.
[624] Kaplan, 6; Walton S. Moody, *Building a Strategic Air Force* (Air Force History and Museums Program, 1995), 466.
[625] Moody, *Building a Strategic Air Force*, 255.
[626] Kaplan, *The Bomb*, 6; Moody, *Building a Strategic Air Force*, 258.

one waged with atomic weapons.[627] The U.S. government commissioned a report in 1949 to study the likely impacts of a future war with the USSR that concluded atomic weapons were the "only means of inflicting shock and serious damage to vital elements of the Soviet war making capability" and that "an early atomic offensive will facilitate greatly the application of other Allied military power with prospect or greatly lowered casualties."[628] This Harmon report, as it would become known, would be the first in a long series of internal research studies that the United States would use to define the nature of nuclear war within the new reality created by the atomic technology triad.[629]

The belief in the eventuality of general war, despite great reluctance by national leaders to ever employ these weapons, was a reflection of the martial knowledge first created in 1945 but was also strengthened by two important factors.[630] The first was the Berlin crisis in 1948 that highlighted the growing tensions between the United States and the USSR.[631] Closely related to the growing international tensions, the general sentiment towards the specter of atomic war within the United States population had shifted from one of fear immediately following World War II to one of broad acceptance by 1949.[632]

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[627] Craig, *Destroying the Village*, 21.

[628] "Evaluation of Effect on Soviet War Effort Resulting from the Strategic Air Offensive" (Report by the Ad Hoc Committee to the Joint Chiefs of Staff, May 12, 1949), Record Group 218, Records of the Joint Chiefs of Staff, CCS 373 (10-23-48) Bulky Package, JCS, National Archives and Records Administration, College Park, MD, https://nsarchive.gwu.edu/dc.html?doc=6895250-National-Security-Archive-Doc-02-Report-by-the; Quotes of interest highlighted in William Burr, "Overkill, Assured Destruction, and the Search for Nuclear Alternatives: U.S. Nuclear Forces During the Cold War," National Security Archive, May 19, 2020, https://nsarchive.gwu.edu/briefing-book/nuclear-vault/2020-05-22/us-nuclear-weapons-posture-during-cold-war-compilation-core-primary-sources.

[629] Craig, *Destroying the Village*, 25.

[630] David Lilienthal, "Meeting with the President July 21, 1948, 4:00 Tp 4:15 p.m." (Entry from David Lilienthal Diary, July 22, 1948), 5, Public Policy Papers, Department of Rare Books and Special Collections, David Lilienthal Papers, box 197, Princeton University Library, Princeton, NJ, https://nsarchive.gwu.edu/dc.html?doc=6895249-National-Security-Archive-Doc-01-Entry-from.

[631] Freedman, "The First Two Generations of Nuclear Strategists," 736.

[632] Paul S. Boyer, *By the Bomb's Early Light: American Thought and Culture at the Dawn of the Atomic Age* (Chapel Hill: University of North Carolina Press, 1994), 334–36.

The new reality defined by a technology triad with each element updated to account for the atomic bomb had totally supplanted the one that existed in World War II. The military innovation within the United States related to the atomic bomb was complete, but the technology triad would continue to evolve over time within this reality in ways that would impact every aspect of United States national defense for the next 20 years.

As soon as the new reality was established, it encountered its first major challenge from an outside source. In 1950, North Korea attacked their neighbors to the south in a war that would put many of the new notions of airpower and the usefulness of atomic weapons to the test. Although airpower would prove less decisive in the Korean War than the USSBS had claimed it was in World War II, the reality within the United States that war was gradations of peace and general war had become so entrenched that the lessons the United States drew from the war were processed through the knowledge system as an external epistemology rather than a true test of the United State's understanding of reality.[633] The United States had just written NSC-68, which would come to define the strategy to counter the USSR for the next several decades when the Korean war broke out.[634] NSC-68, as a doctrine, aligned with the prevalent martial knowledge at the time.[635] This meant that the war on the Korean Peninsula was not *the war* but a small part of a larger conflict in which the specter of atomic weapons employment always loomed.[636] Further strengthening this belief for the newly elected President Eisenhower at the end of

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[633] T. R Fehrenbach, *This Kind of War: The Classic Korean War History* (Dulles, Va.: Potomac Books, 2008); Kaplan, *To Kill Nations*.
[634] "National Security Council Report, NSC 68, 'United States Objectives and Programs for National Security'" (April 14, 1950), History and Public Policy Program Digital Archive, U.S. National Archives, http://digitalarchive.wilsoncenter.org/document/116191; Craig, *Destroying the Village*, 34.
[635] "National Security Council Report, NSC 68, 'United States Objectives and Programs for National Security.'"
[636] Brian McAllister Linn, *Elvis's Army: Cold War GIs and the Atomic Battlefield* (Cambridge, Massachusetts: Harvard University Press, 2016), 52; Craig, *Destroying the Village*, 34.

the war, the North Koreans agreed to sign an armistice agreement shortly after the United States threatened to bomb the USSR to force a peace with their fellow communist country.[637] Thus, despite an ongoing war in which tens of thousands of Americans would die, the United States would continue to send precious resources to the European Theater to prepare for a general war with the USSR.[638] Following the war, there was no realignment of the technology triad at the strategic level to conform to any knowledge generated after years of actual combat. Even within the U.S. Army, modernization efforts through the 1950s continued to prepare for a war that reflected a constructed martial knowledge that was being further validated in the various civilian defense research centers across the nation.[639]

**Doctrine for an Imagined War**

In the five years following the end of World War II, when the martial knowledge was aligning with the new materiel solution within the U.S. military, doctrine also slowly caught up. While atomic weapons had been included in the strategic war plans since mid-1948, the materiel lag in the technology triad was severely impeding the nations' ability to align the practical doctrine with the martial knowledge.[640] There simply were not enough bombs to create the level of destruction that would be needed to prevail in a war against the USSR. In December 1949, the Joint Chiefs of Staff approved an updated strategic plan to fight the USSR without an approved strike appendix due to disagreement

[637] Kaplan, *The Bomb*, 9.
[638] Linn, *Elvis's Army*, 52.
[639] Linn, 49; Fred M. Kaplan, *The Wizards of Armageddon*, Stanford Nuclear Age Series (Stanford, Calif: Stanford University Press, 1991); Edwards, *The Closed World*.
[640] Lawrence Freedman, *The Evolution of Nuclear Strategy*, 3rd ed (Houndmills, Basingstoke, Hampshire ; New York: Palgrave Macmillan, 2003), 48,52.

within the U.S. Air Force over how to use the limited weapons available.[641] The Air Staff drew heavily from the USSBS findings to advocate for a “killing a nation” approach that would focus their attacks on fuel and electric plants.[642] On the other hand, General LeMay drew from his own lessons learned from burning Japanese cities and advocated the destruction of Soviet cities to achieve the greatest effect with the few weapons available.[643]

The open question regarding the best use of atomic weapons as late as 1949 demonstrates two important factors for the technology triad as an analytical tool. First, the limiting effect of the fielded materiel demonstrates how different rates of change within the technology triad create complex feedback loops between each of the elements of the technology triad. Second, the logic employed by both the Air Staff and SAC relied heavily on prior knowledge claims that were in conflict. Both of their positions affirmed the preeminence of airpower and atomic weapons, but the status of the atomic bomb as a continuation of earlier strategic bombing theories or as a weapon apart from any other had yet to be settled within the U.S. military. This demonstrates how the technology triad helps understand shifts within the system at the tactical and strategic levels. The strategic importance of the atomic bomb was not in question, only the appropriate way to employ it tactically. Around the same time that the military was coming to grips with the role of the atomic bomb in the technology triad, a new class of strategists emerged to help address these questions.

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[641] Kaplan, *The Wizards of Armageddon*, 39.
[642] Kaplan, 41.
[643] Kaplan, 44.

As the Deputy Chief of Air Staff for Research and Development, General LeMay oversaw the formation of project RAND in March 1946.[644] RAND, an unimaginative acronym for "research and development," was a civilian research institute with the mission to "study and research on the broad subject of air warfare with the object of recommending to the Air Force preferred methods, techniques and instrumentalities for this purpose," according to its charter.[645] RAND's original focus was on technical engineering knowledge but would soon expand its activities to include the research related to the operational employment of weapons systems.[646] A young historian named Bernard Brodie would be one of the first of many stand-out researchers that worked at RAND to leave their mark on U.S. nuclear strategy.

Brodie, who had not been involved in airpower developments during the war, approached the atomic bomb with a fresh perspective and was able to produce several key insights that would have an important impact on the direction of strategy. He assumed that with the advent of the bomb, future wars could be won or lost in their opening salvos and that defense was no longer a relevant concern because if just one bomber made it through, then the destruction would be too great to bear.[647] From these first principles, he deducted in 1948 that there was "more strategic leverage to be gained in holding cities hostages than in making corpses."[648] The U.S. Air Force brought Brodie to Washington to advise on atomic strategy in 1950, where he readdressed the critical question "what is the bomb for?"[649] As simple as this may seem in hindsight, Brodie's

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[644] Kaplan, 59.
[645] Kaplan, 59.
[646] Kaplan, *The Wizards of Armageddon*; Edwards, *The Closed World*; Gregg Herken, *Counsels of War*, 1st ed (New York: Knopf : Distributed by Random House, 1985).
[647] Kaplan, *The Wizards of Armageddon*, 25–26.
[648] Kaplan, 47.
[649] Kaplan, 47.

work was the first serious effort to grapple with the strategic implications of the atomic bomb. He sought to link the actions that the U.S. military would take with atomic weapons with its strategic objectives.[650] The outcome of Brodie's work would more effectively align the United States strategic doctrine of the atomic technology triad with the martial knowledge that the bomb was something special on the line from peace to war than the U.S. Air Force's earlier attempts to treat atomic weapons as more powerful tools with which to employ strategic bombing doctrines of World War II. This doctrinal change coincided with the martial knowledge change mentioned previously to represent the point when the United States fully adopted the new reality.

Following Brodie's example in treating atomic weapons as something fundamentally different than conventional ones, the entire U.S. military fully embraced this new reality and made nuclear weapons the center piece of the entire national defense posture. If President Truman's nuclear strategy could be considered one of "limited wars," where the level of violence was carefully metered to avoid the use of atomic weapons, as was pursued in Korea, then President Eisenhower's approach would be the strategy of massive retaliation.[651] Secretary of State John Forest Dulles laid out the logic for this massive retaliation in a 1954 speech where he explained that the previous policy of countering communist efforts militarily one by one was too expensive to maintain over a long period of time.[652] He advocated for a strategy that would apply equally as well anywhere in the world with a minimum of investment. In his words, "the way to deter aggression is for the free community to be willing and able to respond vigorously at

[650] Goodpaster and Huntington, *Civil-Military Relations*, 18.
[651] Craig, *Destroying the Village*, 41.
[652] Kaplan, *The Wizards of Armageddon*, 174.

places and with means of its own choosing."[653] Practically, this strategy would entail reserving the right, and communicating the intention, to respond to any USSR provocation immediately with an overwhelming nuclear attack.

To execute this massive retaliation, Eisenhower's administration adopted the "New Look" defense policy, which called for the reduction of non-nuclear forces to shift resources to the Air Force and Navy.[654] While the massive retaliation strategy was a reflection of the newly established reality, it was also inspired by domestic politics that led many in the United States to desire a general reduction in the size of the military.[655] Civ-mil models of military innovation would point to this and use it as evidence of the influence of civilian leadership over the doctrine of a military.[656] But it is important to note that Dulles' logic for why the New Look was the most appropriate action relied on the martial knowledge related to atomic weapons to validate that decision as truth before the military shifted resources. The political pressure to reduce the size of the military became an influence on the production of martial knowledge rather than a direct cause for the shift in resources.

As one could imagine, leaders within the U.S. Army were not completely on board with the New Look. General Maxwell Taylor, the U.S. Army Chief of Staff, unsuccessfully lobbied for the President to abandon his New Look policy.[657] Again, at

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[653] Kaplan, 175.
[654] Ingo Trauschweizer, *The Cold War U.S. Army: Building Deterrence for Limited War*, Modern War Studies (Lawrence, Kan: University Press of Kansas, 2008), 28–29.
[655] Edwards, *The Closed World*, 57.
[656] Posen, *The Sources of Military Doctrine*.
[657] Kaplan, *The Bomb*, 11–12; Andrew J. Goodpaster, "Memorandum For Record Detailing a Discussion between President Eisenhower and the JCS" (Declassified document, November 6, 1957), WHITE HOUSE OFFICE, OFFICE OF THE STAFF SECRETARY: Records of Paul T. Carroll, Andrew J. Goodpaster, L. Arthur Minnich and Christopher H. Russell, 1952-61 Subject Series, Department of Defense Subseries, Box No 1, Department of Defense, Vol. II (3), Eisenhower Library, Abilene, KS.

face value, this appears as further vindication of the civ-mil model of military innovation and an indictment against the technology triad's assertion that the military takes the actions that it believes are the most appropriate rather than those that civilian leadership directs. However, the values inherent in the U.S. Army related to the sanctity of civilian control of the military would have built a martial knowledge within the U.S. Army that made acquiescing to the president the appropriate action. This may seem like a clever ploy to avoid a situation where a competing theory of military innovation provides a better explanation for the actions of the U.S. military than the technology triad. However, in discussions related to literally obliterating entire cities and killing untold millions of people, one has a duty to fully explore the possible motives of those who are making important decisions, no matter how distasteful the implications of that exploration may be. One has only to look as far as the countless military coups in modern history to realize that civilian control of the military is not a law of nature.[658] It is a value that is held in such high regard in the U.S. military that it is unthinkable to imagine a service not accepting the resourcing decisions of the commander in chief. In the language of the technology triad, President Eisenhower and General Taylor shared a reality where it was appropriate for the U.S. Army to give a portion of their resources to the other services once the president made the decision.[659]

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[658] Even in militaries with a strong tradition of civilian control, national leaders must carefully manage civilian-military relations to prevent praetorianism.. Goodpaster and Huntington, *Civil-Military Relations*; And more recently, Mackubin Thomas Owens, "Maximum Toxicity: Civil-Military Relations in the Trump Era," *Strategic Studies Quarterly* 15, no. 2 (May 27, 2021): 99–119.

[659] The Army underwent a dramatic doctrinal transformation during this period to form the "Pentomic Divisions" but never successfully aligned their martial knowledge and material with this new doctrine to achieve a lasting innovation. Despite the short life of this new structure, it is an important example of a failed military innovation in its own right that is a foundational case in the inter-service school of military innovation. The authoritative text on this document is: Bacevich, *The Pentomic Era: The Army Between Korea and Vietnam*.

Eisenhower's strategy of massive retaliation may have been logically consistent with the reality which the U.S. military had built for itself, but it proved impractical to address the challenges of the Cold War. In 1959, President Eisenhower dismissed a study on the prospects of conventional limited war because he believed "we were unfortunately so committed to nuclear weapons" that it was "unrealistic" to speculate that they would not be used in war.[660] This demonstrates the lasting influence that materiel can have on both martial knowledge and doctrine. President Kennedy would disagree, saying in that same year that reliance on massive retaliation was dangerous and "leaves the initiative in the hands of our enemies."[661] To revamp the nation's nuclear strategy, President Kennedy enlisted the help of Ford Motor Company's CEO, Robert McNamara.[662] McNamara employed a hands-on, quantitative management style that he had first developed while conducting operations research to optimize flight routes for the Army Air Forces in World War II.[663] Before the new team could implement a different strategy, the Berlin Crisis of 1961 occurred and forced the administration to navigate a very tense situation with little more than a threat of nuclear annihilation to do so.[664] This incident demonstrates the lag between martial knowledge and doctrine in large militaries. It also proved President Kennedy's point that massive retaliation may have worked well in simulations and wargames at RAND but was ill-suited for competition with other nations.

Spurred by the near-disaster in 1961, McNamara developed his flexible response nuclear strategy.[665] In 1960, a RAND researcher had presented the new secretary of

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[660] Herken, *Counsels of War*, 127.
[661] Craig, *Destroying the Village*, 116.
[662] Kaplan, *The Bomb*, 32–33.
[663] Kaplan, 32–33.
[664] Craig, *Destroying the Village*, 151.
[665] Craig, 153.

defense with a brief based on the latest developments in game theory and quantitative analysis that presented a strategy of compliance in which the United States would employ gradually increasing numbers of nuclear weapons to communicate with the USSR and convince them to sue for peace.[666] This strategy fit with McNamara's management style, and he adopted it as his flexible response strategy, so named because the United States retained the freedom to respond militarily with either conventional or nuclear weapons.[667] It also aligned well with a martial knowledge that viewed nuclear weapons as the far end of the spectrum of war. The difference between the flexible response doctrine and massive retaliation was that the full spectrum could be employed with the flexible response doctrine, and massive retaliation essentially ignored the options between war and peace. Unfortunately for McNamara and his goal of presenting the president with options to employ the nation's nuclear force in situations short of general war, the new strategy proved totally inadequate in the Cuban Missile Crisis just months later.[668] McNamara and President Kennedy replaced their flexible response doctrine with a nuclear war avoidance strategy that would become Mutually Assured Destruction.[669]

Throughout the twenty years following World War II, the general shape of the technology triad related to nuclear weapons remained relatively stable. The martial

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[666] Craig, 153; Kaplan, *The Wizards of Armageddon*, 260.

[667] Freedman, *The Evolution of Nuclear Strategy*, 223; Craig, *Destroying the Village*, 158; Kaplan, *The Wizards of Armageddon*, 282.

[668] Craig, *Destroying the Village*, 159; Freedman, *The Evolution of Nuclear Strategy*, 223.

[669] Freedman, *The Evolution of Nuclear Strategy*, 232–33; Craig, *Destroying the Village*, 161; "Report of the Net Evaluation Subcommittee National Security Council" (Excised Copy of Transcript of Oral Report, FOIA release, August 27, 1963), Record Group 218. Joint Chiefs of Staff Records (RG 218), Chairman's Files, Records of Maxwell Taylor, Box 25, 381 Net Evaluation, National Archives and Records Administration, College Park, MD, https://nsarchive2.gwu.edu/nukevault/special/doc08.pdf; Maxwell Taylor, "Program I Memorandum for the President" (Memorandum from JCS Chairman to Director of the Joint Staff, declassified document, September 23, 1963), Digital National Security Archive, https://nsarchive.gwu.edu/dc.html?doc=6895262-National-Security-Archive-Doc-14-Memorandum-from.

knowledge inspired by the demonstrated abilities of the atomic bomb in 1945 established war along a straight line where strategic nuclear bombing was opposite of peace and capable of producing decisive outcomes in war. The technology triad continued to change over time, but these changes were complementary to the basic shared reality within the U.S. Military that solidified around 1950. Materiel went through several iterations, from the atomic bomb, to the hydrogen bomb, and eventually missiles and elaborate aerial refueling systems.[670] Likewise, the U.S. nuclear strategy shifted from World War II-style strategic bombing, to massive retaliation, to flexible response, and eventually assured destruction.[671] Each iterative change of the materiel and the doctrine, when viewed at the strategic level, conformed to the same basic reality that was introduced in 1945 and influenced every corner of the U.S. military from intercontinental ballistic missiles in the U.S. Air Force to squad reporting procedures in the U.S. Army.[672] But this was the local shared reality of the U.S. military. Built and maintained through simulations, wargames, exercises, and advanced quantitative analysis within the U.S. military's knowledge system, this reality was not necessarily shared by other militaries in the world. When the United States would find itself mired in a protracted ground war in the late 1960s, the reification of the reality imagined around nuclear weapons would become a major impediment to the nation's efforts to achieve its strategic objectives.

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[670] Ken Young and Warner R. Schilling, *Super Bomb: Organizational Conflict and the Development of the Hydrogen Bomb*, Cornell Studies in Security Affairs (Ithaca, [New York]: Cornell University Press, 2019); Craig, *Destroying the Village*, 29; Edwards, *The Closed World*; Kaplan, *The Wizards of Armageddon*, 108.

[671] Kaplan, *The Wizards of Armageddon*; Craig, *Destroying the Village*; Freedman, *The Evolution of Nuclear Strategy*.

[672] Linn, *Elvis's Army*, 315–17; James William Gibson, *The Perfect War: Technowar in Vietnam* (New York: Atlantic Monthly Pr, 2000).

**Vietnam and Shared Realities**

The Vietnam War defies the types of war and peace, violence or no violence classifications upon which the logic for the constructed nature of martial knowledge was built in Chapter 3. There was no clear point where one could say when an invasion happened, as in Poland and France, or even a point where one could identify a precipitous increase in violence to represent the "start" of the war. Certainly, there were incidents that marked the increase of commitment by the United States along the way. After the Tonkin Gulf engagement in August 1964, for example, the United States flew 64 sorties against North Vietnamese targets.[673] In June 1965, General Westmoreland requested an additional 44 combat battalions be sent to support the South Vietnamese in their ongoing operations against Viet Cong guerillas and their North Vietnamese Army allies.[674] But neither of these events or any number of similar escalations in the war could really be considered the start of the conflict. This war is better understood with the more fluid concept of competing realities that was explained in the previous chapter. The United States maintained a shared reality at the onset of the war that South Vietnam was an independent nation whose borders should be observed by their neighbors, and the North Vietnamese maintained a shared reality that did not distinguish between North and South Vietnam and viewed the United States as "imperialists" who "partitioned [their] country and launched an atrocious war in the South."[675] When North Vietnam and the United States were unable to create a shared reality below the level of violence, the Geneva

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[673] Stanley Karnow, *Vietnam, a History*, 2nd rev. and updated ed (New York, N.Y: Penguin Books, 1997), 388.
[674] Andrew F. Krepinevich, *The Army and Vietnam* (Baltimore, Md: Johns Hopkins University Press, 1988), 3.
[675] Chi Minh Ho, *Selected Writings, 1920-1969.* (Honolulu: University Press of the Pacific, 2001), 278.

Conference of 1954 having divided North from South after France's defeat to the chagrin of North Vietnam, the two nations resorted to the universal shared reality of the physical world in an attempt to determine which nation's local reality was more appropriate for the physical world of violence they both shared.[676]

The strategic martial knowledge that defined truth about the correct way to fight a war for the United States in the mid 1960s had been defined by the technology triad related to nuclear weapons over the previous 20 years. All war was viewed as a continuum of violence and resources. Even guerilla war was articulated in this manner. The counter insurgency doctrine that the U.S. Army had developed at President Kennedy's insistence relied heavily on Mao's three phases of an insurgency: latent conflict, followed by guerrilla war, and finally full-scale combat operations.[677] A history of U.S. Army Counterinsurgency and Contingency Operations Doctrine published by the U.S. Army Center of Military History explained that "from the beginning, national policy and Army doctrine alike had tended to treat the differences between the phases in a Maoist revolutionary war as ones of scale and intensity, not method."[678] The U.S. military would fight the Vietnam War with the martial knowledge, materiel, and doctrine that had developed in a reality that imagined a nuclear exchange with the USSR.

When the United States decided to escalate the air war in Vietnam and employ larger numbers of aircraft to influence the war's outcome through airpower, they did so with conventional weapons that employed a nuclear doctrine.[679] The purpose of

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[676] Karnow, *Vietnam, a History*, 52.
[677] Andrew J. Birtle, *U.S. Army Counterinsurgency and Contingency Operations Doctrine 1942-1976; CMH Pub 70-98-1* (Washington, D.C.: Center of Military History, 2006).
[678] Birtle, 255.
[679] Kaplan, *The Wizards of Armageddon*, 329–30, 333; Craig, *Destroying the Village*, 158–59.

Operation Rolling Thunder, the bombing campaign in North Vietnam that started in March 1965, would be to slowly increase the level of violence until the North Vietnamese agreed to a negotiated resolution.[680] This was a direct application of the theories that Schelling had briefed in 1960 and McNamara had fashioned into a comprehensive nuclear strategy in 1962.[681] Even though the United States had abandoned this strategy for nuclear weapons three years prior, they had done so because of the risk of an adversary escalating to nuclear weapons against the United States. The martial knowledge that all wars were gradations of violence along a straight line preserved the underlying of logic of the counter force doctrine, even in a conventional war. Schelling even wrote a book in 1966, a year into the bombing campaign, where he extolled the United States' efforts in Vietnam and used the bombing as further evidence that his theories related to signaling through bombing were still valid.[682] Existing histories of the Vietnam War and nuclear strategy are clear that counter force was the genesis of the Vietnam strategy, but they fail to provide an explanation for why the United States would employ an obsolete doctrine in a new war.[683] The concept of martial knowledge within the technology triad shows how this decision would be logical for the people who made it. As a fundamental truth about the way wars should be fought, it makes sense to slowly increase violence to compel an action from an adversary, especially if they do not have the power to do the same in return.

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[680] Mark Clodfelter, *The Limits of Air Power: The American Bombing of North Vietnam* (Lincoln: University of Nebraska Press, 2006), 85.
[681] Edwards, *The Closed World*, 137; Herken, *Counsels of War*, 209.
[682] Thomas C. Schelling, *Arms and Influence*, A Yale Paperbound, Y-190 (New Haven; London: Yale Univ. Pr, 1976), 171.
[683] Kaplan, *The Wizards of Armageddon*, 329–30, 333; Craig, *Destroying the Village*, 158–59; Edwards, *The Closed World*, 137; Gibson, *The Perfect War*, 319; Osinga, *Science, Strategy and War*, 43.

Three years into this gradually increasing bombing campaign, in January 1968, the North Vietnamese and Viet Cong simultaneously launched attacks against the United States and ARVN troops across the entire combat zone.[684] The Tet Offensive, as it would be called, was a total surprise to the Americans, who had believed the North Vietnamese were all but beat.[685] After one month of increased operations, the United States had lost two thousand soldiers, and the South Vietnamese had lost four thousand.[686] In contrast, the North Vietnamese and Viet Cong had lost an astounding fifty thousand soldiers.[687] Despite the tactical victory demonstrated by the numerical imbalance of the casualties in the battle, the strategic impact was fatal for the United States. After a short period of support from the American public immediately following the battle, support from the war dropped.[688] Walter Cronkite announced after a visit to Vietnam in February 1968 that he was "more certain than ever that the bloody experience in Vietnam is to end in stalemate."[689]

This surprise attack provides an ideal glimpse at the competing realities between the United States and their North Vietnamese adversaries. On 23 February 1968, at the height of the Tet Offensive, Walt Rostow, the National Security Advisor, sent a top secret communication to General Westmoreland explaining that the best U.S. analysis of the North Vietnamese intentions was to "make a virtually total effort with the capital [they have] in hand. [They] may then try to lock us into a negotiation at [their] peak position

[684] Gibson, *The Perfect War*, 164.
[685] Gibson, 165.
[686] Karnow, *Vietnam, a History*, 547.
[687] Karnow, 547.
[688] Karnow, 558.
[689] Karnow, 561.

before we can counterattack."[690] This assessment would have made sense coming from the United States, which was desperately trying to force the North Vietnamese to the negotiating table. However, the North Vietnamese had no interest in negotiating at all. Bui Tin, a former colonel in the North Vietnamese Army, told an interviewer in 2002 that at no point in the war did the North Vietnamese consider a negotiated end to the war.[691] Furthermore, he asserted that the purpose of the Tet Offensive was to "weaken American resolve during a presidential election year."[692] This position was confirmed by a North Vietnamese general in a 2011 interview when he said, "some people have thought that the objective of the Spring Offensive of 1968 was to occupy the southern towns and cities and to liberate them. But they are quite mistaken. But this was only an offensive aimed at creating heavy strategic losses to the enemy, thereby contributing to step by step victories that would eventually lead to the complete liberation of the South."[693]

The two militaries viewed the exact same action from two completely different realities. To the United States, the purpose of military force was to gradually increase destruction to force the enemy to negotiate, as occurred in the RAND wargames of nuclear war. To the North Vietnamese, the purpose of military force was always to wear down the United States' will to continue to fight and eventually force them to withdraw from Vietnam.[694] Bui Tin himself explained that "the United States and Vietnam are two

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[690] Walt Rostow, "Cabel from Walt Rostow to General Wheeler and General Westmoreland" (Declassified document, February 23, 1968), NSF Country File Vietnam 2C(7) General Military Activity, LBJ Library, Austin, TX.
[691] Tín Bùi, *From Enemy to Friend: A North Vietnamese Perspective on the War* (Annapolis, Md: Naval Institute Press, 2002), 93.
[692] "Korean War Memorial," Congressional Record Volume 141, Number 129 (United States House of Representatives, August 1995), https://www.govinfo.gov/content/pkg/CREC-1995-08-04/html/CREC-1995-08-04-pt1-PgH8514.htm.
[693] *Vietnam Interview: Hoang Anh Tuan, Vietnam: A Television History* (WGBH Boston, 2011), https://video.alexanderstreet.com/watch/vietnam-interview-hoang-anh-tuan.
[694] "Korean War Memorial."

countries very distant from each other, with contrasting cultures and systems of government, and it is no wonder that they fought the war very differently."[695] While Bui Tin's communist background induced him to focus on the way that the sociopolitical regimes of the two countries created different ways of waging war, the technology triad shows how the United States could come to adopt a strategy of diplomacy by actions derived from a fundamental understanding of reality within the U.S. military that was influenced by the atomic bomb.[696]

The North Vietnamese reality was more appropriate for their strategic aims than was the United States' reality within the reality they both shared, and Johnson ordered the cessation of Operation Rolling Thunder in March 1968 after his approval rating dropped from 48 to 36 in the six weeks since the start of the Tet Offensive.[697] With the advantage of hindsight, one can discern that Operation Rolling Thunder was never going to have its intended effect. Bui Tin claimed that if the United States would have cut the supply trails to the south or conducted all of their bombing at once, then North Vietnam would have been forced to stop the war.[698] However, the United States pursued a strategy of communication through bombing, while the North Vietnamese were in a protracted struggle with no interest in quitting the fight while they maintained the means to resist. Many of the targets struck in the bombing campaign were related to materiel, especially fuel depots.[699] But, the entire North Vietnamese war effort only required 34 tons of materiel a day.[700] Such a small amount of materials would have been impossible to stop

[695] Bùi, *From Enemy to Friend*, 31.
[696] Bùi, 7.
[697] Clodfelter, *The Limits of Air Power*, 114; Karnow, *Vietnam, a History*, 559.
[698] "Korean War Memorial."
[699] Gibson, *The Perfect War*; Clodfelter, *The Limits of Air Power*.
[700] Clodfelter, *The Limits of Air Power*, 205.

with bombing. Massive bombing did eventually force the North Vietnamese to the negotiating table with the Christmas Raids of 1972, but the subsequent peace treaty only lasted until 1975 when the North Vietnamese reality finally established itself as dominant in Vietnam with their capture of Saigon.[701]

## Analysis and Insights

Military innovation related to nuclear weapons in the United States seemed to follow the three-step process of innovation from Chapter 3 relatively closely. Chapter 5 explained that autonomy was the key step that might indicate that the technology triad model of military innovation was applicable to this case, and that was the strongest fit of the three. The autonomy exercised by those who worked on the Manhattan Project was about as extreme as one would expect to find in a modern democratic nation. That the commanding general of the project could exercise the authority of the President to secure any and all required resources at a time when rationing was imposed on the American population was a clear indication of the level of autonomy the project possessed.[702] In fact, the autonomy and subsequent isolation of the Manhattan Project were so complete that even the Vice President was unaware of American efforts to build the atomic bomb the day he assumed the office of the President.[703] Empowered by this autonomy, the people who worked on the Manhattan Project produced a materiel solution not just outside the reality of any military but outside the bounds of previously harnessed forces of nature.

[701] Clodfelter, 145, 204–5; Karnow, *Vietnam, a History*, 700.
[702] Rick Atkinson, *An Army at Dawn: The War in North Africa, 1942 - 1943*, 1. Owl Books ed, The Liberation Trilogy, Rick Atkinson ; Vol. 1 (New York: An Owl Book, Holt, 2003), 26.
[703] Rhodes, *The Making of the Atomic Bomb*, 614.

Once the U.S. military had made a change to one element of their technology triad, the next step would be to develop the innovation further by aligning the other two elements of the triad. The development phase of the nuclear weapons innovation at the tactical level moved quickly because it could leverage much of the doctrine and martial knowledge that had been generated during World War II in the strategic bombing campaigns. Development at the strategic level progressed steadily over the five years following the end of World War II. First, the martial knowledge adjusted to accept that the atomic bomb represented a new type of weapon that enabled a level of war that was so extreme all other wars were judged in relation to it. The U.S. military accepted as truth that war could be measured on its linear path according to the level of violence it inflicted and resources it consumed relative to nuclear war. Terms like "limited war" and "general war" came into use and denoted where a specific conflict fell along the spectrum of war. Closely following the new martial knowledge, a new strategic doctrine emerged to employ the novel materiel solution within the newly justified truth about war to achieve national-level objectives.

Once each of these elements was aligned, the innovation process was complete, and the triad defined a new reality then maintained it as the elements changed slightly within the bounds of the constructed reality. The reality was reinforced for the people within the U.S. military by a martial knowledge generated through the knowledge system. Within this knowledge system, each of the five influences of knowledge production was present. Prior knowledge was represented in the form of the USSBS and individual experiences from World War II. RAND simulations and operations research analysis served as internal epistemologies and were supported by external epistemologies in the form of intelligence reports.[704] Social, political, and economic influences on the production of knowledge were constant, from popular views on the dangers of atomic weapons to the outcome of elections that reprioritized resource allocations. Finally, each of these influences on the production of knowledge existed within the constant pressure of values systems, such as the sanctity of life, that played a central role in all serious discussions related to nuclear weapons.

This martial knowledge maintained a reciprocal relationship with the evolving materiel within the U.S. military. Although the basic structure of nuclear weapons remained constant throughout this period, there were functional changes to the magnitude and delivery systems of the bombs. The U.S. military-built hydrogen bombs, missiles, and nuclear submarines to enhance its ability to conduct operations within the martial knowledge at the time. All of this materiel took time to build, which introduced a limiting function on the doctrine that the military could employ. Eventually, there were enough weapons to enable a wide range of doctrines, and the U.S. nuclear strategy oscillated between advocating massive strikes and seeking opportunities to employ nuclear weapons in more limited manners. However, each of these doctrines always conformed to the martial knowledge that war was a continuum. They only differed in the relative portion of the continuum that they intended to leverage to achieve strategic objectives.

This reality that the United States constructed for itself defined not just nuclear strategy but also seeped into every aspect of the national defense structure. The centralization that was necessary for the avoidance of fratricide and efficient use of weapons on the nuclear battlefield manifest itself as a culture of control and

[704] Kaplan, *The Wizards of Armageddon*, 109.

micromanagement within the military.[705] When the United States pitted this reality against the North Vietnamese Army's reality over the control of South Vietnam, it was found wanting.[706] The technology triad helps explain, in ways that previous models have not, why the United States would continue to pursue a losing bombing strategy for years.

In his book *Closed Worlds,* Paul Edwards explained how the RAND simulations had come to define an isolated and artificial world that bore little resemblance to the external reality in which the United States waged a war with North Vietnam.[707] His assessment and the one informed by the technology triad are in agreement on the different realities the two nations inhabited. However, the two models differ when it comes to the level of awareness of these two realities. Edwards pointed to the language that national defense leaders used to argue that the United States was aware of the closed world it inhabited and that the USSR was in a similar situation.[708] The technology triad argues that the local shared reality within the United States was never acknowledged as just the United States "version of reality" but defined fundamental truths about the way things are and ought to be. This is different because it means that those making decisions within the local reality would do so with the implicit belief that their reality applied universally. When Rostow saw in the Tet Offensive the objectives that the United States had been trying to achieve, he demonstrated his belief that the United States' reality was not simply a version of reality but a statement about the purpose of violence and force in war that applied to all humans equally. The war was a contest of realities within a greater

[705] Edwards, *The Closed World*; Linn, *Elvis's Army*; Gibson, *The Perfect War*.
[706] Gibson, *The Perfect War*; Edwards, *The Closed World*.
[707] Edwards, *The Closed World*.
[708] Edwards.

shared reality in which the North Vietnamese reality was more appropriate to achieve their strategic objectives.

This case was the first of two tests of the generalizability of the technology triad. Each of the four indicators laid out in the previous chapter was present in this case. The Manhattan Project represented autonomy. Martial knowledge as a concept helped draw the rough sketch of the interactions between doctrine, materiel, and change. The differing rates of change between the elements of the technology triad exerted significant influence over the way the elements changed with each other at various times through the years. And conflicting realities within a shared reality provide a useful framing for actions and events that might otherwise be hard to understand, knowing how the war would end. These indicators are not simply present in this case. One can find just about any interaction in a historical case if they read enough books and old reports. The indicators are present in a way that when they are all put in relation to each other, they provide a new lens through which to view an old problem and start to imply strategies for the future management of technology and military innovation.

Historical analysis can provide useful insights for the management of contemporary military technology. However, as Bertrand Russell's chicken demonstrated, the past is not necessarily a reliable indicator of the future, and when the stakes are extremely high, being wrong just once may be all it takes to lose an entire nation.[709] If the technology triad is going to enable more effective management of military technology when the outcome of decisions is unknown, it must provide useful

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[709] Nassim Nicholas Taleb, *The Black Swan: The Impact of the Highly Improbable*, 2nd ed., Random trade pbk. ed (New York: Random House Trade Paperbacks, 2010), 40; Bertrand Russell, *The Problems of Philosophy.*, Home University Library of Modern Knowledge.35 (New York: H. Holt, 1912), 98, https://catalog.hathitrust.org/Record/001387777.

insights and framings of technology and military innovation in cases as they unfold. In order to accomplish this goal, the model must be able to provide enhanced understanding in situations where the outcome of decisions is not known. Had President Johnson framed conflict and war as competing shared realities, he may have realized that his conventional application of counter force bombing strategy was doomed because he was assuming his local reality was a reflection of the shared reality created by the two belligerents. The technology triad may have been able to help him identify the boundaries of his own reality in relation to the North Vietnamese reality and more effective doctrines to navigate it. But there is no way to tell with any reasonable level of certainty that this would have been possible with the information he had at hand. This research was conducted from start to finish with the bias induced by hindsight and the foreknowledge of eventual outcomes that it provides. In order to test the ability of the technology triad to inform the active management of military technology and innovation, this bias must be removed. The next chapter will explore a currently evolving military technology to see if the technology triad is still a useful tool.

“Pick the smallest, weakest country
with the most minimal air force – [it]
can deal with a Predator.”

-General Mike Hostage
United States Air Force,
2013[710]

# CHAPTER 7

# ARMED DRONES

## Introduction

An effective model of military innovation must generalize to historical accounts. One could hardly claim that a model designed to say something useful about the real world is valid if it does not conform to reality, and all accounts of reality are really just a version of history to one degree or another. However, the historical record is rich with perspectives unavailable to those who lived at that time, both in the eventual outcome of their decisions and contemporaneous events in other nations. Bias induced by the outcome of events and information not available to the actors at the time is unavoidable with historical case studies. If the technology triad is going to be useful for the active management of military innovation in competitive environments, it must provide insights into contemporary events. This chapter will use the case of armed drone development and the doctrine to employ this material solution within the United States’, Russian, Israeli, and Azerbaijani militaries to determine the degree to which, if at all, the four indicators

[710] John Reed, “Predator Drones ‘Useless’ in Most Wars, Top Air Force General Says,” *Foreign Policy* (blog), September 19, 2013, https://foreignpolicy.com/2013/09/19/predator-drones-useless-in-most-wars-top-air-force-general-says/.

from Chapter 5 are present and support a claim of the technology triad's generalizability beyond historical case studies.

The status of armed drones as a true military innovation is difficult to determine within definitions of innovation that require a significant change to military praxis, especially those that require that change to have been demonstrated in combat because the case is currently evolving.[711] What appears in the moment to be a significant change within militaries may prove over time to be a minor shift in one of the elements of the technology triad. On the other hand, shifts in all three elements that produce a new understanding of reality should be detectible, even when the future appropriateness of that new reality for some future conflict is unknowable. This case will employ the technology triad to make an assessment of the status of armed drones as a military innovation or as an incremental change to a previous technology triad as an additional method to test for the usefulness of the insights that the technology triad can produce. Regardless of this case's status as an innovation or as an evolutionary change, the change must be significant enough for the interactions within the technology triad to be detectable, or it will fail to provide a valid test for the generalizability of the model to contemporary military innovations. One would have to wait for the passage of time to indicate the degree to which the elements of the technology triad did or did not change.

Although the idea of a drone dates to Nikola Tesla in 1898, the materiel solution has become capable enough over the last 20 years that it is reasonable to consider the impact that drones have on the way militaries fight and understand war important.[712]

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[711] Grissom, "The Future of Military Innovation Studies."
[712] Michael J. Boyle, *The Drone Age: How Drone Technology Will Change War and Peace* (New York, NY: Oxford University Press, 2020), 31, 10.

Peter Singer, the popular author, has gone so far as to call drones "the most important weapons development since the atomic bomb."[713] Time may prove Singer correct, but Antoine Bousquet, a war studies scholar, probably struck a more appropriate tone related to the impact of drones on the conduct of war when he said, "as long as one avoids fetishizing the drone as a somehow unique or causally determinative technology, it remains an illuminating object of analysis for current trends in the present-day conduct of warfare."[714] Within the technology triad, the armed drone, as a materiel solution, is necessary but not sufficient to create a military innovation without corresponding changes to martial knowledge and doctrine. Analysis of these changes, or lack of change, within the U.S., Russian, Israeli, and Azerbaijani militaries will form the backbone of the final application of the technology triad in this dissertation. The relative applicability of the technology triad to this case will help determine what insights this framing of the relationship between technology and military innovation might provide to aid national defense leaders in their duty to manage the dynamic security environment effectively.

### *Bounding the Cases*

The breadth of this case study, with its application of the technology triad to four different militaries, will preclude an analysis at the level of detail possible in chapters 4 and 6. The events and developments within each military related to armed drones will only go to the level of detail that is necessary to apply the technology triad as an analytical tool with the aim of testing the generalizability of the model. Each case will

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[713] P. W. Singer, *Wired for War: The Robotics Revolution and Conflict in the Twenty-First Century* (New York: Penguin Press, 2009), 10.
[714] Antoine J. Bousquet, *The Eye of War: Military Perception from the Telescope to the Drone* (Minneapolis: University of Minnesota Press, 2018), 4.

follow the same basic structure. It will be bounded in time from the introduction of the first armed drone through February 2021, when the research phase of this dissertation was completed. Organizationally, each case will be held to the national level, rather than the service level, because the distinction between an air force and an army are reflections of a national organizational doctrine and structures within the military knowledge system, which are themselves part of the analysis. Furthermore, maintaining analysis at the national level will provide a greater opportunity to identify the presence of unique local shared realities within the militaries in question with their distinct social and political influences on the development of their martial knowledge. If the technology triad is applicable to this contemporary case, each military should maintain a unique martial knowledge that is a reflection of their individual strategic position and exerts non-trivial influence over their materiel and doctrine.

As an event, the introduction of the first armed drone is itself an ill-defined point in time that will require further clarification on the definition of an "armed drone" to adequately bound the case in time. This dissertation will use the colloquial word "drone" rather than Unmanned Aerial Vehicle (UAV) or Remotely Piloted Aircraft (RPA). General Martin Dempsey reportedly despised the terms "drone" and "UAS" because, to him, they imply an unthinking automaton that had the capacity to kill.[715] Secretary of Defense Mattis shared General Dempsey's view on the term "UAS," but himself used the word "drone."[716] From an analytic standpoint, rather than a public communication-

[715] Jim Garamone, "Military Uses Remotely Piloted Aircraft Ethically," American Forces Press Service, Joint Chiefs of Staff, May 23, 2014, https://www.jcs.mil/Media/News/News-Display/Article/571704/military-uses-remotely-piloted-aircraft-ethically/.
[716] Richard Sisk, "Mattis' Pet Peeve: Calling Drones 'Unmanned Aerial Vehicles,'" Military.com, February 21, 2018, https://www.military.com/defensetech/2018/02/21/mattis-pet-peeve-calling-drones-unmanned-aerial-vehicles.html.

oriented one with the intent to impart a specific official policy to an audience, UAV can be inappropriate because it explains a new machine in terms of an old one by highlighting the difference between the two, the way early cars were sometimes called "horseless carriages."[717] "RPA" could be a way to avoid the implications of "UAV," but "RPA" could imply the exclusion of a large and growing class of weapons systems with various levels of autonomous features and is currently a U.S. Air Force doctrinal term.[718]

Absent an international consensus on the correct language and given the prevalence of the term "drone" in the popular and academic literature, this dissertation will use "drone" to describe a flying machine that does not carry a human operator and is capable of being recovered after use for future missions.[719] This definition includes all of what the U.S. military would call UAVs or RPAs and excludes one-time use weapons, like cruise missiles, that start to blur the line between autonomous drone and missile.[720] The qualification that the drone must have the ability to be recovered delineates the introduction of armed drones in time by producing a useful distinction between systems like the radio-controlled B-17 bombers in World War II and modern suicide drones.[721] Once flight crews armed the B-17s loaded with explosives, they were on a one-way trip

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717 P. W. Singer, "Book Talk with Peter Singer: 'Burn-In.'"

718 Paul Scharre, *Army of None: Autonomous Weapons and the Future of War*, First edition (New York ; London: W. W. Norton & Company, 2018); "United States Air Force RPA Vector: Vision and Enabling Concepts 2013-2038" (Headquarters, United States Air Force, February 17, 2014), https://www.af.mil/Portals/1/documents/news/USAFRPAVectorVisionandEnablingConcepts2013-2038.pdf.

719 Hugh Gusterson, *Drone: Remote Control Warfare* (Cambridge, Massachusetts: The MIT Press, 2016); Boyle, *The Drone Age*; Bousquet, *The Eye of War*; John J. Kaag and Sarah E. Kreps, *Drone Warfare*, War and Conflict in the Modern World (Cambridge, United Kingdom ; Malden, MA: Polity, 2014); Sarah E. Kreps, *Drones: What Everyone Needs to Know*, First edition (New York, NY: Oxford University Press, 2016); Richard Whittle, *Predator: The Secret Origins of the Drone Revolution*, First edition (New York: Henry Holt and Company, 2014), 183.

720 Scharre, *Army of None*.

721 Gusterson, *Drone*, 9.

to their target.[722] Modern suicide drones, such as the Israeli Harop, can return for future missions if they do not find their target.[723] With "armed drones" thus defined, this case will start in 2001 when the U.S. military first fired a hellfire missile from a Predator drone.[724]

The development of armed drones within each of the four militaries in this case will provide a unique case to test the applicability of the technology triad, and the four cases together create contrasting environments to highlight the creation of local shared realities. The United States military was the first military to openly acknowledge the production of armed drones in line with the definition above. Study of the development of drones and the doctrine for their employment will indicate how a stable martial knowledge has influenced this internally generated materiel solution. The Russian development of armed drones, and drones in general, has lagged significantly behind the United States, which will help illustrate how a large military's martial knowledge can influence external epistemologies. Israel is a much smaller military than both the U.S. and Russian militaries and possesses a unique relationship with their civilian industry. The way these aspects of the Israeli military differ from the U.S. and Russian militaries makes Israel a good candidate against which to test the generalizability of the technology triad. Finally, the Azerbaijani military is even smaller than the Israeli military and employed their drone fleet in a novel manner in a 2020 war against neighboring Armenia.[725] The presence of a military innovation related to drones in the Azerbaijani

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[722] Gusterson, 9.
[723] "Harop Loitering Munitions UCAV System - Airforce Technology," July 2, 2015, https://www.airforce-technology.com/projects/haroploiteringmuniti/.
[724] Boyle, *The Drone Age*, 53.
[725] "International Comparisons of Defence Expenditure and Military Personnel," *The Military Balance* 119, no. 1 (January 2019): 513–18, https://doi.org/10.1080/04597222.2019.1561038.

military will provide a strong test of the generalizability of the technology triad, given that military's unique cultural and strategic characteristics in this analysis.

### *Challenges of a Contemporary Case of Military Innovation*

The final aspect of these four nations' military development of armed drones that makes their analysis a strong test of the generalizability of the technology triad is related to the contemporary quality of the entire case study, but this also introduces challenges. Much of the information that was invaluable in the previous two case studies either remains classified or is inaccessible from within another nation's military. For example, any simulation or wargame of any import would be classified, severely limiting the ability to observe epistemologies in action directly. Even a significant portion of the current U.S. military doctrine related to the employment of drones is restricted distribution. No part of the data that informs this dissertation came from a classified or restricted source. While this aspect of the research may make a full account of each case difficult, it could help demonstrate the usefulness of the technology triad as an analytical tool. The purpose of the technology triad from its inception was to provide insights into unpredictable environments with incomplete information. If framing the development of armed drones in terms of the technology triad helps provide useful insights, then that supports the claim that this model might be useful for the management of military technology in real-time.

This dissertation will mitigate the relative lack of information in this contemporary case study by focusing on the fielded equipment of the militaries in question. As the example of the Future Combat Systems from Chapter 2 illustrate, militaries often undertake development efforts of new materiel solutions that may not make it to the units in the field. Overly focusing on the numerous announcements of new weapons systems by militaries can cause a misrepresentation of how the technology triad's elements are actually interacting and changing with each other. Some of those announcements might even be designed to deliberately mislead adversaries about the military capabilities of a particular nation. This artificial reflection of the state of the technology triad could be magnified by the general trend of a shifting locus of research and development from government-owned research centers to civilian companies that is present even in the shift from pure U.S. Army development of tanks in the 1930s to a combined effort between the U.S. military and civilian researchers in the development of the atomic bomb. As these civilian companies need to sell their proposed materiel solutions to the military, their advertisements could easily be mistaken for a reflection of the current state of a nation's technology triad.[726] However, the allocation of resources is a measure of what a military finds relevant.[727] This means the physical fielding of the materiel in question can help focus analysis on the current martial knowledge of a military without the distraction of experimental technologies that were never truly a part of a nation's technology triad.

With a focus on the actual state of the four nations' technology triads this case will provide a more grounded test of the generalizability of the technology triad as a model of military innovation. The relative validity or capabilities of these technology triads and the emergent realities they produce in this case study is beyond the scope and

[726] Any number of military themed magazines and billboards near military installations in the United States are full of advertisements for military equipment. A good example is: "Army Aviation" (The Official Journal of the Army Aviation Association of America, October 31, 2020).
[727] Wylie, *Military Strategy*, 64.

the intent of this dissertation. Furthermore, within the logic of the technology triad, determining the validity of a particular use of drones is impossible without knowing what kind of war for which they may be used in the future. It is true that early tank units were not as good at certain types of reconnaissance as horse cavalry, but in the war that followed, this proved to be less important than other advantages that the tanks provided.[728] Drones may be easy to shoot down or cheaper than manned aircraft, but these factors are only relevant for the purpose of this dissertation so far as they are estimations of worth by a particular military and reflect the current martial knowledge related to drones. The identification of the local realities that emerge from the interactions of the three elements of the technology triad within these four militaries that follows supports the claim that the technology triad can provide useful insights with limited information.

### The United States and Armed Drones

The United States' General Atomics MQ-1 Predator is the quintessential armed drone. Its inverted V-tail and bulbous nose have become the international symbol for drone strikes and are featured in everything from protest posters to Pashtun hand-woven rugs.[729] Despite the production of the first armed drone two decades ago, the United States' military's technology triad has not created a military innovation related to drones. The martial knowledge that predated the armed drone remains an important influence on the production of materiel solutions within the United States. Much like U.S. Army tanks in the 1930s, drones as a materiel solution have bifurcated into two separate doctrines.

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[728] Sickler, "Elon Musk Says Drones Are the Future of War, but He Should Consider Horses."
[729] Gusterson, *Drone*, 43, 128.

One doctrine can be described as “pure drone warfare” and represents the infamous international drone strikes the United States conducts in and out of declared war zones.[730] The second doctrine, “mixed drone warfare,” is aligned with the dominant martial knowledge that maintains a drone’s most effective use is as an aide to manned aircraft and ground maneuver operations.[731] These two doctrines, and their corresponding technology triads, are vying for dominance in the development phase of innovation. This situation precludes a simple application of the technology triad to this case but understanding the role of martial knowledge in the bigger picture does help illuminate the tension between the two roles of drones and their place within the larger U.S. military use of drones.

### *Pure Drone Warfare*

The predator started out as the creation of Abe Karem, a former Israeli Aerospace Industries (IAI) engineer, who carefully shepherded his reconnaissance drone through the initial stages of development by protecting his designs from U.S. government bureaucrats.[732] Karem’s initial designs became the Gnat 750, a joint reconnaissance drone project between each of the services and the Central Intelligence Agency (CIA) built by General Atomics that first saw service in the Balkans War.[733] Building on the success of the Gnat 750, General Atomics designed the Predator drone for the U.S. Government with enhanced payload and rage capabilities in 1993.[734] By 1996, the U.S. Air Force

[730] Gusterson, 14–15.
[731] Gusterson, 14–15.
[732] Whittle, *Predator*, 24, 58–59.
[733] Whittle, 79, 81.
[734] Whittle, 82–83.

assumed oversight of the new Predator drone and employed it in a manner similar to manned reconnaissance aircraft.[735] At this point in its development, the drone as a materiel solution represented a minor improvement to existing aircraft by performing existing missions with a reduced risk to the aircrews who would otherwise fly those missions, but this would soon change as the U.S. Air Force exercised its autonomy to make a fundamental change to the machine.

Drawing inspiration from lessons learned in Kosovo, U.S. Air Force General John Jumper directed that the U.S. Air Force mount a missile on the Predator in May 2000.[736] By the time the U.S. Air Force had created the requisite engineering knowledge to launch a missile from a drone, the CIA was employing unarmed Predators over the mountains of Afghanistan to monitor a particularly dangerous terrorist, Osama Bin Laden, who had recently called for his followers to attack U.S. citizens.[737] The CIA immediately saw great potential in the ability to strike targets from a long range reconnaissance platform, but laws that forbid the United States government from carrying out assassinations prevented the CIA from immediately employing the Predator as an attack aircraft.[738] The legal concerns at the time were so significant that even the engineers who were working on the project became concerned that they might be breaking the law once they found out that the CIA was interested in the armed Predator.[739] Almost immediately after the September 11th attacks, the U.S. government revisited the laws and determined that targeted strikes against known terrorists did not constitute an assassination and were

[735] Whittle, 111.
[736] Whittle, 169.
[737] Boyle, *The Drone Age*, 65.
[738] Whittle, *Predator*, 192; Boyle, *The Drone Age*, 64.
[739] Whittle, *Predator*, 194.

therefore legal.[740] On 17 September 2011, the President signed Executive Order 12333, which specifically granted the CIA the authority to kill terrorists with missiles fired from Predators.[741] With this order, which represented a shift in the martial knowledge of what a drone was for, and the armed Predator, which influenced this new martial knowledge through a demonstrated ability, the U.S. government had developed two of the three elements of the technology triad for a new form of air combat.

The U.S. military's strategic martial knowledge influenced the development of the third element, the doctrine to conduct targeted drone strikes, in a significant way. Just War Theory's obligation to employ proportional force and the preservation of U.S. military members' lives are foundational to the U.S. military's martial knowledge.[742] From General Jumper's first conception of arming a Predator with missiles, the prospect of reducing risk to U.S. air crews and non-combatants on the ground was a significant influence on the design.[743] The influence of the values judgment inherent in this position was so strong on the martial knowledge related to drones that when President Bush first authorized the use of these weapons to kill terrorists, he retained the authority to personally approve strikes with a "moderate or high" likelihood of causing collateral damage.[744] The requirement for high-level authorization of strikes and the institutional procedures developed to grant the authorization became the doctrine for this type of use of force by the U.S. government. Under President Obama, the United States expanded its prosecution of targeted strikes against terrorist leaders and further developed the doctrine

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[740] Boyle, *The Drone Age*, 65.
[741] Whittle, *Predator*, 245.
[742] "FM 6-27 The Commander's Handbook on the Law of Land Warfare"; Michael Walzer, *Just and Unjust Wars: A Moral Argument with Historical Illustrations*, Fifth edition (New York: Basic Books, a member of the Perseus Books Group, 2015).
[743] Whittle, *Predator*, 168.
[744] Whittle, 245.

in line with the martial knowledge with the introduction of weekly approval meetings at the national level, which the participants came to call “terror Tuesdays” referencing the day of the week the meeting was held.[745] Responding to political pressure related to the use of drones to conduct attacks in and out of war zones around the world, President Obama gave a speech at the United States Military Academy on 28 May 2014, where he said, “In taking direct action, we must uphold standards that reflect our values. That means taking strikes only when we face a continuing, imminent threat, and only where…there is near certainty of no civilian casualties.”[746] With this speech, the President demonstrated how the martial knowledge that posited the best use of drones influenced the development of doctrine to employ that materiel solution.

In his book *Drone*, Hugh Gusterson argued that the drone’s influence on the U.S. military’s understanding of how to wage counterinsurgencies represented more than “just a new machine that has been slotted into existing war plans in a space formerly occupied by other kinds of airpower.”[747] Gusterson claims that the drone, along with increased use of special operations units on the ground, created a new way of understanding the enemy as a “cluster of networks and nodal leaders.”[748] In other words, the drone introduced a new martial knowledge for counterinsurgency operations. It is unclear what role, if any, drones played in the U.S. strike on the Iranian Quds Force General Soleimani in January 2020, but this targeted strike against a serving officer in a nation’s military would support Gusterson’s claim. However, the new marital knowledge that views enemy forces as a

745 Boyle, *The Drone Age*, 60–61.
746 John Abizaid and Rosa Brooks, “Recomendations and Report of the Task Force on U.S. Drone Policy” (Washington, D.C.: Stimson, April 2015), 3, https://www.stimson.org/wp-content/files/file-attachments/recommendations_and_report_of_the_task_force_on_us_drone_policy_second_edition.pdf.
747 Gusterson, *Drone*, 23.
748 Gusterson, 24.

network with nodes represented by people that should be targeted has not created a military wide innovation in the U.S. military. The pre-existing reality of traditional airpower and ground maneuver is resisting the influence of the new materiel solution for the conceptualization of all war in the U.S. military.

### *Mixed Drone Warfare*

If "pure drone warfare" is the use of drones to attack targets in isolation, "mixed drone warfare" is the use of drones in combination with other forms of military force.[749] The original mission of the drones developed in the 1970s and 1980s, which would become the forerunners of the unarmed Predators, was to support traditional airpower and ground maneuver through identification of enemy units to attack and inform the movement of friendly units.[750] Progress on drones as a materiel solution to meet this mission was slow. By 2003, the entire U.S. Army V Corps only had enough drones to employ one at a time to support the Corps' invasion of Iraq.[751] Over the course of the wars in Iraq and Afghanistan, the U.S. military increased their use of drone strikes beyond the high-level leaders that characterized pure drone warfare. By 2012, fewer than 2% of drone strikes targeted senior leaders; the vast majority of drone strikes were against lower-level commanders and fighters in support of tactical objectives.[752] In 2017, armed drones proved especially valuable in urban combat as the U.S. military reclaimed Northern Iraq and Syria from ISIS.[753]

[749] Gusterson, 15.
[750] Whittle, *Predator*, 58.
[751] Singer, *Wired for War*, 216.
[752] Boyle, *The Drone Age*, 61.
[753] Valerie Insinna, "In the Fight against ISIS, Predators and Reapers Prove Close-Air Support Bona-Fides," Defense News, August 8, 2017, https://www.defensenews.com/smr/unmanned-unleashed/2017/03/28/in-the-fight-against-isis-predators-and-reapers-prove-close-air-support-bona-fides/.

Despite the demonstrated capabilities of drones in live combat, they still maintain a limited role in current U.S. doctrine, demonstrating the strength of the pre-existing martial knowledge. While U.S. Army and U.S. Air Force tactical level doctrines are restricted, U.S. Air Force operational level doctrine and NATO strategic concepts provide an adequate overview of the role drones play in the predominant U.S. military technology triad. Both of these official sources of doctrine explain armed drone strikes as secondary missions to the primary mission of Intelligence, Surveillance, and Reconnaissance (ISR) to the point where those sections that address drone strikes often assume that the drone is already tasked with an ISR mission.[754] The 2010 Strategic Concept of Employment for Unmanned Aircraft Systems in NATO is an exemplar of this trend when it explicitly states that strike missions "are usually conducted by the armed UA on an ISR sortie."[755] The U.S. military has good reason to resist fully integrating drones into important missions beyond the common critique that armed drones threaten a service staffed by pilots, which is a version of the 'militaries resist change' argument this dissertation explicitly rejects.[756]

Strike missions are an important component of the United States' way of war. Large operations rely on the successful completion of these missions, and the perceived limitations of drones as materiel solutions make them inappropriate to be solely, or even primarily, responsible for this mission. The U.S. Air Force annex on Operational Level Doctrine states unequivocally that drones "generally rely on a nearly continuous stream

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[754] "Air Force Doctrine Publication 3-03: Counterland Operations" (Curtis E. Lamay Center for Doctrine Development and Education, October 21, 2020), 45, https://www.doctrine.af.mil/Portals/61/documents/AFDP_3-03/3-03-AFDP-COUNTERLAND.pdf; "Strategic Concept of Employment for Unmanned Aircraft Systems in NATO" (Joint Air Power Competence Center, NATO, January 2010), 14.
[755] "Strategic Concept of Employment for Unmanned Aircraft Systems in NATO," 14.
[756] Singer, *Wired for War*, 119.

of communications for both flight and payload control."[757] The implication that this communications stream may not be guaranteed in combat against an adversary with the ability to interrupt it. Because today's drones rely on a communications link to perform their missions, the way the U.S. Air Force understands the drone's role in operations is driven by this materiel limitation. U.S. Airforce General Mike Hostage, then the chief of Air Combat Command, went as far as to explain in 2013 that "Predators and Reapers are useless in a contested environment," citing their vulnerability to enemy air defenses.[758] Two years later, a team of RAND researchers agreed with General Hostage about the vulnerability of drones to modern air defenses when they published a document titled "Armed Done Myth 1: They will Transform How War Is Waged Globally," in which they proclaimed that "If Iran tried to use an armed UAV to target Saudi Arabia, it would be unlikely to succeed because of sophisticated Saudi air defenses. This would be the case even if Iran developed a high capacity to use drone platforms."[759]

These statements related to the limited capabilities of drones are best understood as reflections of the U.S. military's knowledge system rather than some statement about an objective truth. In September 2019, Iran conducted exactly the type of attack that the RAND researchers claimed was "unlikely to succeed," even with advances in drone capabilities, when Iranian back militias launched a drone attack against Saudi-owned oil refineries.[760] The role of chance in the conduct of war is well established, so there is a

[757] "Air Force Doctrine Publication 3-0: Operations and Planning" (Curtis E. Lamay Center for Doctrine Development and Education, November 4, 2016), 150–51, https://www.doctrine.af.mil/Portals/61/documents/AFDP_3-0/3-0-AFDP-OPERATIONS-PLANNING.pdf.
[758] Reed, "Predator Drones 'Useless' in Most Wars, Top Air Force General Says."
[759] Lynn E. Davis, Michael J. McNerney, and Daniel Byman, "Armed Drone Myth 1: They Will Transform How War Is Waged Globally," February 17, 2015, https://www.rand.org/blog/2015/02/armed-drone-myth-1-they-will-transform-how-war-is-waged.html.
[760] Humeyra Pamuk, "Exclusive: U.S. Probe of Saudi Oil Attack Shows It Came from North - Report," *Reuters*, December 20, 2019, https://www.reuters.com/article/us-saudi-aramco-attacks-iran-exclusive-

possibility that the Iranian-backed militias caught a lucky break.[761] However, in January 2021, another drone attack launched by Iranian-backed militias in Iraq managed to penetrate the Saudi air defenses and strike the Saudi Royal Palace.[762] These incidents do not necessarily invalidate General Hostage's remarks about the vulnerability of the U.S. military's drones. Senior U.S. generals have publicly acknowledged that Russian private military contractors likely shot down a U.S. drone using a Russian Pantsir-S1 surface-to-air missile in Lybia in November 2019.[763] Nor is it particularly important that a single document from a pair of RAND researchers was demonstrably incorrect in their assessment of Saudi Arabia's threat from Iranian drones. However, this incident does demonstrate that the martial knowledge that posits the absolute vulnerability of drones might be a reflection of the influence of the U.S. military's doctrine and materiel rather than a truth common to a wide range of shared realities.

Reflections of the U.S. military's drone martial knowledge can also be seen in the decisions its leaders make related to which materiel solutions to field. If the reliance on continuous communications is the primary shortfall of armed drones in certain types of combat, increasing the autonomy of the drones is a possible solution. The requisite engineering knowledge to build drones that can conduct certain types of autonomous

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idUSKBN1YN299; Ben Hubbard, Palko Karasz, and Stanley Reed, "Two Major Saudi Oil Installations Hit by Drone Strike, and U.S. Blames Iran," *The New York Times*, September 14, 2019, sec. World, https://www.nytimes.com/2019/09/14/world/middleeast/saudi-arabia-refineries-drone-attack.html.

761 Sun-Tzu and Clausewitz, *The Book of War*.

762 Qassim Abudul-Zahara, "Recent Drone Attack on Saudi Royal Palace Launched from Iraq," AP NEWS, February 25, 2021, https://apnews.com/article/yemen-iran-saudi-arabia-riyadh-middle-east-ab3a83c9090c31f772bad7556bd482f1.

763 Stephen J. Townsend, "Statement of General Stephen J. Townsend, United Staties Army Commander United States Africa Command Before the Senate Armed Services Committee" (Written transcript of testimony, January 30, 2020), 4, https://www.armed-services.senate.gov/imo/media/doc/Townsend_01-30-20.pdf; Garrett Reim, "Record Number of UAV Shoot Downs Prompt New USAF Tactics and Countermeasure Pod," Flight Global, June 30, 2020, https://www.flightglobal.com/military-uavs/record-number-of-uav-shoot-downs-prompt-new-usaf-tactics-and-countermeasure-pod/138908.article.

engagements has been available in the United States since at least the 1980's when the U.S. Navy fielded the now retired Tomahawk Anti-Ship Missile with its automated search and destroy function.[764] However, increasing the autonomy of drones is counter to deeply held values related to the use of force and the requirement to protect innocent life.[765] Even the way senior leaders discuss terms like "UAV" and "drone" emphasizes the important role humans play in the conduct of drone strikes and is a reflection of the most appropriate way to employ drones in combat.

Beyond limiting the capabilities of drones, a martial knowledge that views drones as a materiel solution that is very effective at targeted strikes in uncontested airspace but "useless" against air defenses implies that the correct form of drones should be large, few, and highly capable for long range ISR and limited strike missions. In January 2014, Robert Work wrote a report that highlighted the importance of increasing the numbers of drones in the U.S. military by focusing on smaller, cheaper, less capable systems.[766] When Work became the Deputy Secretary of Defense later that year, he was unable to overcome the established martial knowledge of what drones were for. The U.S. Air Force actually ended up retiring the Predator drone for the much larger and more expensive Reaper drone the year after Work left office in 2018.

The two technology triads, with their common materiel element, related to armed drones in the U.S. military reflect competing realities about the best way to wage a war with drones. If the level of resources allocated to each reality are indicative of their

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[764] Scharre, *Army of None,* 49.
[765] Scharre, *Army of None*.
[766] Robert O. Work and Shawn Brimley, "20YY: Preparing for War in the Robotic Age" (Center for New American Security, January 22, 2014), https://s3.us-east-1.amazonaws.com/files.cnas.org/documents/CNAS_20YY_WorkBrimley.pdf?mtime=20160906082222&focal=none.

relative strength, the new concept of how the U.S. military should fight wars has yet to gain parity with the pre-existing one. New armed drones, while capable of employment for strike missions, are optimized for traditional ISR missions in support of manned aircraft and ground maneuver. The U.S. military has subjugated the success of the new armed drone reality demonstrated in Iraq and Afghanistan to only those wars against adversaries with limited materiel resources. The U.S. military has developed new concepts, materiel, and doctrine related to armed drones for specific types of war, but at the national level, the armed drone has not created a new reality to the degree to displace the previous reality and qualify as a military innovation as defined by the technology triad. The United States introduced armed drones to the world and demonstrated a way that they can achieve certain strategic objectives. Other nations observed these developments and filtered them through their own external epistemologies to update their local martial knowledge.

**Russia and Armed Drones**

Analysis of the Russian technology triad in the period following the first armed drone is simultaneously less complex than the U.S. technology triad's evolution and more difficult to discern exactly what changes occurred in Russia during this time. The Russian case is more straight forward because it is a case of lagging materiel behind a martial knowledge that updated largely in response to external epistemologies induced by combat. However, the Russian concept of "maskirovka" introduces an additional layer of difficulty that one must account for. Maskirovka is a Russian term with no direct English equivalent that signals a concept related to deception, secrecy, and camouflage.[767] The term dates back to at least 1380 AD and is much more than a military tactic; it is woven into the very fabric of their martial knowledge.[768] This means that any information related to the development of new weapons or capabilities must be carefully scrutinized. For example, Russia routinely releases information about fantastic, often fully automated, weapons systems that are at best in their conceptual phase of development.[769] The technology triad helps wade through the sea of Russian disinformation with its focus on fielded equipment as a unit of analysis within the model. By discarding announcements of weapons systems with a more probable purpose of misleading potential adversaries than the free exchange of information, a picture of the Russian armed drone development emerges that indicates their systems are just recently achieving the level of sophistication that the United States' systems demonstrated almost two decades ago. However, the identification of a local reality using the technology triad helps illustrate that the Russian technology triad is simply different from the one in the United States rather than less "technologically advanced."

### *The Georgian Invasion and a Shift in Martial Knowledge*

In August 2008, Russia used a military exercise as a pretext to build an invasion force up on their southern border with Georgia, then surprised the world with a massive

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[767] Charles L. Smith, "Soviet Maskirovka," *Airpower Journal AFRP 50-2* Vol. II, no. No. 1 (Spring 1988): 30.

[768] Smith, 30.

[769] The sustained publicity campaign around the T-14 and its supposed autonomous capabilities is a good example of this Kelsey D. Atherton, "Russia Prepares Robot Tank For Fighting Drones," Forbes, July 23, 2020, https://www.forbes.com/sites/kelseyatherton/2020/07/23/russia-prepares-robot-tank-for-fighting-drones/.

ground invasion supported by aircraft.[770] While the outcome of the war was decisive, Russia's military failed to perform at the level that would be necessary for them to compete on the modern battlefield. One of the Russian military's many shortcomings in the war, their small observation drones were "virtually inoperable" due to low image quality, high acoustic signature, and low flight level.[771] While opposing the Russians, the Georgian military employed state-of-the-art Israeli-made Hermes-450s, which were similar to the United States' Predator drone without the missiles, to great effect.[772] Demonstrating an external epistemology, through the observation of Georgian drones, the Russians updated their martial knowledge to accept as truth that drones to provide intelligence for maneuvering ground units and targeting information for artillery were an important part of modern combat.

Rather than wait for Russian industry to gain the capability to produce drones domestically to replace their inadequate models, the Russian Ministry of Defense purchased Israeli drones in 2009.[773] Relying on Israel to provide Russian drones was not favorable for the Russians because the United States exerted diplomatic pressure on the Israelis to restrict Russian access to certain types of drones.[774] In 2011, Russia announced that they would undertake domestic production of drones with the intent of fielding three classes of drones, a Predator style drone, a larger Reaper style drone, and an even larger

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770 Michael Kofman, "The August War, Ten Years On: A Retrospective on the Russo-Georgian War," *War on the Rocks* (blog), August 17, 2018, https://warontherocks.com/2018/08/the-august-war-ten-years-on-a-retrospective-on-the-russo-georgian-war/.
771 Dan Gettinger, "The Drone Databook" (The Center for the Study of the Drone at Bard College, September 2019), 69, https://dronecenter.bard.edu/projects/drone-proliferation/databook/.
772 Nicholas Clayton, "How Russia and Georgia's 'little War' Started a Drone Arms Race," The World from PRX, October 23, 2012, https://www.pri.org/stories/2012-10-23/how-russia-and-georgias-little-war-started-drone-arms-race.
773 Isabell Facon, "A Perspective on Russia" (Center for New American Security, May 2016), http://drones.cnas.org/reports/a-perspective-on-russia/.
774 Boyle, *The Drone Age*, 252.

stealth drone, all by 2020.[775] Ramping up domestic production, however, was slow, and Russia was forced to source components from foreign industry.[776] This demonstrates how the material lag in a military's technology triad is not just the weapons but also the components of the weapons and the machines to build those components. In 2013, Russia created the 924 State Unmanned Aviation Center (924 HZ BPA) to unify national efforts related to drone development. Prior to this move, "various governing bodies" were involved, and they each had their own competing interests in the development of drones.[777] In terms of the technology triad, the Russian system prior to 2013 allowed the decentralized development of multiple technology triads, but none of them possessed the requisite resources to field an adequate materiel solution completely.

***Reflections of the Russian Martial Knowledge***

The 924 HZ BPA manages all three elements of the Russian drone technology triad. The unit oversees the development of materiel solutions, trains all drone operators in Russia, and develops the martial knowledge related to drones for the Russian military.[778] If ISR missions with limited strike capabilities are the defining characteristic of the U.S. drone martial knowledge, then the Russian drone martial knowledge is

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[775] Facon, "A Perspective on Russia."
[776] Gary Mortimer, "A Russian Drone with a Complicated History," *SUAS News - The Business of Drones* (blog), August 11, 2011, https://www.suasnews.com/2011/08/a-russian-drone-with-a-complicated-history/; Tyler Rogoway and Thomas Newdick, "Russia's Predator-Style Drone With Big Export Potential Has Launched Its First Missiles," The Drive, December 28, 2020, https://www.thedrive.com/the-war-zone/38446/russias-predator-style-drone-with-big-export-potential-has-launched-its-first-missiles.
[777] "A Collection of Articles Following the Results of the Scientific and Practical Conference 'Prospects for the Development and Application of Complexes with Unmanned Aerial Vehicles 2017'" (924 State Unmanned Aviation Center, Russian Defense Ministry, 2017), 8, https://mil.ru/924gcba/reports.htm translated from Russian to English with Google translate.
[778] "A Collection of Articles Following the Results of the Scientific and Practical Conference 'Prospects for the Development and Application of Complexes with Unmanned Aerial Vehicles 2017.'"

defined by the drones ability to directly support “the concentrated use of artillery and rocket artillery along with large tank units,” which “remains at the core of Russian military doctrine” according to an August 2020 Congressional Research Service report on Russian doctrine.[779] Comments by the Russian Deputy Minister of Defense in December 2020 support this assertion when he said, the “widespread use of small UAVs allows to reduce the use of ammunition to defeat targets, to increase flexibility and speed of use of artillery.”[780] This understanding of the most appropriate use of drones reflects the knowledge produced at the 924 HZ BPA.

In 2016 and 2017, the Russian State Unmanned Aviation Center held a series of conferences with topics that ranged from the engineering knowledge required to develop drones capable of operating in the contested electromagnetic environment of the modern battlefield to the doctrinal employment of drones.[781] The topics addressed, the content of those addresses, and the people who presented them all illustrate the state of the Russian drone martial knowledge at that time. For example, a presentation titled “Works on the creation of the research unmanned aircraft in VUNC Air Force” delivered by the head of research for the 924 HZ BPA explained how the

> “purpose of the [experimental] complex [is the] experimental studies of various onboard equipment and loads; development of innovative ideas and technologies in the field of UAVs: new ways [of] optoelectronic, television and thermal imaging reconnaissance, promising methods of

779 Andrew S. Bowen, “Russian Armed Forces: Military Doctrine and Strategy,” In Focus (Congressinoal Research Service, August 20, 2020).
780 Alexey Krivoruchko, “Оружие России опережает время — ‘Красная звезда’ (Russia’s Weapons ahead of time),” *Red Star*, December 30, 2020, http://redstar.ru/oruzhie-rossii-operezhaet-vremya/ translated from Russian to English with the Microsoft Edge browser plug-in.
781 “A Collection of Articles Following the Results of the Scientific and Practical Conference ‘Prospects for the Development and Application of Complexes with Unmanned Aerial Vehicles 2016’” (924 State Unmanned Aviation Center, Russian Defense Ministry, 2016), https://mil.ru/924gcba/reports.htm translated from Russian to English using Google Translate; “A Collection of Articles Following the Results of the Scientific and Practical Conference ‘Prospects for the Development and Application of Complexes with Unmanned Aerial Vehicles 2017’” translated from Russian to English using Google Translate.

> automatic autonomous landing, information interaction with manned and unmanned aerial vehicles; performance of research work to substantiate the requirements for promising complexes with UAVs."[782]

Reconnaissance and information sharing is the focus of this list of "innovative ideas and technologies." The presenter did not mention any research related to strike capabilities for their drones. This is an internal epistemology that accounts for the domestic production of drones, but the same emphasis on reconnaissance can be seen in the way that the presenters at the same conference addressed foreign uses of drones.

Similar to the way that the U.S. cavalry emphasis on the Polish employment of large horse cavalry units was more of a reflection of the importance of horses in the U.S. Army's martial knowledge in the 1930s than an unbiased appraisal of the status of the Polish cavalry, Russian military science professors' emphasis of the link between drones and artillery is a reflection of their martial knowledge in their external epistemologies.[783] In 2016, a professor at the Russian military academy asserted that "one of the most important tasks assigned to complexes with UAVs during armed forces of foreign countries is the service of artillery subunits when performing a fire mission as a target designation means and adjustments."[784] In this same lecture series, a professor of military sciences gave a presentation on the development of electromagnetic warfare operations in foreign countries where he explained that "the most important directions for the

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[782] A. M. Ageev, A.S. Popov, and I. V. Makarov, "Works on the Creation of the Research Unmanned Aircraft in VUNC Air Force," in *A Collection of Articles Following the Results of the Scientific and Practical Conference* (Prospects for the development and application of complexes with unmanned aerial vehicles 2016, 924 State Unmanned Aviation Center, Russian Defense Ministry, 2016), 10, https://mil.ru/924gcba/reports.htm translated from Russian to English using Google Translate.
[783] Herr, "The Cavalry," September 19, 1938, 5.
[784] A. I. Kalnov, "Application of Air Survey Complexes for Artillery Shooting Service," in *A Collection of Articles Following the Results of the Scientific and Practical Conference* (Prospects for the development and application of complexes with unmanned aerial vehicles 2016, 924 State Unmanned Aviation Center, Russian Defense Ministry, 2016), 102, https://mil.ru/924gcba/reports.htm translated from Russian to English using Google Translate.

development of UAVs are the creation of new generation reconnaissance and strike systems intended for solving problems of suppressing the enemy's air defense system."[785] Although the google translate provides the word "strike" for this lecture, the context of the speech makes it clear that the speaker intended to address electromagnetic attack capabilities rather than kinetic strikes with missiles or bombs. Both of these speakers observed the development of drones in other countries, presumably the United States and Israel, and drew the conclusion that the most important developments were related to the integration of drones with kinetic artillery and non-kinetic fires, or electromagnetic attacks. The first speaker addressed the current state of drones in foreign armies, and the second adopted a future-oriented approach with "directions of development," but neither of them highlighted the role of armed drones in the conduct of modern war. This demonstrates the Russian military's external epistemology in work as they interpret observations from outside their technology triad through the lens of their own martial knowledge. The Russians were aware of other uses for armed drones, but they discounted them.

International demonstrations of the effectiveness of armed drone strikes did not fit with the Russian martial knowledge emphasis on integration with artillery units, so the Russians constructed logical explanations for why these developments were less relevant. In the 2017 924 HZ BPA conference on development and application of drones, the senior researcher for the center of studies of military potential of foreign countries

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[785] S.V. Golubev and V.C. Kiryanov, "On Approach to Training in Higher Military Education Institution of Radio-Electronic Fighting Specialists Unmanned Aircraft Control Systems Apparatus and Robotic Equipment [in] Foreign Arm[Ies]," in *A Collection of Articles Following the Results of the Scientific and Practical Conference* (Prospects for the development and application of complexes with unmanned aerial vehicles 2016, 924 State Unmanned Aviation Center, Russian Defense Ministry, 2016), 116, https://mil.ru/924gcba/reports.htm translated from Russian to English using Google Translate.

highlighted the United States' use of drones in targeted strikes in the fight against ISIS.[786] However, a subsequent speaker at this same conference provides three maxims for the most effective employment of drones, in which the third maxim is that a military should only use drones when they are absolutely necessary, such as when the enemy has effective air defense systems.[787] This maxim is interesting in terms of the technology triad for a number of reasons. First, it is directly contrary to the effective use of drones in counter terrorism operations where the enemy air defense environment is very permissive. Second, this is an example of a materiel to martial knowledge link, because only in a military that possesses an adequate number of manned aircraft would such a statement make sense. Finally, the speaker references a quantitative study in his written remarks that, according to him, prove that "not in *all* cases of UAVs turns our [sic] to be more effective than conventional strike aircraft" (emphasis added). [788] However, the data he cites is a weighted efficiency for drones vs. manned aircraft in the range from 0.8 to 2.2, which seems to imply that there are situations where drones are more than twice as effective as manned aircraft by the Russian's own data.[789] It is almost as if he is referring to hard data that demonstrates the advantages of drones but draws the exact opposite conclusion to align with the existing martial knowledge in the Russian military. Even if

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[786] D.G. Astahkin, "Conceptual Views of the United States Air Force Command on Development of Unmanned Aircraft," in *A Collection of Articles Following the Results of the Scientific and Practical Conference* (Prospects for the development and application of complexes with unmanned aerial vehicles 2017, 924 State Unmanned Aviation Center, Russian Defense Ministry, 2017), 185, https://mil.ru/924gcba/reports.htm translated from Russian to English using Google Translate.

[787] I. N. Lyalyuk, "The Main Tasks of Automation of Application Processes Unmanned Aircraft Systems," in *A Collection of Articles Following the Results of the Scientific and Practical Conference* (Prospects for the development and application of complexes with unmanned aerial vehicles 2017, 924 State Unmanned Aviation Center, Russian Defense Ministry, 2017), 242–43, https://mil.ru/924gcba/reports.htm translated from Russian to English using Google Translate.

[788] Lyalyuk, 243 translated from Russian to English using Google translate.

[789] Lyalyuk, 243.

the true meaning of this chart is obscured by the translation from Russian to English, the experimental data to support a claim that drones are not as effective as manned aircraft for strike missions is a strong example of an internal epistemology in action.

Russian values, or the absence of those that are present in other nations that are developing armed drones, played an integral role in the execution of these external and internal epistemologies to support the martial knowledge that drones are best employed on ISR missions for artillery and in support of manned aircraft. In the United States, the reduction of collateral damage significantly influenced both the decision to develop armed drones and the doctrine with which they would be employed. In contrast, the Russian military does not place such great importance on avoiding the killing of non-combatants.[790] Despite Russian President Vladimir Putin's accusation that the United States employs its drones unethically when he said in 2013 that drones "are finding an increasingly wide use all over the world, but we are not going to operate them as other countries do. It is not a video game," Russia's recent combat record demonstrates that they are much more willing to kill civilians than the United States.[791] In fact, Russia has deliberately targeted civilians in Syria, a doctrine they employed with ruthlessness in Chechnya.[792] Russia's willingness to destroy civilian infrastructure and acceptance of the

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[790] Boyle, *The Drone Age*, 252.

[791] Quoted in "Putin Says Drones Aren't Toys, Russia Won't Use Them like Other Nations," Russian Official News Releases/Proganda facing towards the international community, RT International, November 28, 2013, https://www.rt.com/news/putin-drones-not-toys-457/.

[792] Arkady Babchenko, *One Soldier's War*, trans. Nick Allen (New York: Grove Press, 2009); Belkis Wille, "Why Are Russians Paying for Bombing Schools in Syria?," Human Rights Watch, December 17, 2020, https://www.hrw.org/news/2020/12/17/why-are-russians-paying-bombing-schools-syria; Nick Cumming-Bruce, "U.N. Panel Says Russia Bombed Syrian Civilian Targets, a War Crime," *The New York Times*, March 2, 2020, sec. World, https://www.nytimes.com/2020/03/02/world/middleeast/united-nations-syria-idlib-russia.html; Boyle, *The Drone Age*, 252; Maksymilian Czuperski et al., *Breaking Aleppo*, 2017, http://www.publications.atlanticcouncil.org/breakingaleppo/wp-content/uploads/2017/02/BreakingAleppo.pdf.

corresponding collateral damage is so extreme that the Russian Defense Ministry posted a video online in February 2021 to demonstrate the effectiveness of one of their surface-to-surface missiles; the target was a civilian hospital in Syria.[793] Absent a set of values that place the avoidance of unnecessary civilian casualties, such as those that were present in the United States military, Russian martial knowledge focused on the role that drones could play in ISR missions rather than their possibility as a materiel solution to reduce human suffering.

### *Another Shift in Russian Martial Knowledge*

With a martial knowledge that emphasizes the integration of drones with artillery and does not place special importance on reducing the levels of collateral damage those artillery strikes can produce, the influence on Russian drones as a materiel solution shifted development away from armed drones of the type that the United States developed. A decade after the disappointing performance of Russian drones in Georgia, the Russians faced another embarrassing external epistemology that rapidly shifted their martial knowledge related to drones. From 2017-2019, Syrian rebels attacked Russian military bases in Syria with homemade drones packed with explosives (See Figure 9).[794] The state-of-the-art electromagnetic drone countermeasures and air defense systems destroyed many of the drones, but some number of them still struck their targets and

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[793] Samir, "Geolocation of an Alleged Russian Iskander Missile Strike on Azaz Hospital," Tweet, *@obretix* (blog), February 25, 2021, https://twitter.com/obretix/status/1364986455383281667 This source is judged reliable, despite the anonymous quality of the account from which it was posted, because of the detailed and verifiable photographic evidence posted.

[794] Ridvan Bari Urcosta, "The Revolution in Drone Warfare: The Lessons from the Idlib De-Escalation Zone," *The Air Force Journal of European, Middle Eastern, and African Affairs* Volume 02, no. Issue 03 (August 31, 2020), https://www.airuniversity.af.edu/JEMEAA/Display/Article/2329510/the-revolution-in-drone-warfare-the-lessons-from-the-idlib-de-escalation-zone/.

inflicted Russian casualties.[795] This was an important development for the Russian martial knowledge because the employment of suicide drones as kinetic weapons was outside the Russian drone technology triad at the time, and their defenses were unable to fully compete in the new shared reality between the Russians and the Syrian rebels. Then in February and March 2020, Turkey conducted an operation against the Syrian Army, Russia's ally, in Idlib, Syria, employing a pure drone fleet as attack aircraft because the Russians had effectively closed the airspace to Turkish jets.[796]


Figure 9: Homemade drones employed by Syrian rebels against the Russians in January 2018[797]

[795] Urcosta; Konstantin Bogdanov, "Дроны Сбиваются в Стаи | Статьи | Известия," *Izvestia*, January 11, 2018, https://iz.ru/693588/konstantin-bogdanov/drony-sbivaiutsia-v-stai translated from Russian to English using Microsoft Edge browser plug-in.
[796] Urcosta, "The Revolution in Drone Warfare."
[797] Bogdanov, "Дроны Сбиваются в Стаи | Статьи | Известия" translated from Russian to English using Microsoft Edge browser plug-in.

The Turkish drone offensive was an unqualified success, and the Russian military took notice. The Russians proved so unprepared to address the Turkish-made TB-2 drones that the Turks were able to destroy up to three Pantsir-S1 air defense systems, the type that had shot down a U.S. Predator in Libya several years earlier.[798] It is difficult to ascribe a direct causal relationship between the Turkish operation and an updated Russian drone martial knowledge. However, in December 2020, the Russians successfully launched a missile from an Orion drone, which had been fielded earlier in the year, for the first time, nearly two decades after the United States gained that capability.[799] Time will tell whether the Russians have truly updated their martial knowledge to account for the effectiveness of armed drones, which they experienced firsthand in Syria. But there are early indications that the Russian drone technology triad is in the development phase of innovation, with two of the three elements updated to address armed drones. Unlike the last time the Russians updated their drone martial knowledge, after the Georgian war, the Russians already have a materiel solution available and the autonomy domestically to modify it to align with a new reality. This gives them the potential to quickly modify and achieve innovation at a much faster pace than when they were reliant on Israel for their drone procurement.

**Israel and Armed Drones**

Israel's unique approach to military technology has had a profound impact on the development of drones internationally. From 2001 to 2011, Israel was responsible for

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[798] Urcosta, "The Revolution in Drone Warfare."

[799] "Российский беспилотник впервые применил управляемые ракеты," *РИА Новости (RIA Novosti)*, December 28, 2020, sec. Новости, https://ria.ru/20201228/bespilotnik-1591191802.html translated from Russian to English using Microsoft Edge browser pug-in.

41% of the world's drone exports.[800] Three factors have combined to make Israel a driver of innovation in this space. First, their defense forces are much smaller than either the United States or Russia's. This makes their technology triad much more nimble from an organizational standpoint. Second, the near-constant state of war that Israel has endured for much of its existence has shortened its epistemological cycles to produce a situation where Israel can test its martial knowledge in the reality in which that martial knowledge is intended to compete within a matter of months rather than the decades in some of the larger countries. Finally, civilian industry, especially the drone industry, maintains a different relationship with the Israeli Defense Forces (IDF) than in the other countries above. Within Israel, there are 50 companies producing 165 different types of drones for both domestic use and export.[801] The ready availability of different types of drones means that the material lag within the Israeli technology triad is much shorter, and the relative autonomy of the civilian drone industry creates a situation where the materiel element can and does drive changes to the other two elements of their technology triad. These differences from the previous two militaries make Israel a strong test of the generalizability of the technology triad, but the analysis is challenged by official IDF policy related to drones. The IDF maintains a policy of never publicly discussing the existence of armed drones in any way.[802] Despite this official policy, it is still possible to trace the outlines of the Israeli drone technology triad using industry announcements, historical data, and newspaper articles. The ability of the technology triad to provide

[800] Boyle, *The Drone Age*, 246.
[801] Frantzman, "How Israel Became a Leader in Drone Technology," *The Jerusalem Post | JPost.Com*, July 13, 2019, https://www.jpost.com/israel-news/how-israel-became-a-leader-in-drone-technology-595209.
[802] Aniseh Bassiri and Justin Bronk, "Armed Drones in the Middle East," Occasional Paper (London: Royal United Services Institute for Defence and Security Studies, December 2018), 16, https://drones.rusi.org/.

insights related to such a closed system further demonstrates its utility as an analytical tool in uncertain environments.

### ***Two Doctrines in Israel***

Israel's security environment is a mix of conventional and unconventional threats. On the one hand, Israel has fought several pitched wars against their neighbors over the last several decades that are characterized by the use of large formations of modern equipment on both sides. Israel has had to develop a doctrine to address these "force on force" type threats that can allow their military to compete against their neighbors with ground and air forces in concert for short sharp wars. Epitomized by the 1973 Yom Kippur war and the 1982 war with Lebanon, this first doctrine can be visualized as the one that includes combat aviation forces to destroy enemy formations and large numbers of tanks moving forward to secure territory.[803]

The second doctrine that Israel has developed, commonly referred to as "mowing the grass," is a doctrine with roots in a 1955 lecture by Moshe Dayan called "Reprisal raids as a means for ensuring peace."[804] Originally designed to create conventional deterrence against attacks from Israel's neighboring countries through the application of violence, Israel has increasingly used it to counter terrorist threats from non-state actors in Gaza.[805] The basic concept of the mowing the grass doctrine, as it has evolved, is that

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[803] Christopher Robin Lew, "Yom Kippur War: East-West Testing Ground," *Military History* 14, no. 4 (October 1998): 34; David T Zabecki, "A Line in the Sand," *Military History* 25, no. 2 (June 2008): 34–40.
[804] Yagil Henkin, "A High Price for Our Blood: Israel's Security Doctrines," 70 Years of Strategic Success, Special Series of Publications, The Jerusalem Institute for Strategy and Security, June 7, 2018, https://jiss.org.il/en/henkin-high-price-blood-israels-security-doctrines/; Gusterson, *Drone*, 24.
[805] Henkin, "A High Price for Our Blood."

the IDF moves into areas from which terrorists operate to conduct short punitive raids that kill senior terrorist leaders and throw their organizations into disarray.[806]

Mowing the grass is closely related to the tactic of targeted strikes, which Israel first conducted on New Year's Eve 2000, just months before the United States would fire the first missile from a drone.[807] Much like in the United States, Israel's campaign of targeted strikes was controversial domestically and internationally.[808] The Israeli High Court of Justice ruled that these targeted strikes were legal in 2006 but imposed strict limitations on their conduct, including a requirement to use the smallest weapon practicable.[809] The long flight time, low visual and acoustic signature, and small munitions made armed drones a perfect fit for the Israeli doctrine of mowing the grass and its associated marital knowledge. At some point, the exact date being a closely guarded state secret, the Israelis began employing their drones to "mow the grass" with the support of the Israeli population.[810]

***Development of Drones as a Materiel Solution in Israel***

Israel's drone designs were largely driven by the requirements of the two doctrines. In the aftermath of the 1973 Yom Kippur War with Egypt, Israel determined that their military needed the means to produce enhanced situational awareness on the

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[806] Efraim Inbar, "Mowing the Grass in Gaza - The Jerusalem Post," *The Jerusalem Post | JPost.Com*, July 22, 2014, https://www.jpost.com/Opinion/Columnists/Mowing-the-grass-in-Gaza-368516.
[807] Adam Stahl, "The Evolution of Israeli Targeted Operations: Consequences of the Thabet Thabet Operation," *Studies in Conflict & Terrorism* 33, no. 2 (January 21, 2010): 111–33, https://doi.org/10.1080/10576100903487065.
[808] Stahl; Boyle, *The Drone Age*, 64.
[809] Shahaf Rabi and Avery Plaw, "Israeli Compliance with Legal Guidelines for Targeted Killing," *Israel Law Review* 53, no. 2 (July 2020): 225–58, https://doi.org/10.1017/S0021223720000059.
[810] Uri Sadot, "A Perspective on Israel" (Center for New American Security, May 2016), http://drones.cnas.org/reports/a-perspective-on-israel/.

modern battlefield.[811] The first Israeli drones were a materiel solution intended to address the problem of dangerous aerial reconnaissance identified by a wider martial knowledge that posited large scale maneuver of mechanized units supported by tactical airpower was the best way to fight a war.[812] Employing an internal epistemology, the IDF developed the first drone systems to reliably conduct ISR missions in support of ground maneuver.[813] When the IDF tested these new systems for the first time in combat against Jordan in 1982, they discovered an unintended consequence of the new materiel solution.[814] The Israelis launched a large number of the new reconnaissance drones against Jordan to simulate a manned aircraft strike force in Operation Drug Store. When the Jordanians turned on their radars to engage what they thought was a flight of attack aircraft, the Israelis launched radar homing missiles to destroy the Jordanian air defense systems.[815] This external epistemology bifurcated the Israeli drone martial knowledge into two distinct roles roughly aligned with the two doctrines above.

One answer to "how best to employ drones" for the IDF was to recreate the effective destruction of enemy radar sites against a traditional military from the Jordanian war and is a reflection of the doctrinal influence of the force on force doctrine above on materiel. Free from the restrictions of the intermediate cruise missile treaty that limit the types of missiles the United States and Russia can develop, Israel introduced the Harpy

[811] Bassiri and Bronk, "Armed Drones in the Middle East"; Frantzman, "How Israel Became a Leader in Drone Technology."
[812] Lew, "Yom Kippur War: East-West Testing Ground"; Zabecki, "A Line in the Sand."
[813] Frantzman, "How Israel Became a Leader in Drone Technology."
[814] Frantzman.
[815] Charlie Gao, "The Ultimate Weapon of War No One Is Talking About," The National Interest (The Center for the National Interest, January 25, 2019), https://nationalinterest.org/blog/buzz/ultimate-weapon-war-no-one-talking-about-42497.

loitering munition in 1990.[816] The Harpy launches from a canister on a ship or a truck and flies a pre-set pattern waiting for an enemy air defense radar to paint it. Once the Harpy detects a radar, it turns into a homing anti-radiation missile that destroys the air defense system.[817] The first Harpies do not fit the definition of a drone as outlined at the beginning of the chapter. Once the Harpy is launched, it can not be controlled from the ground; it is more appropriately termed a "loitering munition."[818] In 2009, the Israelis updated the Harpy design with the IAI Harop, also called the Harpy II at times.[819] The Harop increased the capabilities of the Harpy with the addition of a camera and data link to control the drone in flight. Additionally, the Harop can be recovered after a mission, making it more of a "suicide drone" than a simple loitering munition.[820] Most recently, Israeli Elbit Systems introduced the Skystriker in 2016, which is a smaller version of the Harop that requires a user-designated target rather than radar homing and employs an electric motor to reduce its acoustic signature.[821] The Skystriker represents the current pinnacle of materiel solutions to address problems identified by the martial knowledge that posits drones are effective weapons as flying missiles to improve "performance, situational awareness and survivability by providing direct-fire aerial-precision

[816] Dan Gettinger and Arthur Holland Michael, "Loitering Munitions In Focus" (The Center for the Study of the Drone at Bard College, 2017), https://dronecenter.bard.edu/files/2017/02/CSD-Loitering-Munitions.pdf; Amy F. Woolf, "Russian Compliance with the Intermediate Range Nuclear Forces (INF) Treate: Background and Issues for Congress," CRS Report Prepared for Members and Committees of Congress (Congressinoal Research Service, August 2, 2019).

[817] "Fire and Forget : Harpy Is an Autonomous Weapon for All Weather," Manufacturer's Website, IAI, accessed June 6, 2021, https://www.iai.co.il/p/harpy.

[818] "Harop Loitering Munitions UCAV System - Airforce Technology."

[819] "Loitering Munitions : HAROP - Electro-Optically Guided Attack Weapon," accessed May 26, 2020, https://www.iai.co.il/p/harop; Gettinger and Michael, "Loitering Munitions In Focus."

[820] "Harop Loitering Munitions UCAV System - Airforce Technology."

[821] Gettinger and Michael, "Loitering Munitions In Focus"; Sebastian Sprenger, "Elbit Systems Pitches SkyStriker Drone in Emerging Market of Loitering Munitions," June 21, 2017, https://www.defensenews.com/digital-show-dailies/paris-air-show/2017/06/21/elbit-systems-pitches-skystriker-drone-in-emerging-market-of-loitering-munitions/; "Skystriker - Elbit Systems," Manufacturer's Website, Elbit Systems, accessed June 6, 2021, https://elbitsystems.com/product/skystriker/.

capabilities to maneuverable troops and Special Forces," in the words of the Skystriker's manufacturer.[822]

Parallel to developments in loitering munitions, or suicide drones depending on their capabilities, Israeli companies made great strides in armed drones that fire missiles to support both the force on force and the mowing the grass doctrines. From the first Zahavan "Scout" drones in the 1982 war with Lebanon through today, Israel has produced numerous models of drones with steadily improved performance in terms of endurance and ISR capabilities to support maneuver in large battles and ISR for target identification in targeted strikes.[823] Despite the official policy of never publicly discussing the use of armed drones, the Israelis have disclosed the fielding of three models of drones that can conduct strike missions with missiles.[824] The IDF drone fleet remains quite small, with no more than 60 drones capable of firing a missile fielded by 2018.[825] The variety within such a small force demonstrates that the IDF is rapidly integrating new materiel solutions into their technology triad to support their martial knowledge and doctrine as they evolve.

### *A Mixed Performance for the Technology Triad*

Israel, as a test of generalizability, stretches the ability of the technology triad to understand how the IDF and drones are changing together. The shifts in the IDF's approaches to drones defy a simple application of the technology triad. Aspects of the technology triad do emerge. For example, the values of preventing civilian and aircrew

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[822] "Skystriker - Elbit Systems."
[823] Frantzman, "How Israel Became a Leader in Drone Technology."
[824] Bassiri and Bronk, "Armed Drones in the Middle East."
[825] Bassiri and Bronk.

casualties influence on the martial knowledge to use drones for mowing the grass and the unintended consequences of the radar drones in 1982. But these are not the large descriptive reflections of the technology triad that are present in the other cases in this dissertation. Part of the reason could be because the IDF severely limits the information they share related to the employment of armed drones. There is also, however, an explanation for the limited interactions between the martial knowledge and the materiel elements, beyond the values influence and the unintended consequences of the radar drones, within the structure of the technology triad. Israel’s wide range of materiel solutions available due to the extensive drone industry and their autonomy combined with the IDFs small size could compress the difference in the rates of change within the technology triad to the degree that they are difficult to identify. Additionally, materiel solutions like the Harop drone blur the lines between different mission profiles, with the capability to collect intelligence, conduct anti-radar homing strikes, and conduct attacks against operator-designated targets. The multi-role capability of the Harop makes it especially useful for a number of different martial knowledges and doctrines, and probably qualifies the weapon as an innovation for the company that produces it with the goal of turning a profit. However, this inability to clearly link Israel’s most advanced drones to a specific martial knowledge or doctrine makes it difficult to identify the ways that the elements of the technology triad are interacting with the limited information available.

Even with the limited application of the technology triad to Israel, one can still describe the developments in the IDF related to drones within the bounds of the technology triad. Essentially, the IDF has produced two distinct new material solutions, armed drones and suicide drones, but has not adjusted their national level martial knowledge or doctrine to align with the new materiel solutions. Israel's way of employing their drones is additive to the large-scale maneuver doctrine and the targeted strike doctrine that existed before the materiel solutions. One could make the case that the mowing the grass doctrine as intelligence and airpower enabled targeted killing to prevent larger wars is an innovation in its own right. However, the role of the drone in this innovation is likely secondary and is the purpose of this case study. If the influence of Israel's drones on its technology triad was limited, the influence of Israeli drones on Azerbaijan's technology triad was profound.

**Azerbaijan and Drone Innovation**

The information available on Israel's use of armed drones was limited by the official policy of the Israeli government. In the case of Azerbaijan, information related to the employment of armed drones is limited by the lack of data available to conduct the research upon which this dissertation is built. However, Azerbaijan did fight a war with their neighbor Armenia in 2016, then again in the fall of 2020. The well-documented conduct of these two wars, along with news reports of Azerbaijani arms deals, provide enough data from which to analyze the progress of the Azerbaijani technology triad over time in relation to internal and external epistemologies in a military where there is little open-source material. Of the four militaries addressed in this chapter, only Azerbaijan has completed all three phases of military innovation related to the employment of armed drones.

### *Aligning the Technology Triad*

In 2016, Armenia and Azerbaijan fought a short war over the Nagorno-Karabakh (N-K) region.[826] At the time, this region had been occupied by Armenia following a bloody 1991-1994 war between the two nations.[827] The Azerbaijanis shared a reality in which the occupation of the N-K region was illegal, and the Armenians lived in a shared reality where the region was part of Armenia. When the two nations could not resolve their differences below the level of violence, they resorted to a higher reality that they both shared and employed military force to determine which of the two nations' realities was the most appropriate. In the 2016 war, both sides employed their aging Soviet weapons in line with their traditional doctrine, and Armenia's reality, as the defender of the territory in question, proved to be the most appropriate one.[828] Compared to the war that would break out four years later, the action was relatively minor. The most notable event of the war in the larger arc of this story was the use of a single IAI Harop suicide drone by the Azerbaijanis to destroy a bus carrying Armenian soldiers.[829] Having witnessed the demonstrated abilities of this new material solution, the Azerbaijanis updated their martial knowledge and purchased more loitering munitions.[830]

Four years later, the Turkish military employed their TB-2 drone to great effect in Syria. Turkey was able to execute the autonomy available to a nation of its size to domestically produce a new materiel solution with only limited parts from foreign

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[826] Aleksandra Jarosiewicz and Maciej Falkowski, "The Four-Day War in Nagorno-Karabakh," OSW Centre for Eastern Studies, April 6, 2016, https://www.osw.waw.pl/en/publikacje/analyses/2016-04-06/four-day-war-nagorno-karabakh.
[827] Jarosiewicz and Falkowski.
[828] Jarosiewicz and Falkowski.
[829] Anna Ahronheim, "Israel's Elbit Systems Sells Azerbaijan SkyStriker Suicide Drone," *The Jerusalem Post | JPost.Com*, January 11, 2019, https://www.jpost.com/israel-news/israels-elbit-systems-sells-azerbaijan-skystriker-suicide-drone-577053.
[830] Ahronheim; Gettinger and Michael, "Loitering Munitions In Focus."

industry and had this system on hand when they needed it to conduct operations in Syria.[831] In 2018, the Russians were allied with the Syrian military and maintained an air defense posture over Idlib that prevented the Turkish Air Force from operating in Syria safely.[832] With the inability to employ manned aircraft using a more traditional doctrine, Turkey employed their fleet of armed TB-2s as a replacement for the manned attack aircraft. The revolutionary doctrine worked, and the Turkish military achieved its objectives.[833] The Azerbaijanis maintain a close relationship with the Turkish military and witnessed the events over Syria, just as the rest of the world did. Having already adopted a martial knowledge that accepted the importance of using drones as attack assets against a wide range of targets after their 2016 war with Armenia, the Azerbaijani military adopted the doctrine demonstrated by Turkey in Syria. The ability to witness the success of Turkey and incorporate it into the Azerbaijani technology triad is an example of their external epistemologies at work. Likely adding to their perceived value of the new Turkish doctrine, the Azerbaijani military only maintained a small number of manned attack aircraft.[834] This put the Azerbaijani military in a similar situation as the

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[831] "Akinci PT-2: A new addition to Turkey's drone inventory," BaykarSavunma, March 16, 2021, https://www.baykarsavunma.com/haber-Akinci-PT-2-A-new-addition-to-Turkeys-drone-inventory.html; "BAYKAR Unmanned Aerial Vehicle Systems | HISTORY," accessed June 6, 2021, https://baykardefence.com/History.html; "Bayraktar TB2," BAYKAR Unmanned Aerial Vehicle Systems, accessed June 6, 2021, https://baykardefence.com/uav-15.html; Owen Phillips, "Cessation of Supply to Baykar Makina Sanayi ve Ticaret A.S," Letter from Andair Ltd. to Baykar, January 11, 2021, https://twitter.com/CivilNetTV/status/1349243020592508930/photo/1.

[832] Ali Bakeer, "The Fight for Syria's Skies: Turkey Challenges Russia with New Drone Doctrine," Middle East Institute, March 26, 2020, https://www.mei.edu/publications/fight-syrias-skies-turkey-challenges-russia-new-drone-doctrine; Urcosta, "The Revolution in Drone Warfare."

[833] Bakeer, "The Fight for Syria's Skies"; Urcosta, "The Revolution in Drone Warfare."

[834] International Institute for Strategic Studies, *The Military Balance. 2019: [The Annual Assessment of Global Military Capabilities and Defence Economics]. 2019 : [The Annual Assessment of Global Military Capabilities and Defence Economics* (London: Routledge for The International Institute for Strategic Studies, 2019), 186.

Turkish military in the way that both countries lacked the ability to employ manned aircraft to achieve their desired objectives, just for different reasons.

By early 2020, the Azerbaijanis had updated two of the three elements of their technology triad. The Azerbaijani approach to integrating drones into its military is unique amongst the cases presented here. The Azerbaijani military started buying drones from Israel as early as 2011.[835] Each of the models of drones that Azerbaijan purchased was either capable of carrying missiles or were themselves loitering munitions.[836] The other three nations in this chapter started out with observation drones then progressed to armed drones. This jump straight to armed drones demonstrates that the martial knowledge that armed drones are an important part of modern war, perhaps even more important than their capabilities as an ISR platform, was already present in 2011. However, the conduct of the 2016 war shows that the martial knowledge at the time was not aligned with a full technology triad to capitalize on the capabilities of armed drones. Somewhere between the 2016 war and the Turkish operation over Syria, the Azerbaijani military fully updated its martial knowledge to embrace a fundamentally different role for drones in combat. But they lacked the domestic industrial capacity to quickly build the materiel solutions to align with the new martial knowledge and doctrine, which had been employed in Syria. In order to shorten the materiel lag in their evolving technology triad, the Azerbaijani military bought a fleet of Turkish TB-2s in June 2020.[837] With the

[835] Gettinger, "The Drone Databook," 59.
[836] Gettinger, 59.
[837] Burak Ege Bekdil, "Azerbaijan to Buy Armed Drones from Turkey," *Defense News*, June 25, 2020, sec. Unmanned, https://www.defensenews.com/unmanned/2020/06/25/azerbaijan-to-buy-armed-drones-from-turkey/.

purchase of those TB-2 drones, the Azerbaijani drone technology triad was completely updated, and a new reality within the Azerbaijani military had replaced the old one.

***Competing Realities in Nagorno-Karabakh***

The next time Azerbaijani and Armenian realities competed over the N-K region; the result was a total Armenian rout.[838] As of April 2021, the raw numbers of losses of the six-week war are still being updated by the Armenians. But the Armenians lost at least 229 tanks, 276 artillery pieces of various types, 127 fighting vehicles, 29 surface to air missile systems, and 550 trucks compared to Azerbaijani losses of 40 tanks, 51 fighting vehicles, and 46 trucks.[839] Video after video posted to the internet by the Azerbaijani Ministry of Defense showed drone strikes on Armenian soldiers and equipment in prepared fighting positions out in the open fields of the N-K region. While many of these fighting positions appeared to have substantial fortifications against a ground attack with large embankments surrounding them, they were totally unprepared for the onslaught of air to surface missiles that the Azerbaijanis were able to produce with their new TB-2 drones. More important than the raw numbers, the Armenians were forced to abandon their claim to the N-K region, which is now under the control of Azerbaijan.[840] The Armenian shared reality proved totally inappropriate for the reality they shared with the Azerbaijanis and their updated drone technology triad.

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[838] Zachary Kallenborn, "Drones Are Proving to Have a Destabilizing Effect, Which Is Why Counter-Drone Systems Should Be a Key Part of US Military Aid to Partners - Modern War Institute," *Modern War Institute at West Point* (blog), December 9, 2020, /drones-are-proving-to-have-a-destabilizing-effect-which-is-why-counter-drone-systems-should-be-a-key-part-of-us-military-aid-to-partners/.
[839] Stijn Mitzer and Joost Oliemans, "The Fight For Nagorno-Karabakh: Documenting Losses On The Sides Of Armenia And Azerbaijan - Oryx Blog," September 27, 2020, https://www.oryxspioenkop.com/2020/09/the-fight-for-nagorno-karabakh.html.
[840] Kallenborn, "Drones Are Proving to Have a Destabilizing Effect, Which Is Why Counter-Drone Systems Should Be a Key Part of US Military Aid to Partners - Modern War Institute."

The Armenian technology triad was largely unchanged since their 2016 victory. They employed the latest Russian equipment, including counter-drone equipment, in accordance with the doctrine that aligned with that equipment.[841] This meant that they were likely counting on their air defenses to protect them from Azerbaijani aircraft and considered the most important role of drones to be that of ISR to support ground maneuver and artillery spotting. However, the Russian built electronic warfare systems that were specifically designed to break the communications link between drones and their operators were just as susceptible to the TB-2 attacks as the vehicles that the Armenians intended the electronic warfare systems to defend.[842] When the systems, which presumably had succeeded in some sort of internal testing before the Armenians literally bet their lives on them, were subjected to the laboratory of combat, they failed to perform their intended purpose, and many Armenians paid for that failure with their lives. Within the logic of the Armenian reality, the contest should have been much closer. The Armenians were in prepared positions in the defense and armed with modern Russian equipment. Especially as the Azerbaijani attack moved into the more mountainous parts of the N-K region, conventional wisdom would have given the defenders the

[841] Vago Muradian, "DEFAERO Report Daily Podcast [Oct 28, 2020]–Sam Bendett on Game Changing UAV Use," Podcast interview with Sam Bendett, *Defense & Aerospace Report* (blog), October 28, 2020, sec. 17:00 minutes, https://defaeroreport.com/2020/10/28/defaero-report-daily-podcast-oct-29-2020-sam-bendett-on-game-changing-uav-use/.

[842] Status-6, "Russian-Made Repellent Electronic Warfare System Operated by the Armenian Armed Forces Destroyed by Azerbaijani Drone Strike during the Conflict in Karabakh Last Fall.," Tweet, *@Archer83Able* (blog), February 2, 2021, https://twitter.com/Archer83Able/status/1356601118122516483; "Electronic Warfare Complex against Small-Sized UAVs Repellent," Manufacturer's Website, Rosoboronexport, accessed June 6, 2021, http://roe.ru/eng/catalog/air-defence-systems/elint-and-ew-equipment/repellent/.

advantage.[843] But the two militaries were more than just unevenly matched; they were operating from different realities.

The Azerbaijani shared reality that they brought to compete with the Armenians' reality was characterized by a different understanding of the best way to employ drones in war. The Azerbaijani military employed their drones in a much more attack-oriented doctrine that was an almost direct copy of the way that the Turkish military did in Syria.[844] Once the Azerbaijani military destroyed the Armenian air defenses using manned aircraft that had been modified to allow for remote control and act as decoys to draw the air defenses into the open, the Azerbaijani drones coordinated with artillery units to systematically destroy the Armenian positions.[845] The use of drones was essentially the only distinguishing quality between the Armenian and Azerbaijani militaries; both nations employed the same Russian equipment, except for some Israeli anti-ballistic missile systems protecting the Azerbaijani cities.[846]

That one difference was enough for the Azerbaijanis to create a new reality, and with the two realities that competed in the N-K region, the war was all but decided on the day that it started.[847] If the Armenians had hoped to win this war, they would have had to update their technology triad quicker than the Azerbaijanis were able to destroy their military. Even if the Armenians could have procured already developed drones, it is

[843] Michael Kofman, "A Look at the Military Lessons of the Nagorno-Karabakh Conflict | Russia Matters," Harvard Kennedy School Belfer Center for Science and International Affairs, Russia Matters, December 14, 2020, https://russiamatters.org/analysis/look-military-lessons-nagorno-karabakh-conflict.
[844] Can Kasapoglu, "Turkey Transfers Drone Warfare Capacity to Its Ally Azerbaijan," Jamestown Foundation, Eurasia Daily Monitor Vol 17, Issue 144, October 15, 2020, https://jamestown.org/program/turkey-transfers-drone-warfare-capacity-to-its-ally-azerbaijan/.
[845] Kasapoglu; Fuad Shahbazov, "Tactical Reasons Behind Military Breakthrough in Karabakh Conflict," Jamestown Foundation, Eurasia Daily Monitor Vol 17, Issue 155, November 3, 2020, https://jamestown.org/program/tactical-reasons-behind-military-breakthrough-in-karabakh-conflict/.
[846] Shahbazov, "Tactical Reasons Behind Military Breakthrough in Karabakh Conflict."
[847] Kofman, "A Look at the Military Lessons of the Nagorno-Karabakh Conflict | Russia Matters."

unreasonable to assert that they could have updated their doctrine in the midst of losing a war. The Azerbaijanis had developed a full military innovation around drones and claimed the N-K region as the prize for their efforts.

**Analysis and Insights**

Martial knowledge, as a concept, helps illustrate the similarities and the differences between the four militaries and their evolving drone technology triads. The United States, Russia, and Israel all share similar martial knowledges of drones as ISR platforms to support maneuver primarily with a secondary role of precision strikes in the United States and Israel. In each of these nations, drones started out as a materiel solution optimized to serve their primary function. The early Israeli influence on the design was carried through both the U.S. predator through the former IAI engineer and the Russian drones through their purchase of Israeli equipment after their invasion of Georgia. This influence tended to produce drones that were few, highly capable, and with good cameras to perform their ISR functions.

Israel was not subject to the same international restrictions as the United States and Russia regarding the development of long-range loitering munitions, so they were able to develop a separate branch of drones with a focus on the destruction of enemy radar systems initially and operator designated targets with later models. The adherence to the intermediate range ballistic missile ban in the United States and Russia is itself a reflection of the two nations' martial knowledges, that it is appropriate to follow such restrictions, and places these two nations in a separate socially constructed reality from Israel. Both realities, the Israeli one that included loitering munitions and the United

States and the Russian one that did not, still existed within a broader shared reality that characterized by a martial knowledge that posited drones are first and foremost ISR platforms.

Elements within the U.S. Air Force exercised their autonomy to create a materiel solution that was well outside the established reality when they armed a Predator with a missile. This enabled a new doctrine and martial knowledge related to a strategic mission to conduct targeted strikes with drones. This new materiel solution aligned with the pre-existing doctrine and martial knowledge of targeted strikes in Israel, so the IDF incorporated the new weapon into their existing technology triad. Legal structures, a facet of martial knowledge, within the US and Israel limit targeted killings to high-level strategic counter terrorism activities. While it is a new technology triad, counter terrorism activities have not displaced the pre-existing technology triad. It is a competing reality within the broader reality in these countries where the previous one retains dominance.[848] Time might well prove this new technology triad will overtake the existing one or that it will lose support as the broader martial knowledge shifts in some way to render its truths invalid. The competing martial knowledge claims demonstrate the challenges of applying the technology triad to a contemporary case. However, the broad outlines of each of these forms of martial knowledge produce a reference against which to orient the Azerbaijani martial knowledge related to drones.

The Azerbaijani drone technology triad is in a separate reality from the other three militaries in this case. Azerbaijani materiel never went through a phase where it was specifically optimized for ISR missions alone, and their martial knowledge was a product

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[848] H.R. McMaster, "Continuity and Change: The Army Operating Concept and Clear Thinking About Future War," *Military Review* 95, no. 2 (April 2015): 6–21.

of their own conflict with Armenia and observations of Turkish operations in Syria. The doctrine that Azerbaijan employed aligned with their unique martial knowledge and attack-oriented materiel solutions to create a different way of using drones that caught the Armenian military by surprise. Of the four countries, only Azerbaijan produced an innovation related to drones. The other three used drones as an enhancing materiel for an existing technology triad.

Together, the four examples demonstrate how it can be challenging to define innovation and assess the relative importance of changes in the arc of history in contemporary cases. Clearly, the United States is doing something new and useful with its use of armed drones. Likewise, the Israeli suicide drones have had an outsized impact on the conduct of ground warfare. However, as these improvements stand at the moment, the changes are relatively minor in the overall system. When Azerbaijan achieved innovation, they restructured their entire reality, not just improved an aspect of it or added something new. This proved important when the Azerbaijani military employed them in combat. Armenia was incapable of fighting the way they had trained and prepared because the ubiquity of relatively cheap attack drones made their technology triad incapable of competition with the Azerbaijani technology triad. The Azerbaijanis had created a reality that was outside the Armenian understanding of what war could be. In contrast, employing new materiel solutions in line with a pre-existing technology triad does not create an unexpected reality and would not produce the kind of advantage over an adversary that the Azerbaijanis enjoyed over the Armenians.

Each of the four indicators of generalizability is present in this case to varying degrees. Autonomy to create a new materiel solution was influential in the U.S.

development of armed drones, but it played a role in every military's decision to purchase or build drones. The United States, Russian, and Israeli militaries have not achieved a military innovation related to armed drones, so they are currently in the development phase of innovation. Azerbaijan, however, passed from the development phase to the disruption phase at some point after they purchased their TB-2s from Turkey and before they stepped off to reclaim the N-K region. As an analytic tool for application to a contemporary case, the three phases of innovation help identify potential sources of change within the technology triad and the presence of a complete innovation.

Separation between martial knowledge and doctrine is much more difficult in the contemporary case than it was in the historical cases. It would be an easier task if one could peer into the foreign militaries to look for differences between the elements of the knowledge system and the way the military actually operates, but this is impossible in the real world. Assessments of values judgments within the militaries and indications of specific epistemologies, either in testing or interpretation of foreign developments, helped tease the martial knowledge apart from the doctrine of the militaries. Delineating martial knowledge from doctrine within the system started to highlight the presence of assumptions passed off as truth buried in the foundations of the martial knowledge, such as the extreme vulnerability of drones, that were driving much larger decisions. These are easy to identify with hindsight but difficult when the outcome of events remains uncertain.

Identification of shared and unshared elements of reality between the four militaries and the root of some of the local truths that various realities posit start to indicate ways that this framework may enable not only the production of innovation but also how various militaries might address different realities if they come in conflict. As the French experience in 1940 or the United States' experience in rolling thunder indicate, it is difficult for militaries to identify aspects of their local reality that are not universally applicable. The ability to draw even the rough outlines of competing realities would help a military identify unstated assumptions that drive their application of military means to achieve strategic ends. The final chapter will explore the implications of this idea further by highlighting how viewing the relationship between technology and military innovation as the creation and maintenance of a local reality can inform strategies to create realities that are applicable for a wide range of possible future realities and what framing of war as a contest of realities might mean for the conduct of war in general.

> "It would have needed a man of outstanding genius to change the whole conception of his strategy after the battle had been joined, and even had such a genius been available, the material ready to his hand would have made any such drastic action impossible"[849]
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> -Marc Bloch on the 1940 French defeat

# CHAPTER 8

# APPLYING THE TECHNOLOGY TRIAD

From its inception, the stated aim of this dissertation and the research that informed it was to explore the relationship between technology and military innovation with the explicit purpose of developing an understanding that could assist in the active management of military innovation. Ideally, one would be able to produce a predictive theory that can reliably link current actions with future outcomes, but that is well beyond the capabilities of contemporary social science.[850] Roger Pielke Jr, the science policy scholar, framed the purpose of political science as "rather than trying to see the future, political science might serve us better by helping citizens to create that future by clarifying the choices we face and the possible consequences for policy."[851] In this same light, the model of military innovation that emerged from this dissertation does not attempt to produce a predictive theory that can guarantee results; rather, the technology

[849] Bloch, *Strange Defeat*, 120.
[850] Kahneman, *Thinking, Fast and Slow*, 218–19.
[851] Roger A. Pielke, "Psephological Pseudoscience," the Guardian, May 9, 2015, http://www.theguardian.com/science/political-science/2015/may/09/psephological-pseudoscience.

triad is intended to be a way of identifying and thinking about the relationships between the most relevant aspects of the military sociotechnical system. Armed with the interpretive lens of this framework, the rough outlines of a relationship between the materiel solutions available to a military, the doctrine they employ, and the martial knowledge that military holds start to take shape. Furthermore, the way these elements change over time defines the system in such a way that it is possible to make assessments about and manage the development of military innovation in uncertain environments.

The technology triad produces potentially useful insights related to the dynamic relationship between technology and military innovation by adopting a fundamentally different conception of technology, or even reality, than is common in the bulk of the literature related to military innovation.[852] The influence of changing technology on the character of war is too complex to adequately explain with traditional causal models that attempt to place technology of all types and ways of war in dichotomous relationships with each other. Historical and contemporary challenges that militaries have faced as they attempt to adjust the way they fight wars with the technology available at the time demonstrate the perils of adopting linear predictive models of technology procurement. The challenges that the British Navy faced in World War I when they assumed that bigger and better-armed battleships would continue to give them the ability to effectively conduct combat operations in an environment where their adversaries fielded fundamentally different technologies stem from the same basic assumptions that doomed the U.S. Army's Future Combat Systems nearly a century later. The implicit assumption

[852] Posen, *The Sources of Military Doctrine*; Rosen, "New Ways of War"; Nielsen, *An Army Transformed*; Bacevich, *The Pentomic Era: The Army Between Korea and Vietnam*; Pierce, *Warfighting and Disruptive Technologies*; Adamsky, *The Culture of Military Innovation*; Grissom, "The Future of Military Innovation Studies"; Griffin, "Military Innovation Studies"; Farrell and Terriff, *The Sources of Military Change*.

that technological development is linear and that the reality in which it progresses is common to all militaries is present in both of these examples.

This positivist world view is pervasive in the military innovation literature and produces models of military innovation that struggle to account for the complexities of the relationship between change in militaries and technology. While the ability to apply hindsight to historical cases of military innovation can produce rich historical accounts and important observations about how individual militaries did or did not change with their environment, the models that emerge from these cases possess limited capabilities for the management of technology and innovation in uncertain environments. Only with hindsight is it clear that the U.S. Army in the 1930s should have abandoned their horses much earlier and allocated more resources to fully develop the nascent technology triad around the experimental Mechanized Force. The combination of the knowledge of which options would have been best in historical cases with the powerful influence of prior knowledge and the high risks associated with failure in military innovation produces an apparent resistance to change on the part of professional militaries. The presumption that militaries are resistant to change as a function of their very nature is so widely accepted in both academic and professional spaces that it rarely is seriously questioned.

Science and Technology Studies concepts provide an established philosophical base from which to both challenge the assumption that militaries are resistant to change as a matter of course and frame the relationship between weapons and ways of war beyond a simple dichotomy. Acceptance of an inherent resistance to change combined with simplistic models of the relationship between means and ways of war leaves two basic options to account for the challenges that militaries face with the employment of new technologies. One may assume that technology changes along a deterministic path and that the militaries that are less resistant to change are more capable of adopting the new weapons to achieve their strategic goals. However, those instances where the more "technologically advanced" military lost a war are clear challenges to granting too much explanatory power to technology for the outcome of wars. Alternatively, one could adopt the position that "it is not the weapons that matter, but how one uses them that determines the war." This emphasis on the social influence on the outcome of wars allows a wider range of outcomes that is independent of the technological capability of militaries. With a more nuanced framing of technology and the way organizations and people construct the knowledge that informs its use and shape, one is able to interpret changes in technology and war that avoids the deterministic nature of the first approach while also still accounting for the clear role that technology must play to some degree in the outcome of conflicts waged in the physical world.

The technology triad leverages this more nuanced framing of technology to interpret changes in technology and war by neither ignoring the influence of new technologies nor overly focusing on any single materiel development as a watershed moment that changes all war in a way that no other weapon could. With the perspective that constructivist STS provides, the relationship between ideas and equipment takes form in the physical world through the interactions of knowledge, materiel, and doctrine to produce a model that is broad enough to have the potential to address a wide range of ideas and equipment in the future, but specific enough to map on to tangible activities and artifacts in the real world where wars are fought and security is challenged. This is a higher-level analysis that asks questions about the fundamental aspects of technology that are common to every weapon, from the first sharpened stick to the latest hyper-sonic missile system.[853] Through this analysis, the shape of the technology triad emerges to form a model of the relationship between technology and military innovation that holds the potential for application in the management of contemporary and future innovations.

## Contributions to Knowledge

### ***The Technology Triad***

The model developed at length and tested throughout this document is the key contribution of this dissertation. The addition of a constructed martial knowledge to the existing concepts of materiel and doctrine helps explain the otherwise intractably complex relationship between changing doctrine and changing materiel. The third critical component to the weapons/doctrine relationship produces complex behavior that more closely resembles the way real militaries change with technology. Artificial though it may be, breaking the complex military sociotechnical system into these three elements according to the rates at which they could change under ideal conditions highlights important interactions between the elements and produces a new way to frame the concept of "technology." These differing rates of change, especially since they change from situation to situation, along with the three-way reciprocal relationships in the technology triad, provide enough variation and opportunity for complex relationships to evolve in the systems to avoid overly simplistic articulations of real organizations' behavior.

[853] Roland, *War and Technology*.

By framing technology in this manner, the more traditional approach of considering the conduct of war a question of different ways to employ various means to achieve some end takes on an additional dimension with the introduction of a mechanism with which to consider different types of war.[854] Martial knowledge describes the best way to fight a war, but it also gives structure to the very meaning of war. It is not the things that a military does to fight a war, that is doctrine, but it is the collection of truths that a military holds to explain why a certain doctrine or type of weapon is most appropriate to achieve strategic objectives. Assumptions and prior knowledge about the purpose, limits, and meaning of war are inherent in these truths. They are so strongly held, thanks to their reinforcement by internal knowledge generation mechanisms and interactions with the other two elements of the technology triad, that martial knowledge is a justified true belief of a military about the conduct of war. That the martial knowledge of a military is dynamic and locally generated provides a structure within which to question and explore why a military might believe that a certain combination of ways and means will produce specific ends and, perhaps more importantly, why those ends are appropriate goals for a military action in the first place.

### *Phases of Innovation*

When a military's fundamental understanding of war changes and the weapons and doctrine align to complement this new understanding, that military's reality has shifted. This shift in reality is innovation. In concert with the three elements, the three phases of innovation provide an identifiable point where one can separate evolutionary

[854] Colin Gray, *The Future of Strategy* (Cambridge, UK ; Malden, MA: Polity, 2015).

change short of innovation in a system from the revolutionary change of innovation. Whether or not that shift turns out to be the correct one for some future war is not important, but that the military is justified in its belief that the shift is an improvement defines the shift as innovation. Methods of identifying innovation that rely on magnitude or time scales are disconnected from the attribute of a military innovation that makes it so important. When a military innovates, it changes the rules of the game in a way that other militaries may not even be able to recognize until they have already lost a war.

In the research that undergirds this dissertation, the shift in reality within militaries undergoing an innovation follows three steps. Logically, the three steps are not terribly novel. They essentially amount to a spark of innovation, developing that innovation, and achieving that innovation. Any beginning, middle, end structure would share this same general quality. However, by framing innovation as a shift in reality, the spark of innovation takes on special qualities related to the ability of a person or group of people to take action outside the existing reality of a military. This is more than just giving someone the resources to do something new. It is also directly related to the manner in which that new thing is judged and deemed useful or frivolous. Without the ability to align all three elements of the technology triad outside the established reality of a military, the development phase, any change will either simply reinforce the established reality or fail to demonstrate its usefulness by the standards of the pre-existing reality. When MAJ Sereno Brett drafted out the vision of the experimental Mechanized Force in 1928, he could have set the U.S. Army on the path to be the world's leading practitioner of armored warfare. But, since he was unable to align all three elements of the technology triad around this new concept, the unit failed to prove its worth according to the standards of the pre-existing reality and was abandoned. By not only identifying the creation of a new reality as the qualifier for innovation but also describing what practical steps must occur before that new reality exists, the phases of innovation both imply methods for creating innovation and for assessing changes in competing militaries for their innovative qualities.

### *Shared Realities*

Militaries exist to compete with each other. Ideally, their competition remains a peaceful demonstration of capabilities that deter the conduct of actual war. But this assumes that both militaries share a common understanding of what those capabilities are and how they relate to the ability to achieve strategic objectives. Acceptance of the locality of knowledge and the way that knowledge interacts with materiel and doctrine creates an explanatory mechanism for the creation of local shared realities. Building on the concepts within the sociology of knowledge, the technology triad includes elements of materiel and doctrine as part of the communications between members of a military that construct shared realities.[855] As local constructions, one military's reality can, and often will, be different from another's. When two nation's realities diverge far enough, they may not maintain sufficient commonalities in their competing realities for an agreement about the potential capabilities of one side or the other to preclude the conduct of war through deterrence.

War itself can be framed as a competition between realities within a higher common shared reality. The concept that the intersubjectivity of our experiences defines

[855] Berger and Luckmann, *The Social Construction of Reality*.

reality can be taken to its extreme logical conclusion to show how all humans are members of various shared realities up to and including the level of physical reality.[856] Within this hierarchal structure of shared realities, separate realities can compete with each other or co-exist, depending on the truths held within the realities. When two realities hold truths that are fundamentally opposed and incapable of co-existing, the two groups that maintain those realities must appeal to a higher reality that is common between the two to resolve it. This reality defines the boundaries of appropriate behavior of the belligerents to settle the dispute. Two nations could appeal to some sort of international legal structure to resolve disputes, for example. The highest reality that all humans share is the physical world. Violence is the ultimate arbitrator of disputes. But even within the conduct of violence to settle competing realities, adherence to socially constructed elements of reality, such as codes of chivalry or refraining from the use of certain weapons, continues to define the boundaries of appropriate behavior within which realities compete.

The technology triad both provides a framing to show how local realities can emerge within a military and helps show how the sociotechnical systems of each military compete with each other within the higher shared reality. This makes the conduct of war not a question of force against force or levels of violence to compel action, but it becomes a question of which military's technology triad, from their basic understanding of war to the weapons and doctrine they employ, is more appropriate for the specific shared reality that exists in that one instance. The North Vietnamese could have undoubtedly applied enough force to kill all of their troublesome POWs, but that would

[856] Berger and Luckmann.

not have allowed them to achieve their strategic objective of employing the American captives to create propaganda. At a larger scale, the conduct of counter-insurgency operations in Afghanistan pitted the U.S. military's technology triad against that of the Taliban. The final outcome of this war is still pending, so it might be too early to make definitive assessments of strategy, but it is clear that the simple application of more and more violence was not the strategy of the United States, nor would it have been very likely to achieve the United States' strategic objectives. The three interacting and interconnected elements of the technology triad provide a framing to help relate how militaries compete within a common shared reality. If there are common elements between the militaries, say both sides are employing essentially the same equipment sets, as Azerbaijan and Armenia did, then the competition of realities takes on a more traditional shape. However, if there are few commonalities between the two technology triads, such as the Viet Cong and the U.S. military in South Vietnam, then the competition between the two realities can be much more asymmetrical in nature and less predictable within the assumptions of either side's martial knowledge. This conceptual framing of conflict may require some reorientation of the way one understands the nature of truth and reality, but the benefit is a worldview that both helps explain war at a fundamental level and helps manage strategic interactions where information is limited.

### Additional Insights

Each of the three main knowledge contributions outlined just above emerged from the deliberate testing of the generalizability of the technology triad in the nuclear weapons and drone case studies. They were the logical extensions of the technology triad that were present in the second and third case studies of this dissertation. Beyond these three main insights, several additional insights emerged from the conduct of the research for this dissertation. These additional insights grew organically from the research and further demonstrate how framing the relationship between technology and military innovation in terms of the technology triad is unique enough to produce novel insights. They also build on the framework developed by the technology triad and will help inform the following discussion that explores ways that the technology triad can enable active management of military innovation.

Autonomy played a key role in the initial spark for each of the innovations studied, which was anticipated and directly tested for in the subsequent case studies, but it did not matter which of the three elements the military changed first, which was unexpected. A change to any one of the elements outside the established reality has the potential to be the first step towards a military innovation. In the armored warfare case, autonomy within the schoolhouses and intellectual centers of the U.S. Army enabled a change to the doctrine. As the nascent innovation developed, it spread to the martial knowledge and eventually to the materiel elements. In the nuclear weapons case, the first change occurred in the materiel element with the development of the atomic bomb. This materiel change initially found a home in pre-existing martial knowledge and doctrine, but soon proved itself fundamentally different and sparked a full shift to the U.S. military's reality at the strategic level. Finally, drones changed first in the materiel elements in the United States and Israel and in the martial knowledge of Russia and Azerbaijan. Even though Azerbaijan is the only military to have created a drone military innovation, the other three militaries may yet create an innovation of their own.

While innovations "start" with a change to one of the elements to a state outside the established reality, the true system is too complex to honestly say where an innovation starts. Any new idea is a reflection of one degree or another of an earlier state of the system. In the armored warfare case, the innovation was accredited to a change in doctrine in the formal educational centers. However, CPT Wilson, who wrote the harsh critique of the 1933 Mechanized Cavalry doctrine, had been an officer in the experimental Mechanized Force several years earlier.[857] In the text of his report, he drew from his experiences with the Mechanized Force several times to justify his judgment on different matters. This indicates that attempts to "think outside the box" or radically depart from the current system for the sake of producing a change to one of the elements of the technology triad alone might not be the most effective means to induce innovation. It seems, from the cases in this dissertation, that successful innovation requires careful management of the full technology triad to protect it from previous epistemologies that might not value the advantages produced by some new change.

Further supporting the inadequacy of a single departure within a technology triad to create a new reality, the presence of a new materiel solution alone did not produce innovation in these cases. In the armored warfare case study, tanks had been a part of the U.S. Army for more than 20 years before the organization was able to align all three elements of the technology triad and produce an innovation. The atomic bomb came the closest to creating a new reality on its own, but even this drastic advancement in weapons technology did not completely change the way the U.S. military understood war without corresponding changes to martial knowledge and doctrine. In the drone cases study, three

[857] Wilson, "A Critical Analysis of the C. & G.S. Pamphlet Cavalry Mechanized," March 23, 1934.

of the four militaries addressed have yet to achieve a military innovation in relation to the employment of drones in combat. Acknowledgment that materiel alone does not make innovation is already well represented in the literature and not a very novel insight on its own.[858] However, the technology triad extends this general observation to explain what kinds of other changes a military must undertake in order to achieve innovation with the introduction of a new materiel solution.

Finally, the constructed delineations between tactical, operational, and strategic weapons do not seem to be as insightful when addressing technology and innovation as they are when addressing the management of specific actions to achieve desired goals in combat. Both drones and nuclear weapons spill across the tactical to strategic divisions to the point where these divisions are a hindrance to understanding what the materiel solutions might enable for the military in question. For example, a platoon-level suicide drone like the Skystriker is clearly a tactical weapon with only a 5kg warhead.[859] But what if the Israeli Prime Minister orders a strike on a terrorist leader using that same weapon? In that case, the weapon would have strategic effect. Admiral Fisher, the architect of the dreadnought revolution, once said that "strategy should govern the types of ships to be designed. Ship design, as dictated by strategy, should govern tactics."[860] The technology triad combines tactics and strategy into "doctrine," which might be why these two levels for technology are not well represented in the case studies. But the technology triad also accounts for interactions within the system that Admiral Fisher's linear structure cannot. In his model, presumably, martial knowledge would be

[858] Van Creveld, *Technology and War*; Horowitz, *The Diffusion of Military Power*; Gray, "Weapons for Strategic Effect: How Important Is Technology?"; Pierce, *Warfighting and Disruptive Technologies*.
[859] "Skystriker - Elbit Systems."
[860] Lambert, "RIGHTING THE SCHOLARSHIP," 296.

represented within his concept of strategy. This makes the influence from martial knowledge to materiel and tactical doctrine unidirectional and direct. The technology triad highlights a reciprocal link from both materiel and doctrine back to martial knowledge, which his approach cannot address. The atomic bomb redefined the boundaries of war. The drone demonstrated what is possible in the skies over Idlib, Syria and changed the way the Azerbaijanis understood ground combat. The early U.S. Army tanks could not live up to their promises and convinced a generation of officers that the machines were at best an enhancement to the traditional roles of the cavalry and the infantry. The technology triad provides an alternate framework against which to understand the role of weapons in the pursuit of strategic objectives rather than classifying them as tactical or strategic while retaining the ability to address how those weapons might influence the way militaries understand war.

### Management of Military Innovation Informed by the Technology Triad

The insights provided by the technology triad imply that an effective way for a military to manage innovation is to create the conditions necessary to align the elements of the technology triad. Throughout the research that informed this dissertation, there were numerous times where a change was made to one of the elements of the technology triad, but the person or people who made it lacked the autonomy to align the other two elements enough to create a viable system against which to test the pre-existing system. Increasing autonomy in general would most likely produce more changes that are outside the established reality, but resources are always limited, and giving too many sub-organizations within a military the autonomy to allocate resources may be too expensive.

Rather, the more appropriate strategy would be to remove institutional barriers between the elements of the technology triad so that they can change in concert with each other as the benefits of a change become clear.

In World War II, Vannevar Bush's OSRD made it a point to embed their scientists with the units that were in the field. For example, when the OSRD was working on airplane-mounted radars to detect submarines, Bush sent the engineers to go fly missions with the search planes.[861] This gave the engineers a sense of how the equipment they were building was going to be used and provided them with information to which they would not otherwise have had access. Nearly fifty years later, a U.S. Air Force engineer working on a secret landing system realized one evening that the pilots' night vision goggles were unusable because the light from the cockpit instruments was washing out the image in the goggles. Within four months, the U.S. Air Force had developed a special filter for the lenses on the pilots' goggles.[862] These examples demonstrate that removing institutional barriers to aligning the elements of the technology triad do not have to involve the allocation of resources; simply sharing the relevant information between those who have already received the resources and authority to allocate them may be enough to create a complete technology triad to test against the existing one.

No matter how effectively a military aligns the elements of their technology triad in peacetime, the reality it represents is not the same one that they will inhabit in wartime. In order to address this, a military could either create the technology triad they believe has the best chance of wining the war and hope for the best or it could create a military

[861] Zachary, *Endless Frontier*, 175–76.
[862] Gary Klein, *The Power of Intuition: How to Use Your Gut Feelings to Make Better Decisions at Work* (New York, NY: Doubleday, 2007), 164–65.

that has a flexible technology triad that can adjust with the environment as conditions change. Assuming that any military with a legitimate desire to win the wars it fights will choose the second option, the competition between realities becomes one of the speed of adaptation to the dynamic environment. Sir Michael Howard famously said, "No matter how clearly one thinks, it is impossible to anticipate precisely the character of future conflict. The key is to not be so far off the mark that it becomes impossible to adjust once that character is revealed."[863] But the technology triad makes this approach more than just a restatement of Boyd's OODA loop because the ability of a military to orient to their observations will be entirely dependent on the materiel and doctrine that existed at the onset of hostilities.[864] The lags between the fastest possible rate of change for materiel compared to the rest of the technology triad produces a limit to how fast a military can "adjust once that character is revealed."[865]

To leverage the insights of the technology triad, militaries should seek to field materiel solutions that are applicable to the widest range of possible martial knowledges and doctrines. This way, as the military's environment changes, there is a better chance that the materiel on hand will be at least partially useful for the new reality. Furthermore, the more flexible the uses of a material are, the more likely a military might discover an unintended consequence of that materiel solution, which sets the stage for a rapid innovation with which their adversary might not be able to keep up. For example, computers are the penultimate flexible materiel solution. Every program that is run on

[863] Quoted in "Strategic Trends Programme: Future Character of Conflict" (United Kingdom: Ministry of Defense, Development Concepts and Dcotrine Center, February 2, 2010), 2, https://www.gov.uk/government/publications/future-character-of-conflict.
[864] Osinga, *Science, Strategy and War*.
[865] Quoted in "Strategic Trends Programme: Future Character of Conflict," 2.

modern computers is really just a form of doctrine, which can change very rapidly because one does not have to train all of the computers individually, just update their software. The possible applications of networked computers are near limitless, especially as they are more and more connected with physical components of the network like power grids, water treatment plants, and even individual cars.

The ability to orient to observations faster than the enemy is not restricted to questions concerning materiel; it is also related to how a military understands what war is at a fundamental level, its martial knowledge. The technology triad enables identification of the bounds of a constructed shared reality from within that reality by producing a framework to contrast it against other realities. By framing conflict as a competition of realities and providing a way to describe those realities in detail, the technology triad provides an analytical tool to achieve Sun Tzu's broad direction to "know the enemy and know yourself."[866] In other words, the technology triad highlights implicit assumptions. By illuminating common elements of two competing realities within a higher shared reality, the technology triad creates the understanding that could provide an advantage in competition. Managing the interactions between the shared realities of militaries is not a one-way system in a war. Implications related to the management of shared realities and the active shaping of an adversary's reality could prove to be an important output of this research.

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[866] Sun Tzu, *The Art of War*, 84.

**Potential Implications and Directions for Future Research**

Framing conflict in terms of competing realties within a shared reality has important implications for the conduct of strategy. If there is no such thing as an objective reality and realities are constructed by the interactions between the elements of a military's technology triad, then how could a military either adjust an adversary's reality or construct a shared reality that produces an advantage? There were indications within the research for this dissertation that strategists have already taken these sorts of actions in the past; they just did not frame their actions in this manner. For example, Secretary of Defense Robert McNamara went out of his way to ensure that the United States' nuclear doctrine related to Mutually Assured Destruction was accessible to the USSR.[867] He actively created a shared reality with the USSR so that he could manage the strategic environment in a manner that he believed would increase the United States' security. The insights of the technology triad imply that these changes could go beyond just communication and creating shared realities through information operations. Traditional missions like sabotage to reduce an enemy's confidence in their equipment becomes an active management of the enemy's reality through altering their materiel solutions. Further research is needed to fully explore this idea of a "strategic theory of shared realities," but there are indications that this research might be worth the effort.

Another area where further research is warranted is the untapped potential of computers to change martial knowledge in ways that are hard to understand. As mentioned above, computers have near limitless potential to conform to a wide range of martial knowledges and doctrines. Furthermore, they can make this change all at once

[867] Freedman, *The Evolution of Nuclear Strategy*, 235.

across an entire system. If a new doctrine for shooting a rifle is developed, each soldier must learn that doctrine from another soldier until the whole military is up to date with the new doctrine. Computers, on the other hand, can update one computer or millions with no difference in effort. Once one combines the speed with which computers can change with ideas related to the local nature of reality, the outlines of a new technology triad start to emerge. The unintended consequences of cheap and networked computers are already starting to emerge, such as the homemade drones that attacked the Russian base in Syria and the regular cyber-attacks perpetrated by adversarial nations.[868] However, much of the language the military currently uses to describe cyber operations is still rooted in ground maneuver concepts.[869] This indicates that there has yet to be an innovation related to the use of networked computers to do anything more than support traditional maneuver and strategic airpower-centric missions.

Finally, there is more work to be done related to delineating the boundaries between civilian and military influences within the technology triad. As the model stands now, it assumes a military that is separate from the civilian population in some non-trivial way. But this is not necessarily a given organizational structure for the defense of a nation. As the influence of computers becomes more pronounced on the shifts within the technology triad, the line between civilian and military may become more blurred.

Accepting the local nature of knowledge and that technological artifacts are a physical embodiment of that knowledge has important implications for the relationship between technology and military innovation. This research also indicates that innovation

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[868] P. W. Singer and Emerson T. Brooking, *Likewar: The Weaponization of Social Media* (Boston: Houghton Mifflin Harcourt, an Eamon Dolan Book, 2018).
[869] Mark Milley, "The U.S. Army in Multi-Domain Operations 2028; TRADOC Pamphlet 525-3-1" (Training and Doctrine Command, December 6, 2018).

can be created, nearly at will, by giving the right person or people the requisite autonomy to create a technology triad outside the established reality. But does this new innovation accomplish the organization's goals? How can a military be sure that the innovation has created a reality that is most, or even more, appropriate for some future reality? The truth is that the new innovation is almost certainly not the best one for the unknown war of the future. The goal for any nation that wants to compete successfully becomes to actively construct and manage all three elements of the reality in a way that will help that nation achieve its strategic objectives. This is more than just managing the elements of the technology triad within whatever reality organically emerges. It implies that militaries should leverage the insight that the elements of the technology triad define reality to intentionally create a reality that is most appropriate for a wide range of unknown and unknowable future conflicts. This is not easy. But the cost of failure is too high to give it anything less than an honest effort.

# EPILOGUE

I had an uncomfortable conversation with a nuclear operations officer one evening at dinner. He and I were both in the summer before we started graduate school to pursue our PhDs. He was planning to focus his studies on a traditional security studies-type topics, and I was excited to dig into the role of technology in the ways militaries change or fail to do so. As we waited for our dinner, he casually asked what I intended to study. We were still in that awkward forming stage of team building where everybody is trying to sort out what roles we will play in a small group. When I told him the plan for my research, he preceded to inform me that it was one of the dumbest ideas he had ever heard. That I was wasting both my time and taxpayers' money with such an irrelevant pursuit because nuclear weapons would prevent any major war from ever happing again in the future. Thank Goodness for nuclear operations officers!

I truly wish I could believe him. Nobody likes being told the topic they intend to devote years of their life to understanding is a waste of time, but I would gladly accept that situation if only it could be true. Unfortunately, nuclear weapons, with all their terrible destructive power, have not seemed to change the tendency of humans to resort to violence when they believe that is the best course of action. Bernard Brodie famously claimed in 1946 that nuclear weapons would make wars of all types too costly to ever fight again, only to be proven overly ambitious four years later when the Korean War broke out.[870] Wars of one form or another will, unfortunately, be with us for the foreseeable future.

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[870] Bernard Brodie, *The Absolute Weapon: Atomic Power and World Order* (New Haven, CT: Yale Institute of International Studies, 1946).

The sincere goal of this research has been to contribute, in some small manner, to the reduction of needless bloodshed that has plagued humanity throughout recorded history when those wars do occur. Even if the elimination of all violence was possible, the last hundred years have demonstrated, from Nazi Germany to ISIS, that there are times when the application of political violence is an unpleasant moral necessity. But the reduction of unnecessary deaths, such as those suffered by every soldier who died charging a machine gun because their leadership was unable to conceptualize a different approach or every civilian that fell victim to a weapon that was employed in a manner inconsistent with its doctrinal limits, is an achievable goal, and one that we should all strive to reach. Without the firm belief that the research that informed this dissertation could help bring humanity even a little bit closer to that goal, I probably would not have been able to complete this dissertation.

I read a lot to complete this research. Some of what I read was more than a little off-putting. The obvious glee with which some authors casually spoke of the violence and suffering at the societal scale leads one to believe that perhaps they have not experienced their preferred subject matter to the degree as those other authors who treated the subject with its requisite solemnity. But the ignorance of fools is hardly limited to discussions of technology and war. The most wearing elements of this research were the primary documents written by people who had no idea that in a few short years, their entire world would be turned upside down by war. I read paper after paper written in the 1930s about how horses had been an important component of war for thousands of years and would continue to be long into the future could be difficult at times knowing that these officers would soon be scrambling to adjust to the new reality of modern war and that many of them would not live through the experience. As difficult as reading these documents could be, they are what kept me going when I was tired and drove me to put every ounce of effort into my work. I became convinced that the people who serve in our military today are no smarter or better informed about the future than those officers were on the eve of World War II or of defeat in Vietnam. I tried to use the emotional response generated by reading the words of people who would die in wars they could hardly comprehend as motivation to do what little I could to try to make things better the next time around.

I recognize that this explicit belief that soldiers of any given time are ill-prepared to fight the wars of their near future and that there must be a better way is a bias that implies the current structure is insufficient. I have made deliberate efforts to maintain awareness of this bias throughout my research to minimize its impact on my findings as much as possible. But I am a currently serving officer, and the model that I built in this dissertation would suggest that I hold my own martial knowledge that reflects both my current organization and personal attributes. The whole point of this entire project has been to try to find ways to frame that martial knowledge and the assumptions that underpin it in a way that could help illustrate where it might be distracting from the goal of peacefully living a moral life in line with my own values while still acknowledging that the world is a dangerous place with people who may exist in totally different realities. I leave it to the judgment of the reader whether I minimized my personal bias to the degree that the product of my research is useful for other people.

The reduction of bias in this work and the imperative to produce something useful is more than an academic exercise. Many of those authors who didn’t seem to comprehend the true nature of what they were writing about also seemed to treat this entire enterprise of studying war as some sort of mental puzzle to keep them occupied and feed their egos. They could not be more wrong. With every word that I typed on this dissertation, I remained acutely aware that some future soldier might use the concepts developed here to risk everything. That without exaggeration, the very act of producing research related to the conduct of war induced a personal responsibility to treat it as a matter of life and death. Even if someone reads this dissertation and decides that it is complete nonsense, there is no way to tell how some of the ideas might indirectly influence some future decision that could cost untold numbers of lives. With this in mind, I treated every argument within this dissertation as if I was making it in real-time with my own life on the line. This meant that everything in here is as truthfully represented as my abilities will allow. Any time I came across something that didn't seem to fit with the model that I was building, I didn't ignore it or massage it to fit my preferred narrative. I kept researching until I felt that I had resolved the inconsistency. I welcome future debate about the validity of these ideas because if they prove to be less useful than I currently believe, I want to find out so that I can spread the word. My "good idea" or "being right" is totally and truthfully inconsequential compared to the scale of the undertaking that I address in this work.

With that qualification in mind, I hope that I have opened the door to a new way of thinking about what military technology is, can be, and how it influences our thinking about change and innovation. The goal was to create an understanding that has a glimmer of a chance of reducing needless bloodshed and suffering when groups of people eventually resort to violence to settle which reality is going to survive the encounter.

Eternal peace would be ideal, even if it is achieved through the threat of nuclear annihilation as my nuclear operations officer colleague envisions, but this is unrealistic in the current, and likely near future, state of humanity characterized by such a wide range of values and realities. The best we can hope for is to avoid the catastrophic mismatches between the capabilities of fielded materiel and our own martial knowledge that led to some of the worst instances of mass butchery in the 20th century. This work seeks to provide a language and framing to illustrate these mismatches. The conclusions drawn from this way of thinking may prove uncomfortable for some, intellectually challenging for others, and nothing more than idealistic philosophizing to still others. Challenging and uncomfortable though the worldview proposed in this dissertation may be, professional soldiers and statesmen entrusted with the lives of other human beings have a moral obligation to seek the understanding that can better help them carry out their duty no matter where that understanding may originate or culminate. The ideas in this dissertation may not be the best answer, but I humbly submit them to the reader as a possible alternative view to the currently accepted knowledge that has historically proven itself incapable of adequately describing the relationship between technology and military innovation. If this product of years of dedicated study does nothing more than spark the conversation that leads to enhanced understanding for someone someday that makes the decisions that impact millions of lives, then it will have served its purpose.

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