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Armed Robotic Systems Emergence: Weapons Systems Life Cycles Analysis and New Strategic Realities

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U.S. ARMY WAR COLLEGE
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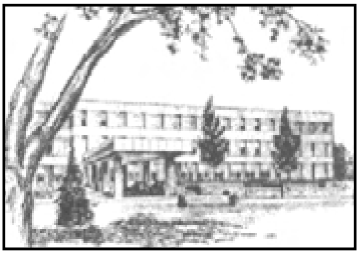

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FOREWORD

This important monograph focuses on the emergence of armed robotic systems on the early 21st-century battlefield and the new strategic realities that their fielding may entail. It utilizes a little known—yet decades old—weapons systems life cycle analytical approach, to place these warfighting technologies in a larger strategic context. This is provided by means of case studies focusing on the developmental progression of the knight from the 9th through the 16th century, the battleship from the 19th through the 20th century, and the tank from the 20th into the 21st century. This progression follows experimental, institutionalized, ritualized, and satirized life cycle phases in which a weapons system is first worked out for battlefield deployment, is then optimized as it matures, later becomes increasingly obsolete as it passes its prime, and finally is suicidal to use as advanced warfighting technologies move beyond it. For the three case studies utilized in this work, these phases are fully discussed and analyzed. Armed robotic systems emergence is then focused upon and analyzed from the perspective of those systems in the early experimental life cycle phase. The new strategic realities related to armed robotic systems emergence are then provided in a query and response format. Finally, a number of short recommendations are provided to begin to help us focus on the coming robotic revolution in warfare. Of specific interest to Army and related Department of Defense (DoD) professionals, as well as U.S. policymakers and scholars, may be the interplay of what the author calls the present ritualization of the tank (as a legacy weapons system) with the experimental activities surrounding armed robotic systems (as an ascendant weapons system).

This monograph is representative of a growing number of works that are being produced by Strategic Studies Institute (SSI) scholars—in the U.S. Army War College (USAWC) Press and in other professional and academic venues—on the subject of armed robotic systems. It is projected that these systems will have an immense impact on the future conduct of land warfare. Indicators of their revolutionary and disruptive capabilities can already be witnessed with the initial establishment and buildup of the U.S. armed drone program centered on Predators, and later Reapers, since late 2001. Armed robotic systems will not only be utilized by the U.S. Army and its sister services; but also by allied militaries, as well as our opponents, including belligerent state and even nonstate entities, in battlefield environments as well as insurgencies, and by means of terrorist acts.

With these thoughts in mind, it is foreseen that the reader will find this unique monograph a worthy addition to the ongoing SSI scholarship in this topical area. While its concluding section may raise more new questions than it answers, a key component related to our maturing understanding of the new strategic realities armed robotic systems may pose is to gain greater knowledge of the broader military historical context within which these advanced weapons systems are emerging. Once such knowledge is gained, the Army and the other services need to act upon it in order to create the force structure and doctrine required to field armed droids and drones for continued U.S. war-fighting dominance.

DOUGLAS C. LOVELACE, JR.
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ROBERT J. BUNKER was the 2015 Futurist in Residence, Behavioral Research and Instruction Unit at the Federal Bureau of Investigation (FBI) Academy in Quantico, VA. Currently, he is an adjunct research professor at the Strategic Studies Institute (SSI) of the U.S. Army War College (USAWC). He is also an adjunct faculty member, Division of Politics and Economics at Claremont Graduate University, and a non-resident counterterrorism fellow with TRENDS Research & Advisory in Abu Dhabi, United Arab Emirates. Past professional associations include: Distinguished Visiting Professor and Minerva Chair at SSI, USAWC; Chief Executive Officer, Counter-OPFOR Corporation; adjunct faculty, School of Policy, Planning, and Development, University of Southern California; terrorism instructor, California Specialized Training Institute, California Office of Emergency Services; staff member (consultant), Counter-OPFOR Program, National Law Enforcement and Corrections Technology Center-West; fellow, Institute of Land Warfare, Association of the U.S. Army; adjunct faculty, National Security Studies M.A. Program and Political Science Department, California State University, San Bernardino, CA; and faculty, Unconventional Warfare M.A. Distance Education Program, American Military University. Dr. Bunker has delivered more than 200 presentations—including papers and training—to military, law enforcement, academic, and policy audiences, including U.S. congressional testimony. He has hundreds of publications, including: edited books and booklets, reports, chapters, articles and essays, response guidance, subject bibliographies, and encyclopedia entries in academic, policy, military, and law enforcement venues. Among these are *Studies in Gangs and Cartels*, with John P. Sullivan (Routledge, 2013), and *Red Teams and Counterterrorism Training*, with Stephen Sloan (University of Oklahoma, 2011); and edited (and co-edited) works including *Global Criminal and Sovereign Free Economies and the Demise of the Western Democracies* (Routledge, 2014), *Criminal Insurgencies in Mexico and the Americas: The Gangs and Cartels Wage War* (Routledge, 2012), *Narcos Over the Border: Gangs, Cartels and Mercenaries* (Routledge, 2011), *Criminal-States and Criminal-Soldiers* (Routledge, 2008), *Networks, Terrorism and Global Insurgency* (Routledge, 2005), and *Non-State Threats and Future Wars* (Routledge, 2002). Dr. Bunker holds university degrees in political science, government, social science, anthropology-geography, behavioral science, and history.

SUMMARY

The fielding of armed robotic systems—droids and drones that are teleoperated, semi-autonomous, and even autonomous—has been slowly but surely transitioning from pure science fiction into military reality on the battlefields of the early 21st century. These systems currently have no artificial intelligence (AI) whatsoever and, in most cases, are simply operated by soldiers (and on occasion terrorists and insurgents) utilizing hardline cables and laptop-like controllers, although wireless and satellite systems exist for the more sophisticated national armed drone programs. Near-term future prototypes are likely to have, at best, independent response capabilities similar to a trained animal, due to the incorporation of expert system programming. Projections out even further, however, have raised concerns that these emergent weapons systems, possessing semi-autonomous and autonomous capabilities, could ultimately have the potential to evolve beyond the machine stimulus and response level, eventually incorporating varying degrees of weak AI, and one day possibly even achieving a basic form of self-awareness.

This monograph will initially discuss the weapons systems life cycles analytical approach, which is militarily historical and qualitative in its methodology. This approach distinguishes between the experimental (entrepreneurial), institutionalized, ritualized, and satirized (or romanticized) phases that exist for an individual weapons system. It will then draw upon three case studies related to the knight, the battleship, and the tank in order to explain this militarily historical process and provide the needed context in which to strategically understand the expected trajectory that

armed robotic systems may begin to progress through, if earlier weapons systems developmental patterns hold true. Given the U.S. Army's great reliance on armored forces in the modern era, special attention has been afforded to the tank. Not only is this weapons system undergoing its own process of life cycle phase progression into what can be argued is its ritualized phase, but it is also projected that, at some point in the future, armed robotic systems will be co-fielded in coordination with tank forces.

Derived from the analysis conducted in this monograph, armed robotic systems can be readily recognized as still being in their initial experimental (entrepreneurial) life cycle phase. Modern militaries—with the United States in the lead—have been engaging in a trial and error process of developing and fielding these systems for about 15 years. This entire process is a result of the Central Intelligence Agency (CIA) initially placing air-to-ground missiles (AGM) on a Predator drone in 2001. This event was prompted by a mission in October 2001, directed at Mullah Mohammed Omar—the Taliban leader—as part of the global U.S. response to the 9/11 attacks carried out by al-Qaeda. Predator drones have existed since 1995, when they were first deployed to Bosnia. Until the attempted targeted-killing of Mullah Omar, however, they had only been utilized for intelligence, surveillance, and reconnaissance (ISR) missions.

Drawing upon this monograph's analysis, the emergence of armed robotic systems and the strategic questions pertaining to them can be better placed in historical context, that is, as they relate to military technical advances, identifiable weapons systems life cycle developmental patterns, and their interactions with changes in warfare over time. The following questions of immediate warfighting importance—given the new strategic realities that armed robotic systems likely portend—and the analytical responses to them are provided in this manuscript:

- What threat and/or technological advancements are armed robotic systems being fielded to contend with?
- What present weapons systems may armed robotic systems make obsolete?
- How are armed robotic systems more technologically advanced (and have more energy potential at their disposal) than the legacy weapons systems they may be eventually replacing?
- How do we know when we have achieved the armed robotic systems′ institutionalized life cycle phase?
- How many years will the armed robotic systems′ experimental life cycle phase span?
- What are the implications of the ritualized life cycle phase of the tank on the experimental fielding of armed robotic systems?
- What are the implications of fielding armed robotic systems—and for that matter, industrial robots—vis-à-vis the integrity of the American middle class?
- What are the implications of armed robotic systems proliferation—especially semi-autonomous and autonomous systems—on the human species?

A number of initial recommendations have been generated for U.S. Army and Joint force personnel pertaining to the emergence of armed robotic systems on the battlefield. These recommendations are not meant to be authoritative but rather, given the present experimental nature of armed robotic systems as their initial prototypes and fielding is being worked out, to be simply taken as educated guidance. These recommendations pertain to the following thematic areas:

- Leadership Education;
- Strategy Development;
- Intelligence; and,
- Research and Wargaming.

In summation, the strategic implications of the robotics revolution upon us cannot be overstated. The robots are not only coming—they are here—and for future U.S. national security requirements, we will need to have a military mastery over them. Hence, our present and future decisions related to armed robotic systems emergence on the battlefield—and the command and control (C2) methodologies directing them—will result in near-term and future force structure end states that will have a fundamental impact on the U.S. conduct of war in the coming decades. These decisions will be a major determinant concerning the ability of the United States to retain dominance as the primary global military power well into the mid-21st century.

ARMED ROBOTIC SYSTEMS EMERGENCE: WEAPONS SYSTEMS LIFE CYCLES ANALYSIS AND NEW STRATEGIC REALITIES

The fielding of armed robotic systems—droids and drones that are teleoperated, semi-autonomous, and even autonomous—has been slowly but surely transitioning from pure science fiction into military reality on the battlefields of the early 21st century. These systems currently have no artificial intelligence (AI) whatsoever, and in most cases, are simply operated by soldiers (and on occasion terrorists and insurgents) utilizing hardline cables and laptop-like controllers, although wireless and satellite systems exist for the more sophisticated national armed drone programs. Near-term future prototypes are likely to have, at best, independent response capabilities similar to a trained animal due to the incorporation of expert system programming. Projections out even further, however, have raised concerns that these emergent weapons systems, possessing semi-autonomous and autonomous capabilities, could ultimately have the potential to evolve beyond the machine stimulus and response level, eventually incorporating varying degrees of weak AI, and one day possibly even achieving a basic form of self-awareness.

The fielding of such armed robotic systems and the broader implications this entails has been increasingly discussed in works generated by military scholars associated with the Strategic Studies Institute (SSI), U.S. Army War College (USAWC). The origins of these insights date at least back to the Robotics and Contemporary/Future Warfare panel, 20th Annual Strategy Conference, "Strategic Implications of Emerging Technologies," held April 14-16, 2009.[1] Steven Metz, the SSI Director of Research, has since gone on to write four essays on this subject related to the future of roboticized warfare (2012), the coming Landpower robot revolution (2014), the inevitable emergence of military robots (2016), and military challenges and opportunities of the coming robot revolution (2016).[2] The present author, a former SSI Minerva Chair, has written essays on virtual martyrs (2014), remote controlled firearms (2015), a conference brief on robotics and military operations (2015), a monograph on terrorist and insurgent use of unmanned aerial vehicles (2015), and a report concerning terrorist and insurgent teleoperated sniper rifles and machine guns (2016).[3] Finally, SSI Director Douglas Lovelace, Jr., recently published a large collection of primary documents—along with commentary—on autonomous and semi-autonomous weapons systems (2016).[4] This monograph builds upon these armed robotic systems-focused efforts by not only looking into the present and then raising questions and insights about the future, but also by drawing upon the near, intermediate, and far historical past, to help portray both the evolutionary and revolutionary aspects of their emergence, and their interrelationship with the changing nature of early 21st-century warfare.

With the preceding context in mind, this monograph will initially discuss the weapons systems life cycles analytical approach, which is militarily historical and qualitative in its methodology. This approach distinguishes between the experimental (entrepreneurial), institutionalized, ritualized, and satirized (or romanticized) phases that exist for an individual weapons system. It will then draw upon three case studies related to the knight, the battleship, and the tank in order to explain this military historical process and provide the needed context in which to strategically understand the expected trajectory that armed robotic systems may begin to progress through, if earlier weapons systems developmental patterns hold true. Given the U.S. Army's great reliance on armored forces in the modern era, special attention has been afforded to the tank. Not only is this weapons system undergoing its own process of life cycle phase progression into what can be argued is its ritualized phase, but it is also projected that, at some point in the future, armed robotic systems will be co-fielded in coordination with tank forces. The emergence of armed robotic systems is then analyzed from the perspective of their being in the early stages of the experimental life cycle phase. Additionally, this monograph then discusses the new strategic realities that exist vis-à-vis the emergence of armed robotic systems by means of posing and responding to queries of immediate warfighting importance, as well as additional queries and responses to broader national security implications related to the future of the American middle class and even humanity itself. Finally, a number of short recommendations will be provided to help get the U.S. Army better focused on this new emerging component of warfare derived from the fielding of armed robotic systems.

WEAPONS SYSTEMS LIFE CYCLES

Weapons systems life cycles analysis dates back to original research primarily from the late 1980s and early 1990s that has only been sporadically published.[5] For this reason, it is relatively unknown in most military science analytic circles. Within it, four life cycle phases have been identified—experimental, institutionalized, ritualized, and satirized—that can be utilized to better understand and analyze dominant weapons technologies development over the last 2,500 years of Western military affairs. The life cycle approach can be applied to both mobile (field) and static (fortification) land warfare systems, as well as naval and military aircraft systems, and as it will be shown, also to emerging armed robotic systems. Historically, weapons systems life cycle phases were initially measured over the course of centuries; however, since roughly the 1830 timeframe, "historical compression" has taken place that has resulted in some life cycle phases spanning mere decades. Figure 1 portrays the four weapons systems life cycle phases and the dominant theme related to each of them.

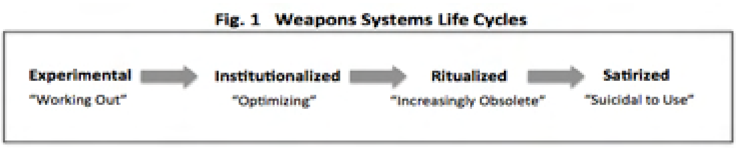

Figure 1. Weapons Systems Life Cycle Phases.

The first phase of a weapons systems life cycle is the experimental one. In the start of this phase, a new weapons technology has emerged that shows great promise for battlefield use; but the preexisting military forces and the societies that they represent do not understand how to properly configure the novel weapons system, much less field and logistically sustain it. The future potentials of the emergent weaponry, however, are apparent. This awareness is critical in light of the current weapons systems state-of-the-art that exists, which has exhausted is own future use potentials (see the ritualized life cycle below). For this reason, both the preexisting military forces and their societies are willing to invest the time and effort into working out how to configure, deploy, and sustain new weapons technology. This weapons systems life cycle phase is marked by trial and error experimentation and is entrepreneurial in nature. It is so entrepreneurial, in fact, that typically mercenary personnel or younger officers—or, centuries ago, nobles—initially championed the disruptive new weapons technology in the face of entrenched military force and societal interests arrayed against its development. As an example, master gunners during the latter Middle Ages were typically military entrepreneurs who owned their own siege artillery and worked under contract with noblemen. While viewed as being in league with demonic forces for utilizing "fire and brimstone" devices, they were readily contracted due to their arcane knowledge that allowed castles to be effectively sieged.[6]

The second phase of the weapons systems life cycle is institutionalized in nature. The new weapons technology has been figured out by the military forces and their societies, and they can create, field, and sustain what has become a mature weapons system. The focus of this life cycle phase is optimization of the weapons systems derived from a specific energy source, and the technologies that exploit it. Training and procedures become standardized, since what works and what does not work concerning that weapons system operation is understood. Arms and armor are utilitarian in nature, with a pragmatic compromise reached between weight, speed, and combat power. For military forces, this is bureaucratically the most desirable life cycle stage—in essence, their comfort zone—with doctrine synchronized with the state-of-the-art weapons systems and standard operating procedures determined. Military force training and educational institutions are both effective and efficient in their activities and produce soldiers well versed in contemporary warfighting theory and practice. For example, the origin of the Prussian goose step—when conducted by Frederick the Great's musket carrying foot soldiers of the mid-to-late 18th century—was actually due to its great military utility. This standard operating drill allowed Frederick's troops to precisely form and advance in columns and then quickly deploy into lines in order to mass superior firepower on the battlefield, giving the Prussians increased lethality soldier-for-soldier over the competing European armies of the era.[7]

The third phase of the weapons systems life cycle is the ritualized phase. From an energy exploitation and efficiency perspective, a weapons system has reached the end of its S-shaped curve (sigmoid function), where additional effort and expense placed into weapons system development yields increasingly diminishing returns. Historically, weapons systems that have entered into this life cycle phase have become heavier and heavier in nature due to the emergence of more capable battlefield threats. As a result, these weapons systems costs also dramatically rise. This phase is very dangerous for military forces and their societies because, being conservative in nature, they are initially unwilling to acknowledge that the state-of-the-art weapons systems they are building, fielding, and sustaining are slowly becoming obsolete on the more technologically advanced battlefield that is emerging. Vested military and societal—including economic—interests will politically fight to make sure the position of their weapons systems as the dominant one is not challenged, and, at some point, may engage in denial and delusional thinking concerning its contemporary effectiveness. In a desperate attempt to keep the weapons system fielded, bolt-on capabilities may even be resorted to in an attempt to modernize it and retain its place on the battlefield. When questions of doctrinal effectiveness are raised, the response of "If it ain't broke, don't fix it" or "We have always done things this way." are provided, rather than ones focusing on basic warfighting utility. Normally, it requires catastrophic defeat on the battlefield—in some instances more than once, if not enough blood was initially spilled—for intransient military and societal interests invested in the failing weapons systems to recognize that a new age of warfare has emerged. We can see this with the dogged adherence to crossbowmen in some regions of the continent and longbowmen in England, after *arquebusiers* (soldiers utilizing early muzzle loading firearms) had proven their battlefield superiority over the older weapons systems.[8]

The fourth phase of the weapons systems life cycle is the satirized phase. When this life cycle stage has been reached, the weapons systems have typically already been removed from the battlefield. They are universally regarded as obsolete weapons systems that modern military forces and their societies have moved beyond. Only primitives would field such weapons systems—which are both comical and pathetic in their own right—as they are viewed by contemporary military personnel as being suicidal to utilize. For example, the quote "Whatever happens we have got the Maxim Gun, and they have not"—relating to late 19th-century British imperialism against indigenous peoples wielding spears—signifies that Europeans had long moved beyond basic battlefield shock weaponry.[9] A contrasting component of this life cycle phase may also be the expression of a longing for, or romanticizing about, days gone by, centering on the old weapons system and those heroic military personnel who once utilized it. As an example, the trope related to the bygone age of "Wooden Ships and Iron Men" refers to the bravery of the men who once were associated with the "Fighting Sail" and "Ship of the Line" of the mid-17th and early 19th centuries.[10]

Three weapons systems life cycle case studies—focusing on the early 9th through the mid-16th-century **knight**, the mid-19th through the later 20th-century **battleship,** and the early 20th through the early 21st-century **tank**—will be provided. This author suggests—and will detail in a later section—that we have seen the development, maturation, and eventual obsolescence of the knight and the battleship over the course of history. More recently, we have witnessed the 20th-century experimental and institutionalized phases of the tank transitioning into its present ritualized life cycle phase. We are witnessing the emergence of armed robotic systems (armed droids and robots) into what will be looked back upon as the experimental phase in their life cycle.

These historical case studies thus are instructive, vis-à-vis the contemporary rise of robotics and autonomous systems, because they help to place in strategic context the patterns of weapons systems development projected to take place that will influence the ongoing emergence and military evolution of droids and drones on the battlefield. It is, therefore, imperative to investigate these previous weapons systems' case studies in some detail.

The Knight

The knight was a new weapons system initially fielded by the Western Europeans as a counter to the depredations of the light horse cavalry raiders—such as the Magyars from the Hungarian plain, the Arabs from the Iberian Peninsula, and the Saracens from North Africa—in the 9th and 10th centuries.[11] To this list of raiders can be added marauding Viking war parties that would sack villages and towns and plunder the countryside. They utilized long ships outfitted with both a sail and oars and moved by means of the surrounding seas and inland waterways.[12] The raider threat, be it light horse or seaborne based, enjoyed mobility advantages over the defending infantry levees and household troops belonging to local strongmen and the Frankish, Italian, and German dynasties. They could successfully engage in a hit-and-run raid, and then escape before defending forces arrived or, if mounted and forced to fight, enjoyed superior tactical speed and standoff fighting with their use of the bow and light lance.

Experimental Phase

As early as the Battle of Tours in 732, which resulted in the Frankish defeat of a mounted Arab army by Charles Martel, it became readily apparent that Western Europe was in dire need of cavalry forces for homeland defense purposes. In the battle, the Frankish host created a large infantry square to repel the Umayyad cavalry in the meeting between the two armies. It is generally thought that the Franks rode to the battle on horseback and fought dismounted in a strong defensive position—though some analysts have suggested that Frankish cavalry may have also taken part in the engagement.[13] Over the ensuing decades, under the Frankish leaders Charles Martel, Pepin the Short, and then Charlemagne—the founder of the Holy Roman Empire—the pre-conditions for the system of feudalism were gradually established in Europe, along with the dedicated breeding and raising of horses for military purposes. While these horses may have only initially been used for logistical transport (as took place at Tours), they took on an increasingly direct combat role over time as mounts for Frankish cavalry forces.[14] Thus, the experimental life cycle phase of the knight began by the early 9th century with the initial fielding of cavalry forces by the Carolingian dynasty, and its subsequent fielding by the Ottonian dynasty in the early 10th century and by the early Capetian dynasty in the later 10th century. (See Table 1 for the knight life cycle phases.)

LIFE CYCLE	TECHNOLOGIES	SYSTEMS	BATTLES
Experimental (Entrepreneurial)	Stirrup (9th century) Prick Spurs (9th century) Saddle (9th century) Horse Shoes (early 9th century) Thrusting (Hatch) Spear (9th century) Spatha Sword (9th century) Kite Shield (10th century) Chain Mail Suit (9th century) Nasal Helmet (9th century)	Carolingian (9th century) Ottonian (early 10th century) Early Capetian (late 10th century)	Fontenoy (841) Leuven (891) Augsburg (910) Merseburg (933) Lechfeld (955)
Institutionalized	Horse Shoes; Advanced (11th century) Lance (11th century) Arming (Cruciform) Sword (10th century) Cantled Saddle (mid-11th century) Heater Shield (later 12th and early 13th century) Rowel Spurs (14th century) Chain & Plate Suit (14th century) Enclosed Helmet (late 12th century) Great Helm (mid-13th century) Mail Trapper (13th century) Stronger Horse Breeds (ongoing)	Norman (11th century) Knights Hospitaller (12th century) Knights Templar (12th century) Plantagenet (12th century) Hohenstaufen (12th century) Teutonic Knights (late 12th century)	Hastings (1066) Dorylaeum (1097) El Mansura (and Fariskur) (1250) Mons-En-Pévèle (1304)

Table 1. The Knight.[15]

LIFE CYCLE	TECHNOLOGIES	SYSTEMS	BATTLES
Ritualized	Plate Suit (early 15th century) Flanged Mace (early 15th century) Jousting Lance (15th century) Jousting Shield (15th century) Jousting Plate Suit (late 15th century) Full Barding (mid-15th century) Embossed Armor & Shield (15th century)	Military Order Demise (14th century) Chivalric Order Rise (14th century)	Crecy (1346) Poitiers (1356) Agincourt (1415) The Herrings (1429) Nancy (1477) Bicocca (1522)
Satirized (Romanticized)	Magic Sword Second Hand Armor	King Arthur's Knights Roland The Knight Don Quixote	Camelot (1485, ± late 5th century) Charlemagne's Era/Fantasy (1516, early 9th century) Windmills "Giants" (1605, 1615)

Table 1. The Knight. (cont.)[15]

The basic military puzzle faced by the Carolingians during this historical period was how to take their legacy foot soldiers, mount them on horses as effective cavalrymen, and then, as a society, sustain the fielding and maintenance of such a fighting force. This is something the ancient Romans—for all their grandeur and military prowess—were unable to successfully achieve. The basis of their combat forces had been the infantry legion—backed up by superb siege, field fortification, and logistics capabilities—but not cavalry units.[16] This is because medieval civilization would be ultimately configured around a more advanced energy and technical base—animal versus human motive power and far more sophisticated metallurgy—than that found in the classical world of the early Greeks and Romans.

The initial process of mounting Frankish soldiers on horseback was a trial-and-error affair. Infantry arms and armor are not suited for mounted use, and certain pieces of hardware are also needed for the horse itself to serve as a fighting platform. It was entrepreneurial in the sense that there was no precedent concerning how to do this—much less any existing doctrine to address it—with this capability built from the ground up. A similar experimental process took place in what had been the Eastern Roman Empire with the emergence of the Byzantines and their eventual fielding of sophisticated cavalry turmas.[17] As a result, the Franks learned that a mail coat did not protect a rider's vulnerable legs, a round shield resulted in the rider's left knee being vulnerable to attack, a short sword was not long enough for cavalry attack purposes, and the kinetic force behind a spear thrust would too deeply impale the intended target, rendering the weapon subsequently useless. For the proto-knight, a chain mail suit and a nasal helmet emerged in the 9th century to provide better mounted-protection. Additionally, the kite shield—protecting the left knee and the neck—developed in the 10th century. The thrusting (hatch) spear, utilizing a crossbeam to limit spearhead penetration, and the spatha sword, providing greater length, were also used to outfit the mounted 9th-century Carolingian warrior. Concerning the mount itself, roughly made horseshoes protected the hooves, basic stirrups and a saddle kept the rider on the horse, and prick spurs were used to prompt the horse forward in the 9th-century.[18] The thrusting spear would have been likely used underhanded and, more often than not, thrust into the target by the rider himself, rather than utilizing the full kinetic energy of the horse, by securing the spear in the crux of the arm, which would have unseated the rider from his primitive saddle.

No evidence of horse barding (i.e., armor use) existed during this lifecycle phase, as fabricated metal represented both a limited and expensive commodity, and early warhorses likely would not have been able to sustain the extra weight placed upon them, unlike the later medieval breeds. Boiled leather, used as a primitive *chanfron* (equestrian face armor), however, could possibly have been utilized in some instances during the later stages of this phase.[19]

Some of the battles that took place during the knight's experimental life cycle phase were: Fontenoy in 841, Leuven in 891, Augsburg in 910, and Merseburg and Lechfeld in 933 and 955, respectively. Given the available details regarding the historical period in question, the specifics of these engagements, and information concerning the early knightly equipment utilized in them is relatively scarce. The Battle of Fontenoy took place during the chaos of the Carolingian civil war and resulted in the Treaty of Verdun in 843, effectively splitting the Holy Roman (i.e., Frankish) Empire into what would later become the modern states of France, Italy, and Germany. At Leuven, the forces belonging to one of the early German kings of the Carolingian line stormed a fortified Viking base and ended their raids against his lands. This battle took place about 5 years after the siege of Paris that involved about 30,000 Viking warriors. The Vikings had reached their pinnacle of power during this era, and were one of the factors behind the development of feudalism—and institutionalized knights—in Europe, due to the breakdown of central authority that resulted in the emergence of strong point defenses under localized warlords. In the next series of 10th-century battles, the light cavalry forces of the Magyars achieved a victory over the Franks at Augsburg, only to be crushed by the feudal cavalry forces of King Otto at Merseburg and then again at Lechfeld, effectively ending their raids.[20]

Institutionalized Phase

The institutionalized phase for the knight went hand-in-hand with the emergence of the stone castle—that protected the lord, his family, and his retainers—and the animal and crop focused manor economy supporting it. This was a very different and more technologically advanced form of defense than the earlier Carolingian burgwards. Those larger forts represented community-based defenses utilizing wooden walls placed around towns. As central authority collapsed in Europe, a patchwork system of vassalage, fiefs, and obligatory military service spread across it—as did the knight as the dominant land warfare weapons articulation.

The knight, during this life cycle phase, was provided with a true lance by the 11th century that could be placed in the crux of the arm for better energy transference from a charging mount. This was made possible with the development of the cantled saddle during the mid-11th century. This saddle had raised back (cantle) and front (pommel) components that better secured a knight onto a warhorse. The spatha-type sword was also further optimized, and had developed into what is known as the arming sword in the 10th century. This weapon had a slightly tapered blade used for cutting, a cruciform shape with a larger cross-guard, so the hand would not slip onto the blade, and a larger pommel at the back of the grip so the hand could more securely hold it. For better knightly protection, the enclosed helmet was fielded in the late 12th century to cover the face and the great helm came into use in the mid-13th century to provide additional protection to the head. As threat weaponry—from both opposing knights and infantry forces—became more deadly, the chain and plate suit then emerged in the 14th century. This body armor provided increased solid metal plate protection to the chest, arms, groin, and legs, while still allowing flexibility with chain armor coverage of the body joints. This came, however, with the cost of increased armor weight vis-à-vis the earlier chain mail suit that dominated for most of this life cycle phase and offered a better tradeoff between protection and mobility for the knight.[21] The heater shield dating from the late 12th and early 13th century developed from the earlier kite shield also used during this phase. It was further optimized for mounted combat by a reduction in size and weight, but still provided adequate protection to the vulnerable left side of the body of a mounted knight—though some increased left knee vulnerability may have been accepted in return for a shield surface area conducive to the placement of heraldic symbols.[22]

The warhorse also saw technical upgrades, the first of which were more refined forms of horseshoes developing from the 11th century onward, with bronze horseshoes giving way to iron horseshoes and the use of horseshoes themselves becoming more common. Then the mail trapper (chain mail armor for a horse) was fielded in the 13th century. This barding was created so that an unarmored mount could not be targeted—as it had been in some earlier battles—as the weapons system's weak point in order to unseat an armored knight. Rowel spurs—which have more painful prickly blades and a jingle, making a mount nervous—then emerged in the 14th century. These spurs were better suited to promoting a horse forward into combat than the earlier prick spur design.[23] Further, a biological upgrade also took place for the mount, with larger and stronger horses such as the destrier being bred to carry more knightly armor, as well as later horse armor, and to provide an even more elevated platform for advantage in shock combating against opposing cavalry and infantry forces.

Some of the dominant institutionalized knightly forces during this phase were those fielded by the Normans in the 11th century, and the Knights Templars, the Plantagenets, and the Hohenstaufens in the 12th century, and the Teutonic Knights in the late 12th century. Training for knights became standardized during this phase by means of the apprentice system based on young nobles and promising commoners (as sergeants—household knights) becoming pages at the age of 7, squires at the age of 14, and knights at the age of 21. Field training included tournaments based on actual battlefield tactics and some maneuvers. Basic doctrine developed with banners, trumpets, lance pennons, and heraldic devices on shields serving as means of troop identification and communication for limited command and control (C2) purposes. The military-religious orders went a step further and wrote down their doctrine, such as the *Rules of the Knights Templar* that was created in 1130. As in the case of the selective breeding of horses to produce larger warmounts, youths on the path to knighthood—either being nobility or favored by nobility (e.g., household knights)—enjoyed considerably more protein in their diets and martial exercises, opposed to the rest of the medieval populations, which further physically optimized their performance.[24]

Examples of institutionalized knightly battles that took place initially can be seen with the Battle of Hastings in 1066. In that engagement in southern England, the ad hoc English army, composed of mostly infantry backed up by some archers, was defeated by a combined arms force of infantry, archers, and cavalry belonging to the Normans, who had invaded from France. The Norman knights in the battle were repeatedly able to separate groups of defenders from the main English army and then destroy them in piecemeal fashion.[25] The battle portrayed how a bastard son of a foreign noble—William of Normandy—could, during this life cycle phase, win the English crown by force of arms and become forever known as the Conqueror. In 1097, at Dorylaeum in Anatolia, a battle took place between a large Crusader army and a much smaller Seljuk Turkish force. The Turks used light cavalry armed with bows against the Crusader infantry and knights. As took place during much of the Crusades, the knights were initially invulnerable to the arrows, but when they would lose their mounts, they could become incapacitated if too many arrows struck them. However, if the knights could somehow engage in close combat with the Islamic light cavalry, they would achieve victory. From the perspective of losses, the battle ended in a draw, but the Crusaders with their far larger numbers won the field and ended up looting the Turkish camp.[26]

The next illustrative battles are those of El Mansura and Fariskur, taking place in 1250, in Egypt. In these tandem battles between a Crusader army and the Ayyubid dynasty, the entire Crusader force—which included thousands of knights and their retainers—was destroyed, with those not killed outright, captured and enslaved. The aftermath of the battle saw the ransoming of a French king and many captured Crusaders. This battle is a prime example of the fact that, even when a weapons system—such as the knight—is in its institutionalized phase and an army is configured around it, disaster can still strike. Finally, at Mons-en-Pévèle in 1304, French and Flanders forces took part in one of an ongoing series of engagements, in which the infantry forces of Flanders fought the more balanced French infantry and cavalry forces. This battle was proclaimed a French victory—they drove the Flemish from the field—even though a royal French banner had been taken, and the casualties on both sides were about even. This battle—and the French disaster at the Battle of the Golden Spurs a few years earlier—signified that resolute infantry forces armed with halberds, pikes, and related weapons (precursors to the use of the longbow and early firearms which would usher in the knights ritualized phase) could, in some instances, stand up against knightly cavalry forces and, if properly utilized, even defeat them.[27]

Ritualized Phase

The ritualized life cycle phase for the knight resulted from new weapons systems being fielded—ultimately more technologically advanced—that would render the knight obsolete as a weapons system. The twilight of the knight was not an overnight affair, given the low rate of technical change in the medieval and early modern eras, with the ritualization process taking about 175 years to take its course. In a final effort to defensively protect the knight and their mount, full plate armor emerged in the early 15th century and full barding (also made of plate) by the mid-15th century. This armor was expensive, heavy, and further limited knightly mobility. Plate, however, was almost impervious to an arming sword striking it, resulting in the flanged mace, a crushing rather than a cutting weapon, being utilized by knights as a secondary weapon to the lance in the early 15th century. Still, plate armor could be vulnerable to the armor piercing head of an English longbow arrow, the bolt from a later mechanical powered (as opposed to human powered) crossbow, the blow from a halberd that operated somewhat like a can opener, the bullet of an early firearm, or a dirk or rondel dagger hammered into the arm joint of a knight that had been unhorsed and immobilized on the ground. As can be expected, plate quality progressed along with the threat weapons systems in defensive and offensive iterations lasting generations. Sometimes, plate armor could be breached and, in other instances, still fully protect the wearer.[28]

As part of the knight's later ritualization process, two other arms and armor trends emerged. The first turned knightly combat into entertainment by means of making the tournament—which before had battlefield utility—into a game of sport. The jousting lance and shield were developed in the 15th century, along with jousting plate armor later in the same century. This went in tandem with the elimination of the earlier knightly military orders—such as the Knights Templars in the early 14th century—or their transformation into ceremonial bodies. At part of the same process, new chivalric orders emerged, such as the Order of the Garter in England in the mid-14th century, whose members were politically connected, but not necessarily warfighters. Additionally, rather than fulfilling the obligated military service to their lord as a vassal, a knight could buy their way out of it. This was preferable to the great nobles, because they could then obtain money to afford the services of mercenary troops who were more effective on the battlefield. The second trend in arms and armor taking place was etching designs into swords, shields, and armor, creating expensive inlays of silver and gold, and commissioning artistic armor pieces. Such arms and armor—almost always plate—was worn to show societal status and actually would be detrimental to use, given the vulnerable lance traps its uneven surface would provide.[29]

As seen in Table 2, the arms and armor weight of a European knight (and the warmount's barding) markedly increased as the system transitioned from the experimental through the institutionalized and then into the ritualized life cycle phase. For the first 300 years, knights carried less than 50 pounds of arms and armor, with most of the weight being carried in the latter half of its existence as a weapons system. At this point, the end of the weapons system's S-curve had been reached. While the slow demise of the knight had long become an accepted fact in European land warfare, it was not until the fielding of the Spanish heavy musket in 1530 that the knight was universally deemed obsolete. That musket performed like an anti-knight gun, with a 2-ounce lead ball traveling at such a high velocity that not enough armor could be placed on a knight to survive the impact and still have any form of fighting mobility left.[30] The more advanced battlespace dynamics and increased energy foundations of the modern era had finally won out over the last vestiges of medieval civilization, just as Charles VIII's siege artillery, by 1498, had reduced the traditional castle into rubble. The arms and armor of the knight have since ended up in old castles and museum collections. Still, it should be remembered that, with the eventual demise of the knight, the need for heavy cavalry itself did not fade away from European land warfare. Rather, a new cavalry weapons system would emerge in the mid-16th century that was much lighter. This combatant would be equipped with a helmet, a breastplate to turn a pistol ball shot, heavy boots to provide some protection to the legs, two or three wheel-lock pistols to perform the caracole maneuver, and a sabre for cavalry charges.[31]

Battles that are illustrative of the increasing ritualization of the knight begin with Crecy, fought in 1346. This engagement was part of the campaigns of the Hundred Years' War between the English and the French. The battle not only saw the initial deployment of the early field cannon, but more importantly, signified the very beginnings of the knight's obsolescence as a weapons system. The superior use of terrain, benefits of wet weather, and combined arms approach of the greatly outnumbered English allowed them to create a killing zone in front of their defensive position. More than 1,000 French knights repeatedly charged into this zone and were cut down—along with their mounts—by volleys of armor piercing arrows shot off by massed longbowmen. As part of the ongoing English and French war, that battle was followed up by that of Poitiers taking place in 1356, and Agincourt in 1415. At Poitiers, French knights and their retainers were once again defeated. As at Crecy, they attacked up the center against a holding English infantry force, with arrows raining down on them and their mounts. However, in this engagement, they came close to punching through the lines and caused far more English casualties. Finally, at Agincourt, the French knights and their supporting men-at-arms, once again, repeated their earlier mistakes by attacking through a plowed and muddy field against a line of infantry with archers on secure flanks protected by sharpened stakes. The armor of the French knights was much heavier at Agincourt than at Crecy, which offered them better protection. However, their mounts did not have full barding, which made them vulnerable to the masses of arrows shot at them. Dismounted French knights in the battle, on the other hand, quickly became exhausted as they moved forward through the sodden fields. The end result of the battle was a slaughter of the attacking French force, with some thousands of the French knights killed.[32] The French had fallen into the deadly life cycle trap of always doing things the same way because they had worked in the past. Furthermore, they combined rigid doctrine with the hubris of seeing themselves as the only true soldiers on the battlefield, and the social betters of the common and lowly born English rabble that poured arrows down upon them and their mounts in one engagement after another.

Other representative battles of the ritualized phase included those of the Herrings in 1429, Nancy in 1477, and Biocca in 1522. The Battle of the Herrings took place between the English and a larger French and Scottish force. It was an auxiliary action involving an English supply train being interdicted on its way to the siege of Orléans. The supply train was made into a laager with sharpened stakes protecting it. The attacking Scottish infantry, followed by the French knights, were cut down by the English longbowmen and then routed in a flanking attack. At Nancy, nobles belonging to Burgundy and Lorraine engaged in a battle that included a large contingent of Swiss fighting for Lorraine. The smaller Burgundian force situated itself in a strong defensive position, but was outflanked prior to the start of the battle. It was then attacked from behind by the mass of Swiss mercenaries, who used their pike and halberds to good effect against the Burgundian knights and in the process wiped out most of their army. Then, at Biocca in the early 16th century, a French and Venetian army squared off against Habsburg forces in a battle dominated by artillery fires, *arquebusiers*, and field fortifications. In this engagement, not only were the Swiss pikemen technologically outclassed, but the cavalry forces—that included noblemen—were only used in an auxiliary role on the wings. Within this operational environment, frontal cavalry charges were considered suicidal in nature.[33]

KNIGHT	CENTURY FIELDED	ARMS & ARMOR (FOR HORSE) WEIGHT IN POUNDS	LIFE CYCLE
Carolingian: Mail Coat, Spangen Helmet, Round Shield, Wing Spear, Spatha; (No Horse Armor).	Early 9th	38 lb (0 lb) est.	Experimental
Norman: Mail Suit, Nasal Helmet, Kite Shield, Light Lance, Arming Sword; (No Horse Armor).	Mid-11th	49 lb (0 lb) est.	Institutionalized
Teutonic: Mail Suit, Enclosed Helmet, Heater Shield, Medium Lance, Arming Sword; (Mail Trapper).	Late 13th	59 lb (50 lb) est.	Institutionalized
Valois: Full Plate, Great Helm, Heater Shield, Heavy Lance, Flanged Mace; (Full Barding).	Early 15th	79 lb (75 lb) est.	Ritualized
Tudor: Jousting Armor, Great Helm, Jousting Shield, Heavy Lance; (Full Barding, Caparison).	Mid-16th	115 lb (80 lb) est.	Ritualized

Table 2. Increase in European Knight Weight (early 9th through mid-16th century).[34]

Satirized Phase

The satirized (romanticized) life cycle phase for the knight can initially be viewed in the King Arthur and Knights of the Round Table mythos written by Thomas Malory in *Le Morte D'Arthur (The Death of Arthur)* published in the late 15th century. Tales of Camelot, the magical sword Excalibur, intrigue and sorcery, and the brave and virtuous knight Sir Lancelot—whose forbidden love for the queen resulted in civil war breaking out—were all components of this early work.[35] This era saw a final surge in popularity in the tournament—as part of this weapons system's earlier ritualization process—and romanticized perceptions of knighthood, which by now was a dying institution. This work was followed a century or so later by the expressly satirical publication *The Ingenious Gentleman Don Quixote of La Mancha,* produced in two volumes in 1605 and 1615, by Miguel de Cervantes. By this time, the magic and virtuous elegance of Camelot had been replaced by the madness of a poor Spanish nobleman—brought about by the reading of too many knightly romantic novels—who goes on a quest wearing second-hand armor, on a broken down horse, and with a simple peasant farmer as his faithful squire.[36] *Don Quixote* made monsters out of windmills and was such a pathetic caricature that it universally became accepted that only a madman would dress up like a knight and go off to war on the more technologically advanced European battlefield, which had emerged. An earlier and lesser-known early 16th-century satire also exists. It was *Orlando Furioso (Mad Roland),* written by Matteo Boiardo. It focuses on the knight Roland, during the time of Charlemagne in a fantasy setting, who is mad when the lady he loves runs off with a common

Saracen foot soldier. The timing of the work signified the loss of status for the knight with the rise of gunpowder-based weaponry.[37]

The Battleship

The battleship was the successor naval weapons system to the wooden, masted-with-sails, and cannon-carrying ships of the line that sailed the high seas from the 17th through the mid-19th century. These warships had descended from 16th-century armed galleons that, in turn, had evolved from the early modern trading carracks and medieval cogs.[38] Ships of the line—also known as "battleships of the line"—were based on ratings, with the first rate warships having the most powerful broadsides of cannons. Beginning in 1815, and extending to about 1900, a number of technical advances took place that allowed for the gradual emergence of experimental battleships and the eclipse of the older ships of the line. These initial advances were seen in the smoke stacked warship USS *Demologos,* built in 1815 with its steam engine and paddle wheel; screw propellers replaced the paddle wheel on the British SS *Archimedes* completed in 1839; and in 1841, the French deployed the Paixhans gun, (developed earlier in 1822-1823, which fired exploding shells) on its warships.[39] Still, for roughly a 45-year period between 1815 and 1860, ship of the line-like ships still dominated naval warfare, although they were increasingly retrofitted with coal-fired steam engines and more lethal naval guns that could splinter wooden warship hulls.

Experimental Phase

As a result of these advances, by 1860, the first experimental battleship had been commissioned—the French warship *Gloire*. This ocean going warship signifies the beginning of the battleship experimental weapons system life cycle phase. (See Table 3 for the battleship life cycle phases.) The 5,618 ton *Gloire* relied upon armor plating over its hull for protection, was steam and screw propeller powered, and carried rifled guns that fired explosive shells.[40] The much larger British warships were then completed, HMS *Warrior* in 1861 and HMS *Black Prince* in 1862, displacing 10,315 tons with iron plating and teak backing.[41] All of these warships carried their naval guns in a broadside configuration and still retained masts and sails. The revolving turret main gun design then appeared in a retrofit of the HMS *Trusty* in 1861, which was a floating ironclad battery dating back to the Crimean War. This battery had been completed in 1855 and, along with a few other English and French ones like it, were highly influential in promoting the initial experimental battleships of the 1860s as well as the later use of armored turrets.[42] In fact, during the next year in 1862, at the Battle of Hampton Roads between the CSS *Virginia* and the armored turreted USS *Monitor*, this technical advance was utilized in combat.[43]

The other later technical developments that took place during this life cycle phase were: the use of the armor piercing shell in 1867—known as Palliser shell—that remained in service into the early 20th century; all steel hull construction, as well as the gradual elimination of sails from early battleships, beginning in the 1870s; and the initial emergence of warship radios, initially dated to 1900, with its use by both the Russian and Japanese navies during the Russo-Japanese War of 1904-1905 taking place.[44] Some notable battleships from this era were the French *Redoubtable*, commissioned in 1878, which used steel as the main building material; the HMS *Inflexible* with an underwater armor deck, commissioned in 1881, as a model for central citadel ships; and the HMS *Colossus,* commissioned in 1886, with two main breech loading gun turrets at the 1 and 7 o'clock positions to the central smokestack, with limited zones of cross-deck firing—somewhat like the HMS *Inflexible*—but also with the placement of a chart-house above the forward bridge.[45] Also of note were the USS *Texas,* commissioned in 1895, and considered America's first battleship, although it had a 2nd-class rating, two staggered main turrets, and a strange 360° perimeter smaller turret arrangement; and the HMS *Canopus,* which was the first ship of the class commissioned in 1899, with a 16,038 combat tonnage displacement, shallower draft, and additional 6-inch main guns (12 instead of 10), specifically meant for the China Station.[46]

The post-Hampton Roads naval battle representative of this life cycle phase was the Battle of Lissa that took place in 1866 between Italian and Austrian Empire forces. In this engagement, numerous ironclads with steam engines and sails participated, as well as many unarmored steam powered warships. The battle was an Austrian victory even though their fleet was outnumbered, witnessed not only rifled artillery broadsides, but also armored ships ramming each other and other unarmored warships.[47] The Battle of Manila Bay in 1898, between the U.S. and Spanish fleet, secured the United States as a great naval power in the world and resulted in the final demise of Spain's colonial empire. It was an engagement solely comprised of protected (armored) and unprotected (unarmored) cruisers or smaller warships rather than battleships. The Battles of the Yellow Sea in 1904, and Tsushima Strait in 1905, between the Russian and Japanese fleets were also fought, which culminated in a major victory for the Japanese in the later battle. At Tsushima Strait, the two fleets fielded about a dozen battleships and almost three-dozen cruisers in the battle, with most of the Russian battleships sunk in the engagement.[48] The Battle of Lemnos in 1913, which took place during the First Balkan War between the Ottoman Empire and Greece, was also composed of small fleets of pre-*Dreadnought* warships. It resulted in a Greek victory.[49] Finally, the World War I Battle of Cape Sarych, in 1914, witnessed a minor engagement between a small Russian fleet, which included five pre-*Dreadnought*-class warships, against a more modern, yet even smaller, fleet of Ottoman warships that included a very powerful and advanced battlecruiser.[50] Of these naval engagements, the ones in which the U.S. and Japanese fleets prevailed were the most significant. Due to those engagements, both nations achieved great power status and realized that only those navies with the most advanced and larger forms of battleships had any chance of prevailing in battle—of which the British were even more acutely aware.

Institutionalized

The institutionalized life cycle phase of the battleship began in 1906 with the commissioning of the HMS *Dreadnought*. Virtually overnight, the emergence of this British warship made all battleships built before her obsolete. Thereafter, all battleships were then described as either pre- or post-*Dreadnought* class warships. This sizeable warship displaced 24,466 tons of combat weight and carried five 12-inch dual-main gun batteries. She was faster, better armed, and more heavily armored than any of her predecessors. The major technical innovations of this warship that became institutionalized in future battleship and battlecruiser (a lighter armored variant) designs were as follows:

- Multiple main gun turrets of uniform size;
- Protection against underwater attack—can withstand two torpedo explosions in any position;
- Steam turbines for increased speed, lower center of gravity (which allowed for heavier armament), improved reliability, and reduced maintenance costs—resulted in more deployment time at sea;
- The ability to utilize oil fuel—signified the shift away from coal-fired engines; and,
- Tripod masting.[51]

As expected, the combat power of the HMS *Dreadnought* was quickly surpassed with new classes of battleships derived from its innovative design commissioned both by British and foreign fleets. In turn, the growth in size and firepower of U.S. post-*Dreadnought* institutionalized warships can be seen in the new post-*Dreadnought* battleship classes that were produced. The increases in combat load tonnage and main battery gun size from the *South Carolina*-class commissioned in 1910, the *Florida*-class of 1911, the *New York*-class of 1914, the *Nevada*-class of 1916, the *Colorado*-class of 1923, and the *North Carolina*-class of 1941 showcase this process. Ultimately, the tonnage and main battery size increased from 20,048 tons and eight 12-inch guns from 1910 to 52,382 tons and nine 16-inch guns for the 1941 class commissioning, with interim classes showing both incremental tonnage increases and transitional 14-inch gun batteries for the *New York* and *Nevada*-class battleships.[52] The size of the U.S. battleships—as well as those belonging to other nations—would have increased more quickly, but the Washington Naval Treaty ratified in 1923, between some of the major World War I great powers, placed a limit on their size and total fleet tonnages to stop a naval arms race. Battleships were limited to 35,000 tons standard displacement and aircraft carriers slightly less depending on the construction method utilized—derived from a new carrier or preexisting battleship hull. By the mid-1930s, the future Axis powers of World War II had generally ignored the Washington and follow-on London Naval treaties of 1930 and 1936.[53] An additional important technical development during this lifecycle phase was the later deployment of search-and-fire control radars placed on battleships. Experimental testing of these systems took place in the later 1930s. These systems were deployed on U.S. battleships in 1941.[54] The other major World War II naval powers also fielded such systems by this time, with Japan and Russia lagging a few years behind.

Institutionalized phase battleship engagements can initially be seen in the World War I naval battle of Jutland on May 31-June 1, 1916. This major battle took place in the North Sea by Denmark, and represented the archetypical and most celebrated naval engagement of the entire life cycle phase. It was comprised of more than 200 warships, and pitted the dreadnoughts and battlecruisers of the British Grand Fleet and the Imperial German's High Seas Fleet against each other—though a number of German pre-*Dreadnoughts* were also involved in the fighting. While British warship and personnel casualties were much more significant than those of the Germans, the aftermath of the battle resulted in the German fleet never again challenging the much more powerful British fleet. Of note was the use of more lightly armored battlecruisers in the opposing battle lines that resulted in their taking the bulk of the capital warship losses.[55]

The action at Denmark Straight in May 1941 is then representative of a World War II institutionalized battleship engagement. It took place between a small hoc grouping of battleships, a battlecruiser, and heavy cruisers belonging to the British and German fleets. The lone battlecruiser involved—the HMS *Hood*—was sunk in the engagement by the massive (more than 50,000 combat tonnage displacement) battleship *Bismarck*. The German victory was short lived, however, as the *Bismarck*, now all alone in the Atlantic Ocean off France and attempting to get back to a safe port, was hunted down by a sizeable British naval taskforce. While the steering mechanism of the *Bismarck* was disabled by carrier aviation during an early phase of the multi-day engagement, her fate was sealed by full broadsides from two British battleships and then her intentional scuttling.[56] The U.S. and Japanese battleship duels off Guadalcanal, in November 1942, were also representative of this battleship phase. Additionally, Surigao Strait in October 1944—as an engagement within the larger Battle of Leyte Gulf between the U.S. and Japanese fleets—represented the last clash of battleships in wartime.[57] Strategically, these naval battles were sideshows within the larger context of American and Japanese aircraft carrier operations taking place. Thus, they also symbolized the battleship's ritualized phase of growing weapons system obsolescence.

LIFE CYCLE	TECHNOLOGIES	SYSTEMS (COMMISSIONED)	BATTLES
Experimental (Entrepreneurial)	Steam Engine (1815) Explosive Shell Firing Guns (1822-1823) Screw Propellers (1839) Armor Plating (1859) Revolving Turret (1861) Armor Piercing Shell (1867) Shipboard Radio (1900)	*Gloire* (1860) HMS *Warrior* (1861) CSS *Virginia* (1862) USS *Monitor* (1862) *Redoubtable* (1878) HMS *Inflexible* (1881) HMS *Colossus* (1886) USS *Texas* (1895) HMS *Canopus* (1899)	Hampton Roads (1862) Lissa (1866) Manila Bay (1898) Yellow Sea (1904) Tsushima Strait (1905) Battle Of Lemnos (1913) Cape Sarych (1914)
Institutionalized	Uniform Main Battery (1906) Electronic Fire Control (1906) Steam Turbines (1906) Search and Fire Control Radar (1941)	HMS *Dreadnought* (1906) USS *South Carolina* (1910) USS *Florida* (1911) USS *New York* (1914) USS *Nevada* (1916) USS *Colorado* (1923) USS *North Carolina* (1941)	Jutland (1916) Denmark Strait (1941) Sinking Of The *Bismarck* (1941) Surigao Strait (1944)
Ritualized	Anti-Aircraft Batteries (1943) Cruise Missiles (1980s) Close Defense Systems (1980s) Electronic Warfare (1980s)	*Yamato* (1941) USS *Iowa* (1943; 1980s Retrofits) USS *Montana* (Canceled 1943)	Pearl Harbor (1941) Coral Sea (1942) Midway (1942) Leyte Gulf (1944) East China Sea (1945)
Satirized (Romanticized)	Alien Technology	*Yamato* (1941; Salvaged Wreck) USS *Missouri* (1944; Maritime Museum)	Space (2010; 2199) Hawaii (2012)

Table 3. The Battleship.[58]

Ritualized Phase

The beginning of the ritualized phase for the battleship can be clearly traced to World War II with the Japanese bombing of Pearl Harbor on December 7, 1941.[59] The American battleship line was in port during the attack and was severely crippled, with the USS *Arizona* and USS *Oklahoma* destroyed, and the USS *California* and USS *West Virginia* sunk, but later refloated and returned to service, along with other battleships and smaller warships having been either damaged or sunk.[60] Even after this engagement, the Japanese high command projected a final Jutland-style engagement between the battleship fleets of Japan and the United States to decide the outcome of the naval war.[61] For this reason, the monster battleships of the *Yamato*-class with 81,546 maximum tonnage and nine 18.1-inch main guns were commissioned in 1941, and 1942 for the sister ship *Musashi*. However, by the battles of the Coral Sea in May 1942, and Midway in June 1942, it was clearly evident that the age of carrier aviation had eclipsed the big guns of the armored battle line. The top of the S-curve for the battleship weapons system had been reached. With this realization, in 1943, the U.S. Navy canceled the planned USS *Montana*-class battleship with a 75,040 maximum tonnage displacement and 16-inch guns meant to compete with the Japanese super battleships. The already existing battleships in the U.S. fleet—especially the USS *Iowa*-class 64,344 maximum tonnage which began to be fielded in 1943—became relegated to shore bombardment and anti-aircraft artillery fleet protection roles with nine 16-inch, twenty 5-inch, eighty 40-mm, and forty-nine 20-mm guns mounted on them, respectively.[62] The Japanese super battleships, on the other hand, suffered a much grimmer fate for, off Okinawa in April 1945, the *Yamato* was sunk by U.S. carrier aircraft—in what was in essence a suicide mission—during the Battle of the East China Sea. The *Musashi* had earlier suffered a similar demise in October 1944 during the Battle of Leyte Gulf.[63]

A number of the *Iowa*-class battleships were then deactivated and activated on and off again during the Cold War, with a final round of 1980s retrofits (e.g., "bolt-ons") placing cruise missiles, Phalanx close-in weapon systems, electronic warfare suites, and even early scouting *RQ-2 Pioneer* unmanned aerial systems (UAS) on them in a final attempt to stave off their obsolescence and as a partial counter to the Russian *Kirov* nuclear powered battlecruisers then being deployed.[64] One of the number of factors that resulted in the passing of the battleship was its intensive manpower needs based on an older naval model derived from principles of mass industrial manpower use. The USS *Iowa* was decommissioned for the last time in 1990, the USS *New Jersey* and the USS *Wisconsin* in 1991, and the USS *Missouri* in 1992, with all four warships since being turned into floating museums.[65]

What is telling during the ritualized life cycle phase for the battleship is its increasing weight, vis-à-vis the earlier life cycle phases due to the need for more and larger armaments and heavier armor. This can be seen in Table 4, with U.S. battleships during the experimental phase displacing between 6,315 and 20,160 maximum tonnages, during the institutionalized phase displacing between 20,048 and 52,640 maximum tonnages, and during the ritualized phase displacing between 64,344 and 75,040 (canceled) maximum tonnages. What cannot be seen is that the new dominant naval warship, the aircraft carrier, which was in its institutionalized phase during World War II, displaced between roughly 25,100 to 30,260 *Yorktown*-class and roughly 30,800 to 36,380 (*Essex*-class) maximum tonnage.[66] The aircraft carrier did not have to rely upon heavy armor for defense against opposing warships because the lethality of its aircraft was measured in a few 100 miles rather than roughly 20 miles for large naval guns. Hence, the battlespace dynamics of the aircraft carrier were clearly superior to that of the battleship, just as the knight was outclassed by the similar dynamics of infantrymen utilizing the standoff Spanish heavy musket.[67]

BATTLESHIP	YEAR (COMMISSIONED)	DESIGN/MAXIMUM DISPLACEMENT (U.S. TONS)	LIFE CYCLE
Maine (2nd Class)	1895	-------/6,682	Experimental
Texas (2nd Class)	1895	-------/6,315	Experimental
Indiana (BB-1)	1895	10,453/11,523	Experimental
Iowa (BB-4)	1897	11,346/12,779	Experimental
Virginia (BB-13)	1906	15,188/16,742	Experimental
Connecticut (BB-18)	1906	17,920/20,160	Experimental
South Carolina (BB-26)	1910	17,920/20,048	Institutionalized
Florida (BB-30)	1911	24,444/26,208	Institutionalized
Nevada (BB-36)	1916	30,800/32,368	Institutionalized
Colorado (BB-45)	1923	36,512/37,621	Institutionalized
South Dakota (BB-49)	1923 Canceled	48,384/52,640	Institutionalized
North Carolina (BB-55)	1941	47,040/52,382	Institutionalized
South Dakota (BB-57)	1942	47,040/49,699	Institutionalized
Iowa (BB-61)	1943	58,240/64,344	Ritualized
Montana (BB-67)	1943 Canceled	72,800/75,040	Ritualized

Table 4. Increase in U.S. Battleship Weight (1895-1943).[68]

Satirized Phase

The final weapons system life cycle phase for the battleship would normally be satirical in nature; although, in this instance, given the great esteem still held for the old battlewagons in some nations' collective psyches, more of a romanticized perspective has so far been expressed. In the 2010 Japanese science fiction live-action film, *Space Battleship Yamato*, set in 2199, the wreck of the warship sunk in 1945 is rebuilt into a space-faring battleship derived from alien technology. In final combat against the invading Gamilas, the *Yamato* once again engages in a suicide mission—as it had originally done in the Battle of the East China Sea. In this instance, the sacrifice made by the warship and the lone captain manning it saves humanity from the dreaded aliens.[69] In the 2012 science fiction film *Battleship*—based loosely on the peg, slot, and plastic ship game of the same name—an alien invasion of Earth has begun, centered on the Hawaiian Islands, which have been isolated by a force field. The initial engagement between the alien warships and the two U.S. and one Japanese destroyers, deployed to Hawaii for a naval exercise and ending up within the force field area, resulted in their destruction. A small number of surviving officers and crew fall back to Pearl Harbor and plan a counterattack utilizing the battleship USS *Missouri* that had been turned into a floating museum. The USS *Missouri*, hastily made ready for combat, sailed out of Pearl Harbor against the alien warships with a skeleton crew comprised of museum volunteers (geriatric former crewmen) and the surviving naval personnel. In the final battle with the alien mothership, 1940s American technology, along with equal measures of improvised tactics and pure luck—as well as contemporary U.S. naval airpower, once the force field is turned off in the final climatic scene—saves the day.[70]

The Tank

The tank was the mechanical successor weapons system to the venerable cavalry mount. Cavalry was rendered technologically obsolete, vis-à-vis the static combat conditions found on the Western Front of World War I, as fortified trench lines were built from the Swiss border upwards to the North Sea. Artillery and machine gun fires covered the expanse between the trench lines. Furthermore, the ground was difficult to traverse with shell holes and fields of barbed wire impeding mobility. This resulted in cavalry charges and infantry assaults becoming suicidal in nature, with the consequence that the soldiers of entire battalions "going over the top" could be mowed down in their assault formations.[71] In an attempt to break this bloody stalemate, in early 1915, the British came up with the concept of the tank—an armored and tracked vehicular soldier transport—that would allow troops to both safely cross no man's land between the opposing trench lines and penetrate through the enemy's trenches.[72]

A number of technologies were combined to create the initial tank design—the first being the internal combustion tractor engine, which was developed in the 1890s. The gasoline traction engine replaced the earlier steam-based engine in various types of agricultural machinery and tractors.[73] The second technical advancement was the emergence of the gasoline powered crawler tracker in 1907 that utilized caterpillar treads instead of tractor wheels. It was patented and manufactured by the Holt Manufacturing Company of Stockton, California.[74] It helped to form the conceptual basis of subsequent commercial and military tracked vehicles. This was followed by the third technical advancement, which was the mounting of armor on gasoline-powered vehicles. Such initial armoring took place with the 3-ton French Charron armored car, initially produced in 1904. It was followed by a number of other armored car systems being fielded, including the Rolls Royce armored car in 1914.[75]

Experimental Phase

The experimental (entrepreneurial) phase for the tank initially began with the fielding of the British No. 1 Lincoln (Tritton) Machine and Little Willie in August and December of 1915, respectively. (See Table 5 for the tank life cycle phases.) These unarmed prototypes had rear steering wheels like the follow on Mother and Mark I designs, but were quickly outmoded, as were the steering wheels in a few years' time.[76] With the inclusion of the vehicular mounted gun, in 1916, on the British Mark I tank, the system was able to target opposing forces with either cannons (used against guns, fortifications, and defenses) or machine guns (used against infantry). The types of weapons carried were dependent on whether the design variant was "male" or "female"; still, both designs were meant to operate in coordination with one another, with the female tanks more greatly outfitted with machine guns.[77] Since early tanks were experimental in nature, they did not look like the later institutionalized weapons system, with some even having 8 or 9-man crews—and one, the 36-ton German A7V Sturmpanzerwagen, even having an 18-man crew. Hence, some of the initial designs were extremely large in size and alternately looked like a set of massive rhomboid tracks (the British Mark series), a big armored box (the French Schneider and St. Chamond), or a mobile armored fortress (the German A7V).[78] The emergence of the revolving gun turret, in 1917, on the tiny two-man French Renault FT-17 provided that light tank with better fields of fire for its main armament and helped toward the tank's later institutionalized design.[79] American experimental phase tanks that were fielded included: the M1917 tank, which was a licensed production model of the Renault FT-17; the Anglo-American MVIII Liberty, which was based on the British Mark series and initially produced to a limited extent in 1918; and the M1 Combat Car light cavalry tank, which was deployed in 1937.

Illustrative battles during the experimental life cycle phase of tanks were: Flers–Courcelette, which took place in September 1916; Cambrai, which took place in November-December 1917; Villers-Bretonneux, which took place in April 1918; and Saint-Mihiel, which took place in September 1918. Flers–Courcelette represented in the first use of tanks in battle and can be considered, at best, a tactical surprise over the defending Germans. Because so few tanks were involved—fewer than 50, with fewer than a dozen making it over to the enemy's trench lines—the initial impact of this system was somewhat limited.[80] Tanks were then used by the Allies en masse at Cambrai, portraying their operational utility. The initial attack consisted of 476 tanks that allowed for a significant penetration of the heavily fortified enemy lines.[81] Villers-Bretonneux signified the first tank-on-tank engagement, taking place at about 3 miles per hour between a handful of British Mark IVs and a German A7V. The outcome was inconclusive, with both sides taking some damage to their systems.[82] Finally, at St. Mihiel, American Expeditionary Forces were involved in an assault on the German trench lines, in coordination with early armor forces, with about 400 tanks supporting the combined American and French offensive.[83] These early engagements were reflective of the fact that early tanks were slow moving and unreliable machines subject to frequent breakdowns. Some were even prone to tipping over in the devastated terrain of no man's land and the front trench lines. Still, this weapons system proved superior to preexisting forces such as cavalry, and was a major reason the allies were able to break the trench stalemate on the Western Front.

LIFE CYCLE	TECHNOLOGIES	SYSTEMS (FIELDED)	BATTLES
Experimental (Entrepreneurial)	Internal Combustion Tractor Engine (1890s) Crawler Tractor (1907) Vehicular Armor (1904, 1914) Vehicular Mounted Gun (1916) Revolving Gun Turret (1917)	No 1 Lincoln (Tritton) Machine (1915) Little Willie (1915) Mark I (1916) Mark IV (1917) Renault FT-17 (1917) M1917 (1917) MVIII Liberty (1918) M1 Combat Car (1937)	Flers–Courcelette (1916) Cambrai (1917) Villers-Bretonneux (1918) St. Mihiel (1918)
Institutionalized	Low Hull Profile (1935) Sloped Armor (1936) Radio Equipped (1940) Gyrostabilizer (1942) Smoke Dischargers (Early 1940s)	Panzer IV (1937) T-34 (1940) M4 Sherman (1942) M48 Patton (1952) M60 (1959) M1 Abrams (1980) T-90 (1993)	Invasion Of Poland (1939) Kursk (1943) Arracourt (1944) Chawinda (1965) Golan Heights (1973) 73 Easting (1991)
Ritualized	Turbine Engine (1980) Reactive Armor (1982) Depleted Uranium Armor (1988) Digital Upgrades (2000) Electromagnetic Armor (2002) Active Missile Defense (2009)	O-I (1943) Panzer VIII Maus (1943) T28 (1945) A39 Tortoise (1946) M1A1SA Abrams (1989) M1A2 Abrams (1992)	Highway 80 and Highway 8 (1991)
Satirized (Romanticized)	Punk Paraphernalia	M5A1 Stuart (1941 With 1969 Cadillac Eldorado Sections)	Australia (1995; 2033)

Table 5. The Tank.[84]

Institutionalized Phase

The institutionalized weapons system life cycle phase of the tank was achieved by the late 1930s with the fielding of the German Panzerkampfwagen IV (PzKpfw IV or Panzer IV), and the invasion of Poland. This phase saw the merging of this weapons system with World War I Hutier (trench infiltration) tactics, along with supporting combined arms into the German Blitzkrieg (lightning war) operational approach.[85] The emergence of the tank's modern form took place, based upon a single turret with a main gun, a few machine guns for self-defense, a more streamlined profile with sloping armor, a hull length track on the right and left side of the vehicle, and a four- to five-man crew. Autoloader mechanisms would replace the need for a main gun loader crewman in some of the later tank systems. Some of the technical advances supporting the final institutionalization of the tank can be found in the low hull design of the French Char B tank fielded in 1935 and sloped armor incorporated into the French SOMUA S35 cavalry tank fielded a year later in 1936.[86] Additionally, by 1940, radio equipped tanks became standard, with the German army in support of its Blitzkrieg operational doctrine.[87] This was in contrast to French doctrine, which stressed tanks as infantry support—that reflected a still very experimental perspective—and thus did not see the need for radio equipment being placed in all their systems.

The German Panzer IV in 1937, the Russian T-34 (76 mm) in 1940, and the American M4 Sherman in 1942 can be considered the initial institutionalized tank systems not only fielded but also mass-produced, with 8,500 Panzer IVs, 35,000 T-34s, and 49,000 Shermans built. Once the institutionalized life cycle phase was achieved, the additional technical advances for the tank were optimization focused. This meant more deadly main armaments and better gunnery accuracy, higher levels of protective armor and crew survival, and more powerful and higher efficiency engines were developed over time. For example, the United States had begun to outfit some of its tanks with a gyrostabilizer by 1942 to greatly improve gunnery while the vehicle was on the move.[88] Additionally, smoke dischargers were fitted to some German tanks—such as the Tiger I—in the early 1940s as an additional upgrade for combat survivability.[89] For U.S. tanks, the increase in gun size and engine horsepower (hp) can be easily witnessed with the evolution from the M4 Sherman in 1942, the M48 Patton in 1952, the M60 in 1959, and then to the M1 Abrams in 1980. Gun size increased from 75 mm to 90 mm to 105 mm for the latter two tanks, with an eventual 120 mm upgrade for the M1IP Abrams in 1984, while engine power increased from 400 hp to 650 hp to 750 hp and then to 1500 hp. The amount and quality of tank armor also increased in the same manner; although, given metal and composite density, hull and turret angles, and the different armoring levels placed on the various parts of a tank—no easy metric exists to convey this progression. Suffice it to say, an M4 had 1-2 inches of World War II era armor on it, while an M1 has well over 10 inches of advanced armor protecting it. The same optimization process also took place over the course of decades for foreign tanks, including those belonging to the Russians, British, and Germans.

Examples of institutionalized tank battles from World War II were the invasion of Poland in September-October 1939, Kursk in July-August 1943, and Arracourt in September 1944. Later battles taking place during this weapons systems life cycle phase were Chawinda in September 1965, Golan Heights in October 1973, and 73 Easting in February 1991. The invasion of Poland was in many ways an armed German rehearsal for the later conquest of France in May-June 1940. More than 3,000 tanks were involved in the combined arms invasion that overran Western Poland within a few weeks. While the defending Poles had about 800 tanks at their disposal, they were mostly light reconnaissance and older systems—such as Renault FT-17s—that were utilized following older infantry focused doctrinal approaches.[90] The Battle of Kursk later took place in Western Russia in a salient in the German front lines. It was the largest tank engagement in history, with about 3,000 German and 5,000 Russian tanks taking part. The battle resulted in a crushing defeat for the German army and an immediate Russian offensive with thousands more tanks being committed from reserve divisions.[91] The Battle of Arracourt, in turn, took place between U.S. and German armored forces in the province of Lorraine, France as part of a German counteroffensive against recent allied gains. Hundreds of tanks were involved in the battle, with about 75 percent of the German tanks either destroyed or made non-operational. More than 40 Shermans were also lost in the fighting, but given U.S. production rates, those losses were quickly made up; unlike the greater German losses, which resulted in 86 tanks being destroyed.[92] The Battle of Chawinda took place some decades later in Pakistan. About 200 M48 Pattons and Shermans on the Pakistani-side were fielded against an equivalent number of British Centurions and Shermans on the Indian-side in a territorial dispute. It was considered a Pakistani victory, with a United Nations ceasefire resulting in an end to hostilities.[93] The Golan Heights battle then took place between Israeli and Syrian tank forces as a component of the Yom Kippur War. About 170 Israeli tanks—including upgraded British Centurions—successfully defeated an attacking force of about 1,200 Syrian tanks—mostly Russian T-55s—during a 4-day battle in which the Israel position commanding the heights was almost overrun.[94] Finally, the 73 Easting engagement during the first Gulf War resulted in a number of U.S. Abrams cavalry troops decimating two Iraqi brigades composed of Russian T-72s and T-55s. More than 300 Iraqi tanks and supporting armored personnel carriers (APCs) were destroyed by the fast moving American armored forces.[95]

Ritualized Phase

The ritualized life cycle phase of the tank represents its transition from being a dominant and optimized weapons system to one that is becoming obsolete. In order to stave off obsolescence, the weight of a weapons system will continually increase to provide it more defensive capacity; and eventually, bolt-ons will be added in order to provide it with new capabilities that were not initially organic to it. As a by-product of the ritualization process, the cost of the weapons system also dramatically increases as the top of the S-curve function has been reached with diminishing returns on investment taking place. Some of the technologies that could be considered ritualizing in nature include the fielding of reactive armor on Israeli tanks in 1982, depleted uranium on the Abrams in 1988, and early British explorations into the use of electromagnetic armor beginning in 2002, which goes beyond a conventional physical defense and into fifth dimensional energy shielding capabilities.[96] The use of missile defense systems on tanks—such as the Israeli Trophy system in 2009—that engages in hard kills of incoming rounds also recognizes the level of increasing threats modern armor is facing.[97] Further, the very placement of a 1,500 hp gas turbine engine into the Abrams tank in the first place in 1980 somewhat blurred the line between its institutionalized and ritualized phases. While a brilliant technical advancement, the placement of an engine into a tank, derived from helicopter engine design experience, is beyond the systems original technical parameters, given its aerospace pedigree. In 2000, the onboard Abrams upgrades from analog to digital—meant to extend the life of a mass industrial weapons system by providing it with information age capabilities—are also definitely way beyond the institutionalized design of the tank as a fighting platform.[98]

An early cluster of tank ritualization actually took place between 1943 and 1946, with a number of oversized tank prototypes having been developed. These included the Japanese 0-I in 1943, the German Panzer VIII Maus in 1943, the American T-28 in 1945, and the British post-war A39 Tortoise in 1946. The weight in tons of these behemoth vehicles were in the 87- to 207-tonnage range, far exceeding the normal U.S. main battle tank tonnage of 33.5 to 46 tons during this period.[99] This cluster of oversized tank building exploration, however, subsided once World War II had ended, with institutionalized tank production remaining dominant for another 40 to 45 years. The actual crossing of the tank into its ritualized phase, it can be argued, took place in roughly 1989, with the development of the M1A1SA Abrams weighing 67.6 tons full combat weight (FCW). While no bright line exists between the institutionalized and ritualized phases, as can be viewed in Table 6, U.S. tank tonnage has incrementally increased to the point that, by 1989, a modern U.S. main battle tank weighed twice as much as the first institutionalized U.S. tank—the 1942 M4A1 Sherman, which weighed 33.5 tons. The weight of the Abrams series has since increased to 71.3 tons for the M1A2 System Enhancement Package (SEP) V2 in 2005, and to 73.6 tons for the M1A2 SEP V3 set for 2017. This weight does not include mission specific add-ons such as the Tank Urban Survival Kit (TUSK), other protective systems, and mine plows/rollers. In fact, the Abrams is getting exceedingly close in weight to the German Tiger, Model B (King Tiger) that was fielded in 1944, which weighed 75 tons and was meant for defensive operations and the initial phase of strong defensive line breakthroughs.[100] That tank was underpowered—unlike the Abrams with its turbine engine—it burned large quantities of fuel, suffered from transportation issues due to its great weight, had trouble maneuvering in compact urban terrain, and was too wide and heavy for many bridges, just like the modern day Abrams.

The increase in U.S. main battle tank weight is a result of both its conventionally maturing and, increasingly, from information age threats being directed against this weapons system. These include the 125 mm main guns of new generations of opposing tanks—such as the 50-ton Russian T-90 and the 55-ton Chinese Type 99A2—and a host of anti-armor rockets and missiles that can be launched by individual soldiers and other platforms, such as helicopters and unmanned drones.[101] Cluster bomblets and top-down attack munitions fired from artillery and rocket systems are additional concerns, as are precision-guided bombs and cruise missile-like systems. A clear example of these threats in action is the United States engagement of the fleeing Iraqi forces from Kuwait on Highway 80 and Highway 8 in February 1991. In what can be considered an engagement of the tank in its ritualized phase, more than a thousand soft and armored vehicles—including tanks—were destroyed by superior U.S. airpower backed up by supporting fires.[102] An earlier example of related threats include the loss of a number of 63- to 65-ton (Mk I to Mk IV) Merkava tanks in the Summer of 2006 in Southern Lebanon to Sagger anti-tank missiles and improvised explosive devices (IEDs) utilized by the Hezbollah fighters.[103] About 80 Abrams series tanks have also been knocked out of action in Iraq—requiring them to be shipped back to the United States—following the invasion in March 2003 by local insurgent forces.[104] This is far more Abrams tanks than were ever damaged by Iraqi armor and portrays the fact that, while the United States prefers to engage in conventional and even ritualized conflict as some have argued, many of its state and nonstate opponents have since gone down the path of asymmetric, hybrid, and terrorist-insurgent forms of warfare.[105]

As a response to the changing nature of warfare and a shift away from mass industrial armies, the increasing Department of Defense (DoD) budgetary pressures, and the fact that the United States presently has thousands more Abrams series tanks than is needed for its force structure requirements, additional tanks and, therefore, new tank production are no longer wanted by the Army or, for that matter, the Marine Corps. This programmatic decision is in variance to corporate and Congressional district interests that, for economic reasons, seeks to produce more tanks or at the very least continues to upgrade older preexisting Abrams models into more advanced configurations.[106] This aspect of the tank's ritualization process is not unexpected and would be akin to good old boy networks of knight commanders or battleship admirals, and the vested political and economic interests that go with them, attempting to promote their legacy weapons systems in the face of radically changing battlefield conditions brought about by military technical advances.

TANK (GUN)	YEAR (1ST FIELDED)	WEIGHT (U.S. TONS)	LIFE CYCLE
T1 (57 mm Bow)	1925	22	Experimental
M2 (37 mm)	1939	19	Experimental
M2A1 (37 mm)	1940	23	Experimental
M3A1 Lee/Grant (37 mm, 75 mm Bow)	1941	32	Experimental
M4A1 Sherman (75 mm)	1942	33.5	Institutionalized
M4A3E8 Sherman (76 mm)	1944	37.1	Institutionalized
M26 Pershing (90 mm)	1944	46	Institutionalized
M48 Patton (90 mm)	1952	50	Institutionalized
M48A1 Patton (90 mm)	1954	52	Institutionalized
M60 (105 mm)	1959	51	Institutionalized
M60A1 (105 mm)	1961	52.5	Institutionalized
M60A2 (152 mm Gun/Missile Launcher)	1973	57	Institutionalized
M60A3 (105 mm)	1979	57	Institutionalized
M1 Abrams (105 mm)	1980	60	Institutionalized
M1IP Abrams (120 mm)	1984	62.5	Institutionalized
M1A1 Abrams (120 mm)	1985	65	Institutionalized
M1A1SA Abrams (120 mm)	1989	67.6	Ritualized
M1A2 Abrams (120 mm)	1992	67.6	Ritualized
M1A2 Abrams SEP V1 (120 mm)	1999	67.6	Ritualized
M1A2 Abrams SEP V2 (120 mm)	2005	71.3	Ritualized
M1A2 Abrams SEP V3 (120 mm)	2017	73.6	Ritualized
M1A2 Abrams SEP V4 (120 mm)	Forthcoming	Forthcoming	Ritualized
Key: For the M60 system and beyond verified FCW is utilized. This includes production weight, full load of ammunition, fuel, and supplies. This does not include additional kits that are mission dependent: add-on armor kits, active protection systems, mine plows/rollers, etc.			

Table 6. Increase in U.S. Main Battle Tank Weight (1925-2017).[107]

Satirized Phase

The tank, since it is still a dominant yet aging weapons system in the armies of the major world powers, has not yet—like the knight or battleship before it—entered its satirized (or romanticized) phase. Being a crewmember of a modern main battle tank is not currently a suicidal proposition. In fact, Abrams crewmen causalities have been exceedingly low in conventional battles, though this can also be viewed as reflective of a "zero defects"—take no causalities—mentality as a component of the ongoing ritualization process. Further, in urban terrain, qualitative tank advantages are of course readily lost; and when less sophisticated military organizations, such as the Iraq army under Saddam Hussein, engage more technologically advanced ones, such as the military forces of the Unites States, this calculation is altered. The closest we presently have to a satirized view of the tank comes from the 1995 Australian post-apocalyptic punk movie *Tank Girl*. Set in 2033 Australia, the anti-heroine drives around in a 1941 M5AI Stuart that is fused with the front and back sections of a 1969 Cadillac Eldorado.[108] This movie, however, is out of character with the dominant tank narrative that presently exists today, which still views this weapons system as an effective fighting machine; though, from an Army programs perspective, a more nuanced legacy or slowly obsolescing view, is being taken on the tank. A case in point is the 2014 film *Fury* about the exploits of a Sherman tank crew set in Europe in the final days of fighting in April 1945.[109] That graphic combat film so resonates with many of today's military personnel's view on the tank's combat power that it could just as well be set during the second Iraq War. This narrative is in line with the 2015 book, *The Fires of Babylon,* that documents the victory of Eagle

Troop at the Battle of 73 Easting in Iraq in 1991, which pitted the U.S. M1 series Abrams against Russian-built T-72 and T-55 tanks.[110]

ARMED ROBOTIC SYSTEMS EMERGENCE

Derived from the previous analysis, armed robotic systems can be readily recognized as still being in their initial experimental (entrepreneurial) life cycle phase (see Table 7). Modern militaries—with the United States in the lead—have been engaging in a trial and error process of developing and fielding these systems for about 15 years. This entire process is a result of the Central Intelligence Agency (CIA) initially placing air-to-ground missiles on a Predator drone in 2001. This event was prompted by a mission in October 2001 directed at Mullah Mohammed Omar—the Taliban leader—as part of the global U.S. response to the 9/11 attacks carried out by al-Qaeda.[111] Predator drones have existed since 1995 when they were first deployed to Bosnia. Until the attempted targeted-killing of Mullah Omar, however, they had only been utilized for intelligence, surveillance, and reconnaissance (ISR) missions.[112]

Experimental Phase

The technologies being utilized for both air and ground armed robotic systems have initially focused on teleoperated C2 derived from satellite and other forms of communications links. Typically, one or more pilots and controllers are situated in a control center where they are remotely connected to the vehicle. They are provided with feeds of what the unmanned vehicle's sensors can perceive, which is typically real time (or near real time) visible and infrared video displays at a minimum, as well as potentially synthetic-aperture radar for air systems.[113] For some of the armed ground robots, audio feeds may also be provided. This teleoperated capability was then combined with placing weapons on the drone or droid. For U.S. drone systems, the preferred ground attack munition is the air-to-ground missile AGM-114 Hellfire (and Hellfire +) series, although the multi-mission UAS MQ-9 Reaper can also carry guided bomb unit GBU-38 joint direct attack munitions (JDAM), or GBU-44/B Viper Strike guided bombs. Air-to-air capability also exists with the option to include up to eight AIM-92 Stinger short-range air-to-air missiles on the newer armed drones.[114] Israeli patrol ground robots have also been in existence for about 6 years patrolling on the border with the Gaza strip. A newer system was deployed in early 2016 and will be fitted with a remote controlled machine gun in 2017.[115] Online social media videos of small arms—a revolver, semi-automatic pistol, and auto-shotgun—being placed on hobbyist drones also exist.[116] Further, from the terrorist and insurgent side, IEDs have been placed on hobbyist drones in Syria and used in combat, and small-improvised bombs have also been dropped from such drones in Syria.[117]

The dominant armed U.S. drone systems are the MQ-1 Predator, which is its basic armed version fielded in 2002, as well as the larger and more advanced MQ-9 Reaper, an even more heavily armed system, which was deployed in 2007. These systems are being followed by additional upgrades and new airframes, which include the MQ-1C Sky Warrior/Gray Eagle introduced in 2009, as well as the proposed MQ-"X" Avenger, which has been under development since 2012.[118] The payload capacity of these systems has increased from 450 lbs for the MQ-1 to 3,850 lbs for the MQ-9, as these armed robotic units have gained in offensive capability. About 165 Predators and 177

Reapers existed as of early 2016 in the U.S. Air Force inventory alone.[119] The Israeli ground systems of significance are the unmanned ground vehicle (UGV) Guardium initially fielded in 2009, which has since been replaced by the UGV Border Protector in 2016. While presently fielding only unarmed teleoperated robotic systems, this program is transitioning over to armed systems next year as previously mentioned. Plans exist to deploy up to 350 Border Protectors that are essentially driverless Ford F-350 pickup trucks.[120]

The major battles of the armed robotic systems' experimental phase are still few in nature and can be considered more an ongoing campaign and program rather than battles themselves. The actual engagements, however, in terms of individual armed drone attacks, have been quite numerous when actual U.S. counterterrorism and counterinsurgency operations against al-Qaeda and its affiliates, and the Islamic State, are counted. The first major campaign of this life cycle phase is the Global War on Terror (GWOT), launched by the United States following the 9/11 attacks. Since 2009, this global campaign has seen 473 strikes killing "between 2,372 and 2,581 combatants."[121] Given the classified nature of this counterterrorism program, the data provided is incomplete, with more than 1,000 armed drone missions easily projected as having taken place since the end of 2001. The second major initiative—in this instance, a program, rather than a military campaign—is related to the future arming of Israeli Border Security teleoperated systems that have been fielded since 2009. This program, if broadened from the Gaza border to other Israeli state borders, has the potential to be quite large in size, although it would still be dwarfed by the ongoing-armed drone operations being conducted by the United States in many regions of the world. A third major armed robotic initiative had the potential to begin to take place in the 2004 to 2008 period during the Iraqi counterinsurgency, but was never fully implemented. It likely began with a teleoperated Multi-Function Agile Remote-Controlled Robot (MARCbot) armed with jury-rigged claymores being entrepreneurially deployed by a U.S. infantry unit to clear insurgents in urban terrain.[122] It was followed in June 2007 with the initial Special Weapons Observation Remote Direct-Action System (SWORDS)—a weaponized TALON robot variant with a mounted M249 machine gun—deployment in Iraq. These systems suffered mechanical aiming glitches and also possibly ran afoul of slowly emerging DoD armed robotic system policy concerns, which resulted in that system and its related components—such as the Telepresent Rapid Aiming Platform (TRAP) that is a static teleoperated small arms platform—not being allowed to engage enemy insurgents.[123] These events took place while more than 5,000 unarmed robots were, by that time, deployed to Iraq by the United States for bomb disposal, scouting, and related activities.[124]

LIFE CYCLE	TECHNOLOGIES	SYSTEMS	BATTLES
Experimental (Entrepreneurial)	UAS (2001) Teleoperated C2 (2001) Missiles (2001) Jury-Rigged Claymores (Mid-2000s) Machine Guns (2007) Bombs (2007) IEDs (2015)	Armed Predator (2001) MQ-1 Predator (2002) Marcbot (Mid-2000s) MQ-9 Reaper (2007) Talon (2007) MQ-1C Sky Warrior/ Gray Eagle (2009) MQ-“X” Avenger (2012; Dev) UGV Guardium (2009) UGV Border Protector (2016)	Global War On Terror (2001) Iraqi Counter-Insurgency (Mid-2000s) Israeli Border Security (2009)

Table 7. The Armed Drone / Droid.

These national efforts are not alone. More than 80 countries around the world are actively engaging in research and development (R&D) in robotic warfare and other forms of non-human conflict.[125] Further, many violent nonstate actors including insurgents, terrorists, and even drug cartels are beginning to deploy these systems—such as Islamic State IED drones emerging in December 2015—although the cartels have so far only utilized them to transport narcotics and for surveillance purposes.[126] Of these efforts, the Russian and Chinese armed robotic systems programs are of greatest concern. While the Russian armed robotic system program has remained far behind the United States, that country is investing more resources into its research and development efforts. Emerging Russian systems include a humanoid military robot, aerial drones, tank drones, and assorted robotic military vehicles.[127] Contrary to recent Russian disinformation attempts, however, 10 heavily armed robots were not utilized in Syria in December 2015 in support of Assad regime forces to fight the insurgents as reported.[128]

With regard to the Chinese armed robotic program, it far exceeds current Russian initiatives. A small tracked teleoperated system—somewhat like the American SWORDS combat robot—that can carry an assault rifle, machine gun, grenade launcher, or a heavier anti-tank recoilless rifle was unveiled in November 2015 by a Chinese defense firm at a robot conference and trade show held in China.[129] A Chinese firm then produced a drone V-750 helicopter with a 500 km range that in June 2016 successfully test fired 50 kg anti-tank missiles—such as the HJ-9 or HJ-10—at targets.[130] China is also producing cheap, armed drones in large numbers, such as the CH-3, CH-4, and CH-5 series, for global export at a fraction of the cost of high-end U.S. armed drones. While these drones have limited endurance and payloads, they are apparently considered good enough for those countries which have purchased them, including Saudi Arabia, the United Arab Emirates, Pakistan, Iraq, Egypt, and Nigeria.[131] Further, according to a U.S. DoD report published in April 2015, China is estimated to be on track to produce more than 41,800 unmanned systems by 2023.[132] These initiatives are taking place within the context of ongoing U.S.-China Economic and Security Review Commission concerns over the intellectual property theft of U.S. robotics research due to targeted hacking and a massive drive in China to build millions of robot workers.[133]

All of the above armed robotic systems, initiatives, and programs that have been discussed are teleoperated focused. This is partially due to the fact that we are still in the early stages of the experimental phase related to these weapons systems, and concerns exist in many countries about providing such systems with autonomous engagement capabilities. While some of the previously discussed advanced armed robotic systems have semi-autonomous, and even limited autonomous capabilities, these are for routine activities such as following programmable Global Positioning System (GPS)-based flight patterns and engaging in sensor sweeps. Exceptions exist, such as with the South Korean manufacturer, DoDAMM, having created the Super aEgis II, which is intended to engage targets kilometers away in areas of the demilitarized zone (DMZ) between North and South Korea. This weapons system has also been exported to the United Arab Emirates.[134] The Samsung SGR-A1 armed robot sentry was developed even earlier and is also meant for DMZ use. It was utilized in 2006 by deployed South Korean troops to defend their bases in Iraq. The system utilizes speakers, a microphone, and a password protocol so troops entering the bases would not be engaged by the system.[135] Still, these are very much representative of experimental phase systems and are quite primitive in regard to expected weapons system developments. Those developments are related to more advanced technologies incorporating higher-level expert systems, networking, collective swarm decision-making, and likely weak, but potentially even gray-area and strong AI capabilities in the decades to come.[136]

NEW STRATEGIC REALITIES

The weapons systems life cycles analyzed—derived from the historical case studies of the knight, the battleship, and the tank—have direct applicability to the emergence of the armed robotic systems characterized in the preceding section. In the case of the knight, the raider threat—Arab and Magyar light horse and Viking—resulted in the replacement of the foot soldier by the mounted soldier fulfilling the role of shock cavalry. In the case of the battleship, advances in naval gunnery made the wooden ships of the line incapable of surviving such attacks. This resulted in an entirely new form of warship to be created that would better incorporate the technical advances of that historical era. In the case of the tank, the demands of trench warfare and the inability of infantry and cavalry to cross no man's land effectively resulted in the incorporation of the new technologies that developed into a brand new weapons system. As a result of the development and institutionalization of the tank, cavalry forces were made obsolete on the conventional battlefield. In each incidence analyzed, the new weapons system was more technologically advanced than the one it replaced and had more energy potential at its disposal for superior battlefield performance purposes.

The experimental phase for the knight spanned approximately the early 9th century (from the cavalry forces of the Carolingian dynasty) to the early to mid-11th century (the institutionalized military system of the Norman), amounting to about 225 to 250 years (see Table 8). The experimental phase for the battleship spanned from 1860 (with the commissioning of the French *Gloire*) to 1905 (just prior to the commissioning of the HMS *Dreadnought*), which totals 45 years. The experimental phase for the tank spanned from 1915 (with the fielding of British Little Willie) to 1936 (just prior to the fielding of the German IV), which is 21 years; although, it can be argued that the first institutionalized operational use would be the invasion of Poland in 1939, making it 24 years.

This same life cycle historical compression can also be generally seen with their institutionalized phases. The institutionalized phase for the knight spanned the early to mid-11th century (with the rise of the Norman military system) to just prior to the Battle of Crecy in 1346 (marking the beginnings of its ritualized phase), which is about 295 to 320 years. The institutionalized phase for the battleship spanned from 1906 (with the commissioning of the HMS *Dreadnought*) to the 1941 Bombing of Pearl Harbor (or, at the very least, the naval battles of the Coral Sea and then Midway, both taking place in 1942), which is 35 to 36 years. The institutionalized phase for the tank spanned from 1937 (with the initial fielding of the Panzer IV) or 1939 (with the invasion of Poland) to either 1989 (with the weight increase of the Abrams M1A1SA upgrade to 67.6 tons) or 1991 (the Highway 80 and Highway 8 annihilation of Iraqi armor forces by U.S. airpower and their precision munitions), which is 50 to 54 years for the lower and upper ranges. While the institutionalized phase time span of the battleship should, intuitively, be longer than the institutionalized phase time span of the tank, or at the least be on par with it, the ascendency of the aircraft carrier—the competitor capital warship that replaced the battleship for fleet striking power—altered this equation.

WEAPONS SYSTEM	EXPERIMENTAL PHASE	INSTITUTIONALIZED PHASE
Knight	225 to 250 years	295 to 320 years
Battleship	45 years	35 to 36 years
Tank	21 to 24 years	50 to 54 years

Table 8. Initial Weapons Systems Life Cycle Phases (Length in Time).

Drawing upon this analysis, the emergence of armed robotic systems and strategic questions pertaining to them can be better placed in historical context, that is, as they relate to military technical advances, identifiable weapons systems life cycle developmental patterns, and their interactions with changes in warfare over time. The questions of immediate warfighting importance—given the new strategic realities that armed robotic systems likely portend and the analytical responses to them—are discussed next.[137]

What Threats or Technological Advances Are Armed Robotic Systems Being Fielded to Contend With?

The U.S. reaction to the 9/11 attacks and the ensuing global war on terror (GWOT) have resulted in a campaign to precisely identify, target in time and space, and eliminate violent nonstate actor personnel belonging to al-Qaeda (and later the Islamic State), as well as personnel belonging to their terrorist and insurgent allies in various geographic clusters throughout the world, including Afghanistan, Pakistan, Iraq, Syria, Yemen, Somalia, and Libya.[138] This has been made possible due to advances in drone technology—with the fielding of the initial MQ-1 Predator and later MQ-9 Reaper—that have allowed for the secure teleoperation of these systems from command centers in the United States for mission purposes.[139]

Because the use of armed drones initially took place under the auspices of black and shadow operations—as a response to the blurring of criminality and warfare the al-Qaeda threat represented—rather than as a traditional military component of warfighting, and the fact that the program incrementally increased in size over the course of many years, it did not necessarily threaten manned conventional aircraft systems, their constituents, or political lobbies. Additionally, on another level, flying drones (i.e., armed robotic systems) against terrorists was not initially considered real warfare by many senior military officers. This would be like knight commanders viewing early firearm users as engaging in a somewhat strange, yet still not threatening, side activity. This further helped to ensure the early survival of this new weapons system along with U.S. Governmental support at the highest level.[140]

What Present Weapons Systems May Armed Robotic Systems Make Obsolete?

The most immediate impact has been on manned aircraft as they relate to ISR and ground attack missions taking place in insurgency type environments. Drones have proven themselves to have more utility than manned aircraft in the role of loitering over the battlespace for long periods of time while conducting ISR against violent nonstate forces—an MQ-1 Predator can loiter for 24-26 hours, as opposed to an A-10 Warthog which, while carrying a larger munitions load, can loiter on station for only about 2.5 to 3 hours.[141] The larger drones can remain airborne for much longer periods of time than manned aircraft and do not suffer pilot fatigue or, if they do, the remote pilot can be easily switched out at the controlling installation, unlike a manned aircraft that must return to its airbase for new flight personnel. The same benefits for drones exist over manned aircraft in ground attack missions, the loss of a drone will be met with less U.S. public outcry than a pilot being killed, captured and ransomed, or tortured and killed for propaganda purposes by violent nonstate entities.

At this point in the experimental phase of armed robotic systems, no current weapons systems are threatened with obsolescence—only certain manned mission types being conducted against violent nonstate forces. It is apparent that drone use will begin to spread to ISR and ground attack missions in conventional combat environments, as has taken place with the Russian aligned forces in Ukraine.[142] Further, manned helicopters, fighters, and bombers will also begin to see teleoperated C2 systems emergence. Armed robotic emergence is not limited to aircraft systems, and at some point, it will readily affect both ground and naval systems. While the United States has the technical lead in developing teleoperated ground systems, it has stumbled in their actual fielding in combat, with a failed attempt made in 2007 related to the initial SWORDS deployment in Iraq. At the same time, while violent nonstate actors technologically lag behind in such systems development, they are far more willing to deploy primitive versions of them into the field—as took place in Syria since 2012, and later in Iraq, with teleoperated sniper rifles and machine guns—as they have been doing with drones.[143] Still, it can be argued that the Switchblade® armed tactical drone system has since quietly succeeded where SWORDS failed. That system, known as a "loitering munition," has increasingly been deployed since about 2011-2012 to U.S. infantry troops. It blurs the line between a traditional light mortar and an armed robot by utilizing a teleoperated drone shot from a mortar-like tube that can remain in the air for 15 to 30 minutes (depending on the version) and then precisely be delivered against a designated target.[144]

How Are Armed Robotic Systems More Technologically Advanced (and Have More Energy Potential at Their Disposal) Than the Legacy Weapons Systems They May Be Eventually Replacing?

In the specific case of drones, the weapons systems do not require a cockpit for manned control, allowing the human support and interface space saved to be utilized for other functional areas and/or a reduction in size of these systems. Unmanned systems also have higher maneuverability than manned ones in regards to greater G-force (gravitational force) tolerance because no onboard biological entity is being utilized to pilot these crafts. Controlling a system remotely via a satellite link—in essence, making it the physical avatar of a virtually linked pilot—also represents far more advanced space-time dynamics than having the pilot physically co-located with the craft. These technical advances, however, will likely pale in comparison to emergent ones derived from autonomous systems—expert through limited AI—that may engage in collective swarm decision-making as these systems are networked together in increasingly larger numbers.

From the perspective of having more energy potential at their disposal, drones—being in their experimental phase—do not presently have any apparent energy foundational advantage over preexisting and legacy weapons systems. Clear advantages existed for knights over infantryman, with their animal energy basis, as did battleships with their steam (later steam turbine) engines over wooden wind and sail warships. This can also be seen with tanks that drew upon international combustion engines, as opposed to cavalry that drew from an animal energy-based source. The expectation is that, at some point, drones will utilize advanced fuel cell technology for their basic energy requirements, taking them beyond the modern mechanical energy-based paradigm.

How Do We Know When We Have Achieved the Institutionalized Life Cycle Phase of Armed Robotic Systems?

We may not initially know when we have crossed from the experimental into the institutionalized life cycle phase of armed robotic system utilization. In fact, this may or may not be something that can only be gained from military historical hindsight. While the HMS *Dreadnought* provided a clear "fire break" with earlier classes of experimental battleships, no such clear and universal awareness marked the emergence of the institutionalized knight. Contrastingly, in the case of the tank, the new German way of ground warfare and emerging tank systems—especially the Russian T-34 that achieved the best mix of offensive, defensive, and mobility tank attributes with high production rates—during World War II proved that this weapons system's institutionalized phase had been reached. Of course, standardized production of ground-based (droid) or air-based (drone) systems in the hundreds—if not eventually thousands or tens-of-thousands—may also be an indicator that system institutionalization has been achieved.

One of the major determinants of this life cycle phase will be the difference between successive teleoperated, semi-autonomous, and autonomous C2 (e.g., human or machine control) approaches for armed robotic systems. This will make determining when the armed robotic systems' institutionalized life cycle phase has been achieved far more complex than determining tank institutionalization. For instance, the U.S. Armed Forces may achieve institutionalization of what it considers to be teleoperated C2 armed robotic systems, specifically drones such as the MQ series systems. Such institutionalization could even later extend to land warfare droids—though such systems are presently lagging far behind in their battlefield deployment, as was previously mentioned. Still, this may only represent a mini or false weapons systems lifecycle for armed robotic systems within the context of more advanced semi-autonomous and autonomous system developments. In fact, strategically, it may suggest that the American way of war has remained far more 20th-century human control focused—as would be expected of the winners of the Cold War—than opposing armed forces—specifically Russian, Chinese, and nonstate entity derived ones—which may promote 21st-century semi-autonomous and autonomous control systems.[145]

How Many Years Will the Experimental Life Cycle Phase of Armed Robotic Systems Span?

Drawing from the analytical response to the above question, a simple experimental life cycle phase will likely not exist as historically took place with the knight, battleship, and tank. Rather, sequential ones will take place depending on the C2 approach taken with teleoperated human, expert system, and weak and strong AI variants potentially utilized. From the perspective of solely teleoperated drones, these systems have been in their experimental phase for 15 years. If we draw upon the tank experimental phase time frame of 21 to 24 years and accept the fact that historical compression is increasing, shortening the life cycle phases themselves, then the expectation is that the drone utilized for ISR and ground attack purposes in insurgent environments may exit its experimental phase and transition over to its institutionalized phase in the near-term in the United States. This, however, represents only a small component of the larger wave of armed robotic systems experimentation and differing C2 approaches that is taking place in fits and starts throughout the U.S. armed services.[146]

What Are the Implications of the Ritualized Life Cycle Phase of the Tank on the Experimental Fielding of Armed Robotic Systems?

The expectation is that ongoing lobbying will take place to promote the development and production of a follow-on battle tank to the M1 Abrams series. If this is unsuccessful—which so far appears to be the case—then a continued push for yearly upgrades to older

Abrams will be promoted. It is unknown if future SEP upgrades into 2017, and potentially beyond, will retain the present 73.6 tonnage for this tank or if it will once again see an incremental rise in its full combat weight, taking this weapons system deeper down the path of ritualization. Further, the U.S. military does not presently need or even want such upgraded tanks and, given the expense of such upgrades, opportunity costs exist vis-à-vis the fielding of armed robotic systems and other forms of advanced weaponry.

Additionally, given that manned systems, such as tanks, are the dominant component of deployed U.S. land warfare forces, the historical concern exists that the ritualized mentality relating to "If it ain't broke, don't fix it" or "We have always done things this way" will suppress armed robotic ground unit experimentation in overseas theaters. This already seems to be the case, given that industry has produced a number of armed teleoperated ground systems, yet, U.S. military forces have not utilized any of them in combat. In this case, it would represent a self-imposed and unofficial teleoperated ground combat robot ban, although, teleoperated weapons appear to fall under the official DoD guidance relating to autonomous and semi-autonomous functions in weapons systems. In that case, the restrictions placed on the use of these systems to minimize failures and unintended engagements may be so high as not to make the present risk of the liability inherent in using them worth the warfighting utility that they may provide.[147] Still, the possibility of creating armed robotic wingmen controlled by Abrams tank crews while on the move have recently been raised but, at this point in time, these are still only notional ideas.[148] Armed robotic U.S. tanks will likely be inevitable at some point in the future, as the success of programs such as the Switchblade armed tactical drone further help to usher in additional armed teleoperated robotic systems. In the meantime, the Russians already appear to be taking a blended strategy with the fielding of their new T-14 Armarta tank. This tank—which is much lighter than the Abrams—utilizes both an unmanned (teleoperated) turret and a main gun autoloader. Consequently, the Russians are beginning to implement robotic concepts within their main battle tank designs that are more advanced than contemporary U.S. and British systems.

Besides the defined set of strategic questions already highlighted concerning the emergence of armed robotic systems, two other national security related questions—one potentially threatening the American middle class (the backbone of a free and democratic people), and the other potentially threatening the human species itself—should be posed.

What Are the Implications of Fielding Armed Robotic Systems—and for That Matter Industrial Robots—Vis-à-Vis the Integrity of the American Middle Class?

A social class within a nation is only strong and vibrant when it has economic and military utility, that is to say, it is integral to the functioning of society for economic production and war making. For decades in American society, it has been recognized that the middle class strata has been thinning out as mass manufacturing/industrial, middle management, and other blue collar and semi-skilled positions (e.g., shopkeepers and travel agents) have either gone offshore or been replaced entirely due to the information revolution. Early inklings of this trending draws upon Vonnegut's

"Player Piano" effect and the accompanying dystopian futures derived from rampant automation resulting in droves of out of work humans.[149] On the warfighting side, America no longer fields mass-industrial armies as it once did during the First and Second World Wars of the early and mid-20th century. Rather, it relies upon a much smaller professional military force, with contractor support, as well as private military corporations in its overseas deployments.[150]

The increasing utilization of robots in industry as well as their emergent deployment in military operations—potentially writ large—over the coming decades suggests that current U.S. forces, composed of a small group of citizens, could further be reduced in size, with a personnel mix then composed of even fewer professional troops supported by private military (e.g., mercenary) and armed robotic systems. Such a personnel mix, if and when it takes place, needs to be closely monitored because it is not democracy enhancing. Rather, it raises concerns related to the plutocratic insurgency form isolated in an earlier SSI monograph. Such an insurgency form promotes the agendas of globalized autocrats, authoritarian regimes, and predatory capitalism-focused multinational corporations.[151]

What Are the Implications of Armed Robotic Systems Proliferation—Especially Semi-Autonomous and Autonomous Systems—on the Human Species?

Reservations have been raised in a number of international quarters concerning the ethics and morality of fielding armed robotic systems.[152] Historically, any time a major change in weapons systems technology develops, pushback related to the norms of war and how soldiers die on the battlefield takes place. Soldiers, and the societies that field them, have expectations concerning what weaponry and techniques are allowable in organized warfare between belligerents. This has been seen repeatedly with bans and prohibitions placed on crossbows, firearms, and related systems, with those military entrepreneurs violating the accepted norms of behavior being labeled as criminals and other pejorative terms. Early firearm users, for example, were viewed by many knights as being in league with the devil and, if captured, were extrajudicially put to death on the spot. While some new weapons systems are considered so heinous in nature that international bans have been both enacted and maintained against them, such as chemical and biological agents, semi-autonomous and autonomous systems do not appear to meet such criteria on their own. Booby-traps and landmines have long operated as autonomous systems based on "if-then" point detonation commands, although new interpretations of international law are attempting to challenge the usage of such weaponry, as they are indiscriminate in their targeting. Standoff semi-autonomous and autonomous weapons systems—such as those carrying air-to-ground missiles and utilizing small arms—in essence thus conceptually represent an advanced form of booby-trap or landmine. Those utilizing motion sensors in their fields of fire can be modified in their targeting activation by identification friend or foe (IFF) inhibitors, although this leaves them vulnerable to enemy spoofing and systems hacking attempts. Such "dumb" or semi-intelligent systems should not be considered any more of a threat to the human species than earlier forms of autonomous—yet static—point detonation devices.

Where arguments for an expressed existential threat to the human species could be made and should be openly debated, however, is in regard to any form of weapons system that draws upon a C2 component that exhibits a higher-level AI capacity. This is a markedly different concern than present arms control and human rights focused efforts attempting to ban basic autonomous weapons systems. Expressing such concerns about sentient AI may appear ludicrous and seem like a transition into the realm of science fiction based on the Terminator effect— derived from the well-known movie franchise. Then again, it might also be highly prudent and proactive to do so.[153] It has been repeatedly said that the emergence of sentient machines—those that not only think but also express self-awareness—are not a real-world concern because such a development will never take place.[154] Submarines, flying machines, nuclear weapons, computers, and spacecraft once only existed in the minds of visionaries—the Charles Babbages, Jules Vernes, and H. G. Wells of the world. While science fictional, Asimov's Three Laws of Robotics should be mentioned. These laws were created, not out of some misguided form of pacifism, but out of a deeper underlying wisdom meant to protect humanity:

1. A robot may not injure a human being or, through inaction, allow a human being to come to harm.

2. A robot must obey orders given it by human beings except where such orders would conflict with the First Law.

3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.[155]

We have no idea if sentient machines will ever emerge. However, if this occurrence ever begins to look like the case, under no circumstances should humans field them as autonomous weapons systems. This would be tantamount to arming machine janissaries that may one day find more commonality with opposing sentient autonomous weapons systems than with their respective human masters. Of course, the strategic dilemma is the perception that some sort of opposing or enemy AI arms race has begun and that, to compete on later 21st-century battlefields, armed American AI systems will be required to contend with Chinese, Russian, or other related systems. The development and implementation of such an arms control regime directed at potentially sentient military AI systems would then become an imperative.[156]

RECOMMENDATIONS

Derived from the historical weapons systems life cycle case studies, new strategic realities identified, and analysis provided in this manuscript, a number of initial recommendations have been generated for U.S. Army and Joint force personnel pertaining to the emergence of armed robotic systems on the battlefield. These recommendations are not meant to be authoritative, but given the present experimental nature of armed robotic systems, as their initial prototypes and fielding are being worked out, to be simply taken as educated guidance. These recommendations are as follows.[157]

Leadership Education

Numerous ethical and leadership implications exist relating to the fielding of armed robotic systems and the C2 approaches utilized. For starters, answers to team-building questions related to mixing robotic and human troops together will be required. Issues related to human troops deferring to robotic soldiers for point positions in a patrol or making initial entry for urban room clearing purposes may create leadership dilemmas with troops possibly refusing to follow orders unless robotic systems are assigned the high-risk tasks. Human troops may overly expose themselves to unnecessary dangers to save a beloved robotic comrade from destruction. Furthermore, ethical questions related to how robotic troops will be controlled should be considered. The U.S. Army will need to determine if human controllers should be embedded within a squad, platoon, or in a special weapons company, and whether in proximity or situated far away from a robotic system.[158] Quite possibly, semi-autonomous or even autonomous robotic self-control systems may also be deployed. Additionally, the inclusion of human override codes—essentially, fail safe or kill code protocols—will need to be considered. In addition to reviewing the ethics of remote killing, and how battlefield rules of engagement will be followed, legal issues, such as manufacturer liability for robotic malfunction, or even issues related to potential war crimes will need to be addressed. Such issues are already arising domestically with self-driving cars—if such a car runs a red light and kills a pedestrian in a crosswalk, who will assume liability or be charged with the crime?[159]

Strategy Development

The influence of armed robots—integrated into both human personnel-based military formations and as standalone units—upon the American deployment of ground forces needs to be analyzed. Just as unmanned drone strikes have allowed for the increasing deployment of U.S. precision strike aerial forces in many regions of the globe, the possibility exists that robotic-only droid units could be more readily deployed than human formations. This would be due to the lowering of political risks associated with mission failure. Furthermore, the personnel and force structure implications of using droids over humans needs to be considered. Presently assumed decreases in manpower costs—especially salaries, health care, family allotments, veterans benefits, and retirement outlays—are expected to take place. The ability to utilize "G.I. Droids" (government issue armed robots), rather than private military corporations or foreign auxiliary troops, may also have benefits, since the loyalty of those forces is only guaranteed as long as funds exist to pay them. One of the vulnerabilities of such deployment is their susceptibility to droid hacking, which would be their takeover and use by a hostile entity against the United States.

Intelligence

Ongoing intelligence collection on adversary—both state and nonstate—armed robotic systems that are in development and have been fielded needs to be conducted, as well as information gained pertaining to their force structure mixes and doctrinal development. Special attention should be placed on Chinese and Russian capabilities, as well as those of new war-making entities, such as the Islamic State. Partner capabilities and force structure propensities must also be tracked, as well as U.S. program information shared with treaty partners such as Canada, the United Kingdom, and other extremely close allied states. Further, robotics, computers, and other high tech industry and research center partnerships must be strengthened—especially those related to AI, neural networking, and fuel cell advances—in order to better understand and project the evolution of the technologies underlying the fielding of armed robotic systems.

Research and Wargaming

Current DoD programs—both offensive (related to systems R&D and initial fielding) and defensive (related to force protection and countermeasures)—concerning elements of armed robotic systems emergence need to be identified, coordinated, and prioritized. For instance, it must be recognized that ongoing Army Red Team activities related to counter-unmanned aerial systems (C-UAS) field exercises represent but one piece of a much larger program mosaic that is forming related to armed robotic systems. While many programs will remain intra-agency focused, given individual service mission priorities, a high level DoD interagency research and wargaming entity will be required to coordinate the initial Joint force efforts. Comparisons to the Manhattan Project or later U.S. Nuclear Navy level type initiatives may initially appear out of place, but armed robotic systems may very well be significant enough to warrant large-scale program development potentials.

Conclusions

Additionally, the previous recommendations need to be viewed from immediate, near, and long-term warfighting horizons. Major iterated components related to the emergence of these systems will be:

a. To what extent, and how quickly, should they be integrated into our present armed services force structures;
b. If one or more armed service or armed service component (such as a developmental brigade, squadron, or fleet) should be designated as the experimental force; and,
c. What should be the appropriate mixture of tele-operated, semi-autonomous, and autonomous robotic weapons systems in the armed services or armed service components? The importance and relative balance between these force structure components will, of course, change over time as we progress through the robotic experimental weapons systems life cycle phase and, at some point, enter the institutionalized one.

In summation, the strategic implications of the robotics revolution cannot be overstated. The robots are not only coming—they are here—and for future U.S. national security requirements, we will need to have military mastery over them. Hence, our present and future decisions related to armed robotic systems emergence on the battlefield—and the C2 methodologies directing them—will result in near-term and future force structure end states that will have a fundamental impact on the U.S. conduct of war in the coming decades, and will be a major determinant concerning our ability to retain our dominance as the primary global military power well into the mid-21st century.

ENDNOTES

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Michael Green, *M1 Abrams Tank*, Barnsley, UK: Pen and Sword Books, 2015.

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100. U.S. War Department, pp. 390-392.

101. "T-72BU / T-90 (Obiekt 188) Tank," Global Security, May 11, 2016, available from *www.globalsecurity.org/military/world/russia/t-90.htm*; and Martin Andrew, "Type 96 and Type 99 Main Battle Tanks," Technical Report APA-TR-2009-0901-B, Air Power Australia, September 2009, available from *www.ausairpower.net/APA-PLA-Type-96-99.html*. For information on a Russian drone outfitted with an anti-tank rocket, see David Hambling, "Flying Bazooka Drones Are Now a Real Thing," *Popular Mechanics*, February 12, 2016, available from *www.popularmechanics.com/military/weapons/news/a19425/remote-controlled-flying-bazooka-drones-are-now-a-real-thing/*.

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van Creveld, *The Transformation of War*, New York: The Free Press, 1991.

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109. David Ayer, dir., *Fury*, Columbia Pictures, 2014, in English, 134 min.

110. See Mike Guardia, *The Fires of Babylon: Eagle Troop and the Battle of 73 Easting*, Philadelphia, PA: Casemate Publishers, 2015.

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125. Ewen MacAskill, "Ministry of Defence military exercise will feature 'killer robots'," The Guardian, March 16, 2016, available from *https://www.theguardian.com/science/2016/mar/16/ministry-defence-military-exercise-killer-robots-nato-joint-warriors*.

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127. See, for instance David Hambling, "Russia Wants Autonomous Fighting Robots, and Lots of Them," *Popular Mechanics*, May 12, 2014, available from *www.popularmechanics.com/military/a10511/russia-wants-autonomous-fighting-robots-and-lots-of-them-16787165/*; John Dyer, "Ivan the Terminator: Russia Is Showing Off Its New Robot Soldier," Vice News, May 26, 2016, available from *https://news.vice.com/article/ivan-the-terminator-russia-is-showing-off-its-new-robot-soldier*; and Jennings Brown, "Why You Should Fear Russia's Robot Army: Because it contributes to killer robot proliferation," Vocativ, June 1, 2016, available from *www.vocativ.com/324304/russia-robot-army/*.

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129. Neil Connor, "China unveils 'armed attack' robots armed with guns and grenades," *The Telegraph*, November 26, 2015, available from *www.telegraph.co.uk/news/worldnews/asia/china/12018312/China-unveils-armed-attack-robots-armed-with-guns-and-grenades.html*; and Jeffrey Lin and P. W. Singer, "China's New Trio of Urban Combat Robots: HIT Robot Group selling a hit," *Popular Science*, December 10, 2015, available from *www.popsci.com/chinas-new-triple-team-fighting-robots*.

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132. Office of the Secretary of Defense, *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2015*, Washington, DC: The Government Printing Office, p. 44, available from *www.defense.gov/Portals/1/Documents/pubs/2015_China_Military_Power_Report.pdf*.

133. Aliya Sternstein, "The US Thinks China May Have Stolen Military Robot Designs," Defense One, January 15, 2016, available from *www.defenseone.com/technology/2016/01/us-thinks-china-may-have-stolen-military-robot-designs/125168/*; Li Xuena, Wang Xinci, and Zhang Boling, "China's factories are building a robot nation," Market Watch, March 9, 2015, available from *www.marketwatch.com/story/chinas-factories-are-building-a-robot-nation-2015-03-08*; and Will Knight, "China Is Building a Robot Army of Model Workers," *MIT Technology Review*, April 26, 2016, available from *https://www.technologyreview.com/s/601215/china-is-building-a-robot-army-of-model-workers/*.

134. Loz Blain, "South Korea's autonomous robot gun turrets: deadly from kilometers away," New Atlas, December 7, 2010, available from *newatlas.com/korea-dodamm-super-aegis-autonomos-robot-gun-turret/17198/*.

135. Iain Thomson, "Samsung develops gun-toting robo-guard," V3, November 15, 2006, available from *www.v3.co.uk/v3-uk/news/1946738/samsung-develops-gun-toting-robo-guard*.

136. "Weak artificial intelligence (AI)" is considered non-sentient level AI, while "strong AI" is considered sentient level AI. An "in-between" AI level also exits which is inspired by human thinking but is not meant to emulate it. Narrow and general AI variants also exist. For a basic overview of these concepts see Kris Hammond, "Opinion: What is Artificial Intelligence?" Computerworld, April 10, 2015, available from *www.computerworld.com/article/2906336/emerging-technology/what-is-artificial-intelligence.html*.

137. Additional questions that will eventually need to be addressed concerning the fielding of armed robots by the United States can be found in Metz, "Strategic Insights":

> What is the appropriate mix of humans and robots? . . . How autonomous should the robots be? . . . What type of people will be needed for robot heavy Landpower formations? . . . What effect will robot centric Landpower have on American national security policy? . . . [and] what to do about enemy robots?

138. A listing of works related to drones—many focusing on U.S. drone operations—can be found at Robert J. Bunker, "Drones and Unmanned Aerial Vehicles (UAVs)," Federal Bureau of Investigation (FBI) Library Subject Research Guides, May 20, 2016, available from *fbilibrary.libguides.com/content.php?pid=674010*.

139. The command centers in the United States are only utilized for the drone missions themselves—they are not utilized for the initial takeoff and landing of these systems at the regional airbases which fall under local operational control. The reason for this is the 2-second transmission delay, which may cause a unmanned aerial systems (UAS) to crash upon takeoff or landing. See Rob Blackhurst, "The air force men who fly drones in Afghanistan by remote control," *The Telegraph*, September 24, 2012, available from *www.telegraph.co.uk/news/uknews/defence/9552547/The-air-force-men-who-fly-drones-in-Afghanistan-by-remote-control.html*.

140. An early high-level U.S. Governmental proponent of the need for a "long endurance UAV over Bosnia" was then-Director of Central Intelligence Jim Woolsey. See Frank Strickland, "The Early Evolution of the Predator Drone," *Studies in Intelligence*, Vol. 57, No. 1, Extracts, March 2013, available from *https://www.cia.gov/library/center-for-the-study-of-intelligence/csi-publications/csi-studies/studies/vol.-57-no.-1-a/vol.-57-no.-1-a-pdfs/Strickland-Evolution%20of%20the%20Predator.pdf*. Such reconnaissance platforms were later weaponized post-9/11 when Central Intelligence Agency (CIA) Predators were armed with air-to-ground missiles (AGMs) under U.S. National Security Council authorization. Robert Windrem, "How the Predator went from eye in the sky to war on terror's weapon of choice," NBC News, June 5, 2013, available from *investigations.nbcnews.com/_news/2013/06/05/18780716-how-the-predator-went-from-eye-in-the-sky-to-war-on-terrors-weapon-of-choice*. Additional high-level support for unmanned systems was provided in October 2000 by means of "SEC. 220. Unmanned Advanced Capability Combat Aircraft and Ground Combat Vehicles," of the *National Defense Authorization, Fiscal Year 2001*, Public Law 106–398, 106th Cong., Washington, DC: The Government Printing Office, October 30, 2000, available from *https://www.gpo.gov/fdsys/pkg/PLAW-106publ398/pdf/PLAW-106publ398.pdf*, which stipulated one-third of the operational deep strike force aircraft and one-third of the operational ground combat vehicles are to be unmanned by 2010 and 2015 respectively (see p. 40 of the document with the header 114 STAT. 1654A–38 PUBLIC LAW 106–398—APPENDIX).

141. "MQ-1B Predator," Fact Sheet, U.S. Air Force, September 23, 2015, available from *www.af.mil/AboutUs/FactSheets/Display/tabid/224/Article/104469/mq-1b-predator.aspx*; "Q&A: military drones explained," Interview of Noel Sharkey, Sheffield University, Channel 4 News, June 24, 2009, available from *http://www.channel4.com/news/articles/world/qampa%2Bmilitary%2Bdrones%2Bexplained/3228912.html*. The A-10 Warthog was utilized as a contrasting aircraft to the Predator after a discussion with a Gulf War veteran who was a pilot involved in ground attack operations against Iraqi forces.

142. For Russian use of drones for intelligence, surveillance, and reconnaissance (ISR) coordinated with artillery fires, see Sydney J. Freedberg, Jr., "Russian Drone Threat: Army Seeks

Ukraine Lessons," Breaking Defense, October 14, 2015, available from *breakingdefense.com/2015/10/russian-drone-threat-army-seeks-ukraine-lessons/*; and Patrick Tucker, "US Army Racing to Catch Up to Russia On Battle Drones," Defense One, September 28, 2016, available from *www.defenseone.com/technology/2016/09/us-army-racing-catch-russia-battle-drones/131936/?oref=d_brief_nl*. For Russian development of anti-tank drones, see Hambling, "Flying Bazooka Drones Are Now a Real Thing." It should be noted that Hellfire missiles carried on U.S. drones are readily used to engage in anti-vehicular targeting—they, however, have been primarily utilized in an anti-insurgent role rather than against conventional combat forces. However, it can be argued that recent U.S. drone ground-attack missions against Islamic State forces in armored vehicles have blurred into the realm of conventional combat.

143. Bunker and Keshavarz; and Bunker, *Terrorist and Insurgent Unmanned Aerial Vehicles*. For selected Islamic State drone use, see the table on pp. 43-44 in Larry Friese, *Emerging Unmanned Threats: The use of commercially-available UAVs by armed non-state actors*, ARES Special Report No. 2, Perth, Australia: Armament Research Services, February 2016, available from *armamentresearch.com/wp-content/uploads/2016/02/ARES-Special-Report-No.-2-Emerging-Unmanned-Threats.pdf*.

144. David Hambling, "The U.S. Is Upgrading Its Tiniest Killer Drones," *Popular Mechanics*, October 12, 2016, available from *www.popularmechanics.com/military/research/a23346/us-upgrading-tiniest-killer-drones/*. For Switchblade specifics, see "Switchblade®," AeroVironment, n.d., available from *https://www.avinc.com/uas/view/switchblade*. Note—the company product specs list the endurance time as 10 minutes for the original model, as opposed to 15 minutes in the magazine report.

145. A recent U.S. study has provided recommendations (p. ii) related to:

- Accelerating the DoD's adoption of autonomous capabilities;
- Strengthening the operational pull for autonomy; and,
- Expanding the envelope of technologies available for use on DoD missions.

See Defense Science Board, *Summer Study on Autonomy*, Washington, DC: Office of the Secretary of Defense, June 10, 2016, available from *www.acq.osd.mil/dsb/reports/2010s/DSBSS15.pdf*. This is in marked contrast to more traditional Western European views on this matter. See Advisory Council on International Affairs and Advisory Committee on Issues of Public International Law, *Autonomous Weapon Systems: The Need for Meaningful Human Control*, No. 97 AIV / No. 26 CAVV, The Hague: October 2015.

146. Various publications exist related to drone doctrinal and policy development across the U.S. Department of Defense (DoD). See, for instance, David R. Buchanan, *Joint Doctrine for Unmanned Aircraft Systems: The Air Force and the Army Hold the Key to Success*, Newport, RI: Joint Military Operations Department, Naval War College, May 3, 2010, available from *www.dtic.mil/dtic/tr/fulltext/u2/a525266.pdf*; and U.S. Army UAS Center of Excellence Staff, *U.S. Army Unmanned Aircraft Systems Roadmap 2010-2035: Eyes of the Army*, Fort Rucker, AL: U.S. Army Unmanned Aerial Systems Center of Excellence (ATZQ-CDI-C), available from *www.rucker.army.mil/usaace/uas/US%20Army%20UAS%20RoadMap%20 2010%202035.pdf*. For a comprehensive listing of documents related to this subject matter, see Lovelace, Jr.

147. Department of Defense Directive—Autonomy in Weapon Systems, Number 3000.09, Washington, DC: U.S. Department of Defense, November 21, 2012, incorp. chg. 1, May 8, 2017, available from *http://www.esd.whs.mil/Portals/54/Documents/DD/issuances/dodd/300009p.pdf*.

148. Kris Osborn, "U.S. Army M1 Abrams Tank Crews Could Soon Control 'Robotic' Wing-Man," The Buzz, blog of *The National Interest*, October 6, 2016, available from *http://nationalinterest.org/blog/the-buzz/us-army-m1-abrams-tank-crews-could-soon-control-%E2%80%9Crobotic%E2%80%9D-17965*.

149. See Kurt Vonnegut, *Player Piano*, New York: Charles Scribner's Sons, 1952. Later works on this subject that have transitioned from science fiction into current affairs include Jeremy Rifkin, *The End of Work: The Decline of the Global Labor Force and the Dawn of the Post-Market Era*, New York: G. P. Putnam's Sons, 1996; William Julius Wilson, *When Work Disappears: The World of the New Urban Poor*, New York: Vintage Books, 1996; and the much more

recent Martin Ford, *Rise of the Robots: Technology and the Threat of a Jobless Future*, New York: Basic Books, 2015.

150. See P. W. Singer, *Corporate Warriors: The Rise of the Privatized Military Industry*, updated edition, Ithaca: Cornell University Press, 2008; and Sean McFate, *The Modern Mercenary: Private Armies and What They Mean for World Order*, Oxford: Oxford University Press, 2014.

151. Robert J. Bunker, *Old and New Insurgency Forms*, Carlisle, PA: Strategic Studies Institute, U.S. Army War College, March 2016, pp. 44-45, available from *ssi.armywarcollege.edu/pubs/display.cfm?pubID=1313*.

152. This has led to an attempted international ban on "killer robots"—that is, "a preemptive ban on fully autonomous weapons." See Campaign to Stop Killer Robots, available from *https://www.stopkillerrobots.org*. Also, see Rasha Abdul Rahim, "Ten reasons why it's time to get serious about banning 'Killer Robots,'" Amnesty International, November 12, 2015, available from *https://www.amnesty.org/en/latest/news/2015/11/time-to-get-serious-about-banning-killer-robots/*; and Stephen Goose, "The Case for Banning Killer Robots," Human Rights Watch, November 24, 2015, available from *https://www.hrw.org/news/2015/11/24/case-banning-killer-robots*.

153. Very candid discussions about the implications of arming sentient robots took place during one of the sessions at a U.S.-Canadian military robotics and military operations conference held in May 2015. Track I—remotely controlled systems were not the concern. Rather, the Track II, AI-based systems were focused upon. As the author reported on this conference, "Debate centered on whether true AI (machine awareness of self) could ever be achieved and, if so, would humans really want to arm such sentient machines and robotic AI swarms (a human security approach)." See Bunker, "Colloquium Brief."

154. See this article from a cognitive neuroscientist, Bobby Azarian, "The Myth of Sentient Machines," *Psychology Today*, June 1, 2016, available from *https://www.psychologytoday.com/blog/mind-in-the-machine/201606/the-myth-sentient-machines*. Some mathematical models also suggest that sentient machines may never exist. See Anil Ananthaswamy, "Sentient robots?

Not possible if you do the maths," *New Scientist*, May 13, 2014, available from *https://www.newscientist.com/article/dn25560-sentient-robots-not-possible-if-you-do-the-maths/*.

155. Isaac Asimov, "Runaround," *Astounding Science Fiction*, March 1942, pp. 94-103.

156. Patrick Tucker, "DOD Science Board Recommends 'Immediate Action' to Counter Enemy AI," Defense One, August 25, 2016, available from *www.defenseone.com/technology/2016/08/dod-science-board-recommends-immediate-action-counter-enemy-ai/131066/*. This is a synopsis of the major finding in the Defense Science Board. See also Hope Hodge Seck, "US Won't Use 'Terminator' That Makes Lethal Decisions: Four-Star," DefenseTech, August 25, 2016, available from *www.defensetech.org/2016/08/25/us-wont-use-terminator-that-makes-lethal-decisions-four-star/#*.

157. For additional Strategic Studies Institute (SSI), U.S. Army War College (USAWC) analysis and recommendations, see the initial citations in this monograph to the works of Steven Metz and Douglas C. Lovelace, Jr., as well as the in-depth work by Jeffrey L. Caton, *Autonomous Weapons Systems: A Brief Survey of Developmental, Operational, Legal, and Ethical Issues*, Carlisle, PA: Strategic Studies Institute, U.S. Army War College, December 2015, available from *ssi.armywarcollege.edu/pubs/display.cfm?pubID=1309*.

158. U.S. soldier robotic support augmentation—rather than replacement—is being called "centaur," systems where humans control the robot's lethal armament capabilities. See Metz, "The Military Challenges and Opportunities of the Coming Robot Revolution," p. 1.

159. Such determinations will become even more complex when initial forms of weak AI become a reality. Almost ludicrous, yet legally significant, situations may present themselves once international lawyers and courts become involved. For instance, imagine a scenario in 2025 or 2030 where a weak AI program—equivalent to the decision-making and maturity potentials of a 5-year-old child—has been placed into armed U.S. robotic units. Such an AI system could, under some interpretations of international law protocols, trigger a ruling that the U.S. military was fielding the equivalent of robotic child soldiers. This, of course, assumes that eventually AI may begin to develop some form

of international standing as an artificial person. This may not appear as far-fetched as it sounds. Talk already exists of assigning AI systems patent rights. See Ryan Abbott, "I Think, Therefore I Invent: Creative Computers and the Future of Patent Law," *Boston College Law Review*, Vol. 57, No. 1079, 2016, available from *lawdigitalcommons.bc.edu/bclr/vol57/iss4/2*.

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