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POM AND THE MILITARY

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1 Introduction: Differentiating the Improvement of Arsenals from the Application of Weapons, Strategy, and Tactics in War

The early attempts at efficient management of large-scale operations in support of military power may be traced back to the Venetian Arsenal. Established in the 1100s, this employed a type of assembly line to mass produce galleys (Lane 1973). The industrial revolutions of England in the eighteenth century and the United States in the late nineteenth century engendered tremendous growth in the application of scientific principles to industrial problems and processes. The development of interchangeable parts and the division of labor into specified, discrete tasks facilitated the refinement of production operations at a level of precision that was impossible before.

In the United States, Frederick Taylor developed “best methods,” time studies, and made tremendous contributions to “shop management” (see Taylor 1911; 1912 for the original and enduring works). Frank and Lillian Gilbreth shot more than 250,000 feet of 35mm film, capturing the movements of workers, which led to the development of the motion study methodology used in conjunction with Taylor’s time studies to develop the practice used by industrial engineers today (see Gilbreth and Gilbreth 1917, for a collection of their publications). The publications of Harris (1913) inspired a flurry of work in production and inventory planning that carries on today, and Shewhart (1931) ushered in methods for controlling quality through the use of statistical methods that would carry on through the work of Feigenbaum (1945), Deming (1982), Juran (1988), Ishikawa (1990) and contribute to the development of Ohno’s (1988) Toyota Production System. All of these methods and innovations resulted in the capacity of national arsenals to make greater quantities of reliable and even more destructive weapons at a lower cost. This fundamentally changed the nature and scope of war from 1914 onward. The production efficiency and quality of national arsenals has never been greater at any point in history.

1.1 Differentiating the Character of Operations Management in the Civilian and Military Contexts

Differentiating operations research from operations management or management science has concerned scholars for some time (see Miser 1997, for example). In the end, however, we
conclude that if they are not different moods of one personality, then they are close cousins of
the same species. What distinguishes operations management in the military context from the
civilian context is that the focus is on fighting under extremely volatile and dynamic conditions.
The contributions of Frederick Taylor (1911) differ fundamentally from those of Morse and
Kimball (1951), who collected the most effective methods and approaches to operational prob-
lems that were so successful during World War II and introduced them to the broader scientific
and industrial community. Taylor was focused on repetitive processes in a controlled environ-
ment that would result in a best method resulting in long-run gains. Morse and Kimball’s work,
however, focused on effective methods that tended to provide a decision maker with a scientific basis
for a decision in a deadly, dynamic environment that would yield some immediate advantage.
Another distinguishing feature of operations methods in the military context is that new methods
and models may be adopted almost immediately because the focus is on fighting more effectively
and winning in an existential competition.

Operations management in a civilian context has non-lethal competition as its context. How-
ever, a wartime enemy is much more compelling in his lethality, and the rate of change that
must be made to counter an enemy’s actions has a much shorter time constant. Intelligence and
information is vital but cannot be perfect, and the often-lethal countermeasures by which we
try to slow down the enemy’s knowledge and decisions are not available in a civilian context.

1.2 The Pirandello Principle

Military applications of operations management confront what Machol (1977) described as the
Pirandello principle where “numbers which are quite reasonable to obtain in theory, [cannot] be
obtained in practice” because it is infeasible. In military operations, battlefield data is notoriously
unreliable and “dirty.” The “fog of war” and the presence of danger inhibit accurate collection.
Hit probabilities, casualties, and damage measurements are unreliable or mixed in their accuracy.
But combat data is better than controlled tests and simulations, and good enough to get first-
order approximations. The military analysts’ rule is “when there is a war on, study the war.” This
implies that operations analysts must be forward deployed with the forces that are operating and
fighting at the scene of the action.

We have described how the industrial revolution brought methods used to build and improve
the efficiency and quality of arsenals. We have also differentiated between the practice of devel-
oping and improving arsenals with the application of methods to improve military operations
which must necessarily include the application of weapons as well as strategy and tactics devel-
opment. We will now address past history beginning in the early twentieth century and how
operations analysis evolved in support of war.

2 Past History

Prior to World War II, there was a tradition of applying quantitative methods, as well as deliber-
ate and advance operational planning, to military operations. This application of quantitative
methods was especially successful for logistics planning when the timely movement of troops
and their supplies to a specific site or theater of war could be measured with relative precision
(i.e., accurate within a factor of two or less). Lynn (1993) and van Creveld (1980) give impressive
examples of how the profession of military logistics developed during modernity.

World War I proved to the world that warfare was now an industrial endeavor. The com-
plexities encountered while implementing and utilizing new and innovative weapons such as the
airplane, machine gun, chemical agents, armored tank, wireless radio, and the submarine would require bringing to bear scientific discipline in order to realize the full destructive power of these technologies. Many veterans from World War I would go on to apply their experience as well as their scientific training to the problems encountered in World War II.

The accelerated rate of technological change from the years 1939 through 1945 placed significant demands on warring nations to increase the rate of adoption, implementation, and adaptation in the most destructive and controlled manner possible to better their chances of winning. After the attack on Pearl Harbor in December 1941, most American warship classes changed their functions. For example, aircraft carriers with their longer range of attacks replaced battleships as the capital ships in every fleet that had them (Hughes 2000). Battleships became primary naval gunfire ships to support the many opposed amphibious assaults in the Pacific and European theaters. New employments entailed changes in the way analysis in support of tactics and battle planning was conducted.

Many of the core methods used in operations analysis during this time were developed many years before the war. Notably, the works of Babbage, Bridgman, Feller, Lanchester, Pearson, and Von Neumann were influential. The 1930s witnessed such advances in mathematical and statistical methods as game theory (von Neumann 1928), sequential sampling (Dodge and Romig 1929), confidence limits (Fisher 1932), the formula for $M/G/1$ queues (Pollaczek 1930; Khintchine 1932), control charts (Shewhart 1931), continuous time Markov processes (Chapman 1928; Kolmogorov 1931), hypothesis testing (Neyman and Pearson 1933), martingales (Lévy 1934), matroids (Whitney 1935), the design of experiments (Fisher 1935), and Turing machines (Turing 1936). However, it was during the war that new operations methods were developed as well as advances in computers.

The British led the way to better tactics that increased supply and troop convoy survivability, exploited radar, sonar, voice radio, aircraft homing devices, developed airborne identification methods as to friend or foe, and the employment of chaff as well as other decoys. The British Anti-Aircraft Command Research Group—known also as “Blackett’s Circus”—were a motley crew of physicists, physiologists, mathematicians, and a surveyor working under the leadership of P. M. S. Blackett (who went on to win a Nobel Prize in physics in 1948) that made significant headway in the application of science to all aspects of war at the time (Budiansky 2013; Kirby 2003). The United States followed in April 1942 by creating the U.S. Antisubmarine Warfare Operations Research Group (ASWORG). The ASWORG was staffed by civilians working under a Navy admiral (Gass and Assad 2005). Then, in October 1942, the United States also deployed a civilian team to support the Eighth Air Force in Britain (Jewell 1977). The declassified work by Koopman (1946) on search and screening is worthy of several hours reading, not only for its historical significance, but also for the elegance and thoroughness of its exposition and applicability to emerging problems.

The defining characteristics of the early military operations giants were (1) familiarization with the technologies and tactics that allowed them to make quantitative recommendations that saved lives and enhanced weapon performance; (2) acknowledgment that analysis of war alone could not cover all aspects of the decisions, actions, and results for war; and (3) the way that analysts had to work directly under the decision maker and his top staff with no layers between them and the commander to be effective due to both factors. It became obvious during the war and thereafter, that if the decision maker was not astute enough to recognize how military operations methods of research and management could help them, as well as its limits, then the analyst teams—even the best ones—were wasting their time and must go somewhere their assistance would improve combat effectiveness.
2.1 Bringing Advances in Military Operational Research to Civilian Operations Management

Shortly after the war, scientists who worked on operational problems sought to introduce the rest of the world to the rapid developments that had been made in methodologies and the results achieved that helped improve the efficiency and efficacy of combat. The 1950s and 1960s witnessed the publication of several works devoted to expounding the methods of operations management, research, and analysis (see, for example, Morse and Kimball 1951; Kaufman 1963). However, there was a struggle to reconcile how or whether to bring the new methods and approaches into the disciplinary fold that constituted the monastic structure of academe. Kittel (1947) was one of the early prognosticators of the potential impact of these new methods on industrial society with a publication in Science. Hindrichs (1953) proposed a philosophy for operations analysis that would bridge military operations research with business, management, and general industrial problems. Churchman et al. (1957) provided a timely survey of operations research methods and their applications that expanded upon wartime work and is to this day an extremely useful introduction to the subject. Beer (1967) introduced the term management science and defined it as “the business use of operations research.” However, the views on the emerging field of operations research were not all welcoming or enthusiastic (Mood 1953). In spite of the discussions regarding where operations research “belonged” as a discipline or field, its influence and methods spread into finance, commerce, production, and transportation industries.

The creation of the operations curriculum and the award of Masters Degrees at the Naval Postgraduate School in Monterey, California, gave coherence and structure to the operations discipline, for both military and commercial purposes. After 1962 when the Department of Operations Research was chartered, it was accompanied by a greatly expanded officer student population. Simultaneously, systems analysis and management science curricula were established in order to create complementary disciplines as well. The work on operational military problems continued at a rapid pace after the war at places like the RAND Corporation in Santa Monica, California. RAND exemplified a place for scientists to work together on the interdisciplinary problems faced by the United States during the Cold War. Scientists not on permanent staff would retreat to the sunny beaches of Southern California for the summers to work in a vibrant atmosphere that seemed to produce an endless fountain of new ideas that directly addressed military problems. It was here that the work of Dantzig, Arrow, Aumann, Schelling, Koopmans, Nash, Kahn, Enthoven, Baran, Marshall, Bellman, Hitch, Speier, von Neumann, the Wohlstetters, and many others found fertile ground for their intellectual seeds to bloom. In the United States, the first Military Operations Research Symposium took place in 1957 with support from the Office of Naval Research and was held at least once a year until the Military Operations Research Society (MORS) was created in 1966 and continues to convene an annual meeting and publishes the Military Operations Research Society (MORS) Journal dedicated to the subject of military operations research.

From 1950 through the 1970s, advances in analytic methods and algorithms, as well as computing machines, encouraged analysts to take on larger and more complex problems. Dantzig (1957) showed that some of the most important decision problems in war and industry could be stated as linear programs. His development of the simplex method allowed for fast solutions. The post-war development of operations research, systems analysis, and policy analytical works shaped far-reaching subjects as military basing (Wohlstetter et al. 1954), intelligence (Wohlstetter 1962), and strategic conflict, especially between two competitors. This resulted in further development, and elaboration upon, von Neumann’s early work in game theory (Nash 1950; Flood 1952; Luce and Raiffa 1957; Schelling 1960; Dresher 1961). Miser and Quade’s contribution to the area
of systems analysis is well known and established in their seminal handbook containing three volumes (Miser and Quade 1985; 1988; Miser 1995; 1997). It was also during this period that systems analysis gained ever-increasing influence in the national policy circles. Operations research and analysis in their original forms were not about procurement and programming but about **fighting** more effectively. Systems analysts, beginning with McNamara, Hitch, and Enthovan in the 1960s, had ever-increasing influence in Washington, D.C., and often claimed more predictive power with their methods than they could deliver—particularly in making macro-planning, programming, budgeting, and execution (PPBE) decisions.

We have described how, at the dawn of World War II, it was broadly recognized that the analysis of war alone was insufficient for winning wars. The rate of technological change increased significantly and war was now a technical business from both the standpoint of weapons as well as methods of application and concepts of operation. After World War II, systems analysis developed out of the early analytic, operational approaches, which shaped strategic developments in the programming of military force sizes and capabilities. Today, it is understood that there is a dialectic between the practice of operations management in the context of military and non-military settings, and that the applications advance and expand as a result of the cross-fertilization over time. We will now address the present situation and how operations management has been used to support contemporary wars.

### 3 Present Situation

More than thirty-five years ago, Bonder (1979) wrote, “The relevance of current mathematical developments in OR is continually questioned and, perhaps more significant, the techniques and methods are being developed by individuals who have more of a disciplinary allegiance to mathematics and economics than to operations research.” Operational (or operations) research took shape from 1939 to 1945 in response to fundamental changes in the technology and resulting conduct of war. Today, operations research as it exists outside of military application barely resembles what it was when it began more than seventy years ago, containing much more emphasis placed on sophistication of methods regardless of efficacy (Ackoff 1999). However, within institutions that focus primarily on military problems, there have been refinements on past methods as well as new developments that have contributed to both operational and cost effectiveness during recent wars and conflicts. Much of the applied operations work in support of the military is of little interest to the academic community because the methods may not be entirely new (mathematical programming is widely used) or the problems are not easily solved in a closed-form, analytic expression; as computing has advanced, algorithms and approximate approaches that produce fast, feasible and “good enough” solutions are preferred by decision makers that must act quickly. Some approaches may be so interdisciplinary or novel that they do not easily fit within the orderly and cautious bounds of the peer-reviewed journals and find better homes in books; the Delphi method (Brown 1968), the focus group and Guttman scale (Stouffer et al. 1950), and the Monte Carlo method (Ulam et al. 1947) come to mind.

#### 3.1 The Problems of Search, Optimization, and Exchange

The problems of search, optimization, and exchange were particularly pressing during World War II and they remain so today. Morse and Kimball (1951) identify many of the fundamental problems addressed at the time as well as measures of effectiveness. Sweep rates of patrol and search include submarines searching for ships and ships and aircraft searching for submarines. Exchange rates address the ratio of enemy and own losses such as during air-to-air combat or
convoy versus submarine actions. Comparative effectiveness addresses the effect of weapons (such as whether to use submarines or aircraft to destroy ships). The evaluation of equipment performance addresses the effectiveness of new weapons or weapon applications during the course of a war. Determining optimal routes for transporting troops and supplies inspired the development of the transportation problem (Hitchcock 1941; Koopmans 1949). These problems, and of course, the atomic bomb, required a high degree of interdisciplinary work and swift application. Today, the problem of search, optimization, and exchange are extremely relevant. Precision strike weapons necessitate military formations become smaller, more dispersed, and heavily armed.

The wars in Iraq (1991–1992 and 2003–2011) and Afghanistan confronted decision makers with problems of search (for people and improvised explosives), logistics, and pacification. The first two were well studied in previous conflicts—particularly World War II—and the last was covered by the seminal works of Gwynn (1934), Galula (1964), Trinquier (1964), and Kellen (1970). The search for people and improvised explosives took on a different approach from the past given the availability of empirical data collected from unmanned systems (or drones), sensors, and first-hand reporting from soldiers in the field. The amount of empirical data being collected aided the effort to find targets, identify patterns of activity and behavior, and focus resources to neutralize or kill the enemy. The need to quickly and effectively address improvised explosive device (IED) attacks became particularly urgent and the use of empirical data gave rise to behavioral analysis that resulted in some success during the second Iraq war of 2003–2011 (Davis et al. 2013). The U.S. solidified its reputation as having the world’s greatest man hunting capability evidenced by a continuous cycle of successful raids that killed or captured high-ranking figures within Al Qaeda and its splinter groups across Iraq and Afghanistan. The man hunting capability, too, was built upon earlier scientific models of problem solving. Anyone familiar with the find, fix, finish, exploit, analyze (F3EA) cycle used by special operations forces under General Stanley McChrystal (2011; 2013) will recognize the similarity to Shewhart’s plan, do, check, act (PDCA) cycle (Shewhart 1931; Deming 1982). The availability of data also made streamlining the logistics operations much easier and faster as combat operations evolved (Peltz et al. 2015; Peltz et al. 2005a; 2005b) and algorithms were developed, resulting in unprecedented inventory service levels in the history of the U.S. Army (Peltz et al. 2008; Girardini et al. 2004; Peltz and Robbins 2007). As the nature of warfare is changing, there remain many problems in the areas of sourcing, interoperability, resiliency, stock positioning, basing, and integration of unmanned systems that remain to be addressed (Yoho et al. 2013) and we will discuss some of these in Section 6.

4 Future Projections as the Character of Conflict Changes

The current and past application areas of operations management in the military context are in the following seven areas: (1) battle planning, (2) wartime operations, (3) weapon procurement, (4) force sizing, (5) human resource planning, (6) logistics planning, and (7) national policy analysis. A comprehensive discussion of each is addressed in Hughes (1997). Battle planning includes the preparation for wartime operations, based on friendly and enemy orders of battle as well as the existing strategic or tactical environment. Wartime operations are concerned with the actual conduct of war and are distinguished from battle planning by available, current, wartime data and known, immediate military objectives. Weapon procurement involves the selection from among competing weapon systems or characteristics for procurement decisions. Force sizing involves the decision of how many weapons systems of which types to (1) operate, (2) support, and (3) procure in the future, either in the defense establishment as a whole or in a major component such
as the army or the nuclear weapons arsenal. Human resource planning involves the design and operation of manpower, personnel, training, and assignment systems. Logistics planning includes the design and operation of all manner of military logistic support. And finally, national policy analysis addresses supra military actions that influence, or are influenced by, military considerations such as arms treaties or subsidies of commercial transportation.

Five of these seven topics (planning, operations, procurement, human resource planning, and logistics planning) are also important in a non-military context, but the costs, consequences, and planning horizons tend to be much different. Ship building plans, traditional aircraft design, and even small arms development may take place over decades whereas capital investment decisions in the non-military setting are typically shorter. For both the military and non-military settings, the application areas will likely remain the same, but the problems within them will change as will the need to solve the problems of trade-offs given the interdependencies between them all. Future warfare will be conducted in two domains: (1) what may be called “high-end” or conventional warfare between two peer or near-peer actors possessing missiles and other precision strike weapons and (2) warfare with non-state actors capable of carrying out military, para-military, or terror operations both within and outside their geographic span of control.

### 4.1 High-End Warfare

What might be called “high-end” or conventional warfare will require the use of salvo equations (Hughes 1995) to illustrate potential losses and survival where precision weapons are used by two peer or near-peer combatants possessing precision strike weapons. Additionally, campaign analyses such as those described by Kline et al. (2010) supported by wargaming will be critical to developing and maintaining sharp thinking about security, conflict, and combat; these types of analyses often point to where more refined mathematical, computational, and/or analytic work should focus. The war games played at the Naval War College—more than 300 between 1919 and 1940—illustrated that the prevailing U.S. strategy that was intended to guide any campaign against the Japanese in the Pacific was unexecutable (Hughes 2012). The influence of Boyd (1976; 1996) who introduced the OODA (observe, orient, decide, act) loop has never been more present as the need for making good enough decisions quickly is paramount, and Boyd’s echo of “he who can handle the quickest rate of change survives” remains valid.

### 4.2 Warfare with Non-State Actors

The newest category of military operations analysis is in methods of conducting irregular warfare and fighting non-state actors to include terrorist and trans-national criminal organizations. As the nature of conflict and stability has changed, there are opportunities to apply operational analytics to security in arenas beyond the military battlefield. The methods of village stability operations (CJSOTF-A 2011; Galula 1963; Jones 2010; Krepinevich 1986; Petit 2011; and Shackleton 1975) as well as behavioral analysis to predict attacks, has crossed over from warfare into policing in order to prevent crime, improve the effective use of resources, and to track potential terrorists (Levine and Tisch 2014). The use of mathematical models to predict whether a terror cell is still functional after a number of operatives have been removed will continue to be important (Farley 2003).

We are in the age of what Arquilla and Ronfeldt call netwar (Arquilla and Ronfeldt 1996; 1997; 2001). The analytical techniques needed will likely be patterned after antisubmarine warfare analysis, which emphasizes search theory techniques. In irregular warfare, as in antisubmarine warfare, usually if you can find your enemy, you can track him, and if you can track him, you can kill or neutralize him. There are likely continued opportunities to apply game theory to

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important military problems at the operational and tactical levels as it has been in the past (Haywood Jr. 1954). However, the classic two-player games that proved useful for analyzing strategic competitions such as the Cold War struggle between the U.S. and Soviet Union will have to be expanded upon to include multiple players—many of whom are not rational—with sometimes competing and other times complementary objectives. Approaches and models that consider ethology rather than the purely rational calculating, and maximizing *homo economicus*, will be useful. Finally, the development of algorithms and models that contribute to the effective development of swarming autonomous systems as well as the defeat of swarming autonomous systems will be in great demand throughout the remainder of this century. Swarming behavior has been studied in the natural sciences to understand group behavior of ants, locusts, bees, birds, and fish. However, it is also a serious area of study with respect to the future of war. Edwards (2000) and Arquilla and Ronfeldt (2005) discuss the application of swarming in warfare as well as its implications for the future of war.

5 Implications for Managers

Growing computer power has enhanced the ability to explore ever more complicated problems and variations on friendly and enemy choices. Among these are spreadsheet applications and geographic information systems (GISs) to include the simplest available through a web browser, and presentation software that permits the swift preparation of presentations, either artfully simple and communicative or robust with visual display and graphical exposition of relationships. Google Maps has, almost unnoticed, become one of the most powerful aids to analysis, just as electronic maps have become valuable for planning operations. Because future conflict will require coordination and cooperation of allies and partners to function as a coordinated network, the ability to bring together information quickly and develop concrete pictures that translate across time and language barriers will be critical. However, like all innovations in communication technology, the power to gather and disseminate data quickly brings with it the danger of both information overload and enemy intrusion, so we emphasize the value of analyst experience and quality over brute force and comprehensive quantity.

Finally, there are opportunities to capitalize on management techniques that allow organizations to execute important warfighting processes more efficiently and effectively. For example, developing methods and processes that allow for searching for the enemy, fixing the enemy’s location, killing or immobilizing them, and then exploiting what we may learn from the engagement in order to make new decisions that are cheaper, better, and/or faster are highly desirable. Advances in this area would combine key aspects of what we have learned from the application of repeatable, data-driven scientific processes (such as Shewhart’s PDCA cycle), “lean manufacturing” (eliminating waste, visual management, and reducing handoffs and bottlenecks), Boyd’s OODA loops, and search and eliminate targeting cycles such as find, fix, finish, exploit, analyze, and disseminate (F3EAD). This area will likely be the sole burden of managers and warfighters. Academicians will steer clear of the process domain because it is a subject not aligned with their primary evaluation metric: the peer-reviewed academic journal. The academic journals almost never publish applied articles focused on process or the “how”; note that Shewhart (1931) published his PDCA cycle in a book, Boyd (1996) presented his OODA loop in lectures, “lean manufacturing” was documented in a book (Womack and Roos 1990), and the F3EAD process emerged in practice and was later documented in news (Gray 2014) and trade press (Flynn et al. 2008). However, there is significant opportunity in this management and process domain to increase the speed, efficiency, and effectiveness of all military operations that will be critical for winning in the new warfare environment.
6 Directions for Future Research

Research opportunities for military applications are nearly boundless, because operations and systems analysis are techniques limited only by the imaginations of receptive decision makers and the artful and communicative skills of the analysts. There are two categories that we see as fertile ground for advancement: (1) methodological development that may extend optimization techniques, the scope of data analysis, and data culling (to include what is being called “big data”) for useful presentation in support of critical decisions in a timely way and (2) substantive work, with growing interest in defeating drug running, containing terrorist attacks, and irregular warfare operations—these are all defensive operations. For the offense, a fertile field with many applications is in swarming autonomous systems as well as the support of special operations, with new and more effective ways to conduct clandestine or surprise attacks in support of legitimate authority.

The methodological field is widening in terms of opportunity largely due to the increased speed and decreased cost of computing that has occurred over the last several decades. The influential text by Holt et al. (1960) came as a result of U.S. Navy funding and included, among other significant contributions, optimal linear decision rules and exponentially weighted moving average forecasting methods (Gass and Assad 2005). However, there were many problems pointed out by the authors that could not be easily solved through analysis alone but would benefit from computational studies if there were enough computing power available in the future (Rappold and Yoho 2008). Many problems have been waiting for computing to catch up in terms of power and cost. Today, there is ample computing power available at reasonably low costs to address very complex problems and come up with computationally efficient and managerially satisfactory solutions. Again, in armed conflict, the optimal solution is not as important as having a better, cheaper, and/or faster solution than your opponent. Both the problem framing and solution benefit the decision-making process most when it can be comprehended visually. The importance of useful data presentation cannot be overstated. The speed and cost of computing, as well as the availability of shared, distributed networks, support that ability to bring together lots of information into singular “views” that are meaningful and support effective and efficient decision making.

Work that addresses networks and the complexity of systems with multiple actors will be beneficial for identifying promising directions for applied operations analysis and management. Moffat (2003) has contributed a good primer on this area and would be a good place for scholars interested in making contributions, but are new to the area, to begin. Substantive work that takes networks of cooperating agents as its subject will find a wide field of application in security studies. As conflict and long-run competition take place increasingly outside of the domain of high-intensity warfare, approaches that develop solutions for defending against networks intent on attacking will be useful. On the other hand, approaches that are focused on developing effective attacks using a network of distributed but lethal actors will also be useful particularly as warfare becomes increasingly unmanned and autonomous.

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