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# Reflections on the Future of Warfare and Implications for Personnel Policies of the U.S. Department of Defense

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What could the future of warfare look like? How might the policymakers in the U.S. Department of Defense (DoD) who are responsible for managing military and civilian personnel prepare for this new environment? This Perspective addresses these questions by reviewing the views of foresight practitioners and experts on advanced warfighting technologies and assessing implications for the management of military and civilian personnel, as viewed by policymakers and analysts from the defense manpower and personnel community.

The purpose of a RAND Perspective is to provide an informed view on a timely topic of interest. This Perspective examines the perspectives from a small group of defense experts about the future of warfare. We first selected a few key topics that participants discussed during a one-day workshop in 2017. We then drew on research from a range of academic fields to make informed speculation about the future of warfare. This speculation carries its own biases, however. The themes that workshop participants discussed, which themes we decided to highlight in this perspective, and our analysis of these selected themes were all subjective decisions.

The consensus among this group is that the face of warfare is changing, as evidenced by both changes in battlefield doctrine and practice of U.S. adversaries and in the rapidly evolving development of advanced warfighting technologies. Among these, advances in such areas as artificial intelligence (AI), autonomous systems, and human augmentation technologies are of special interest. Such technologies can be threatening in the hands of adversaries, coupled with both conventional and asymmetric strategies of engagement with U.S. forces. At the same time, mastery of such technologies can provide U.S. forces with strategic and tactical advantage. The issue is to determine the role of the human as advanced warfighting technologies develop and how policies for managing defense human resources should change to provide personnel with the necessary capabilities to operate with these technologies in this new environment.

We assume that the nature of threats and the technology that militaries use to combat them will change in the future. We further assume these broader changes have the capacity to define the military profession of the future.[1] In this perspective, we explore operational trends in future warfare and trends in emerging technologies that are likely to play a major role in future warfare and then discuss the implications for future personnel policies.

**Abbreviations**

| | |
|---|---|
| AI | artificial intelligence |
| BCI | brain-computer interface |
| BLS | U.S. Bureau of Labor Statistics |
| DoD | U.S. Department of Defense |
| IoT | internet of things |
| ISIL | Islamic State of Iraq and the Levant |
| NATO | North Atlantic Treaty Organization |
| NSTC | National Science and Technology Council |
| OODA | observe, orient, decide, and act |

## The Future of Warfare

In a speech to the U.S. Military Academy in 2011, then–Secretary of Defense Robert Gates remarked, "When it comes to predicting the nature and location of our next military engagements, since Vietnam, our record has been perfect. We have never once gotten it right, from the Mayaguez to Grenada, Panama, Somalia, the Balkans, Haiti, Kuwait, Iraq, and more—we had no idea a year before any of these missions that we would be so engaged."[2] Of all people, Gates should know. A career intelligence officer, former director of Central Intelligence Agency, and later Secretary of Defense, Gates spent his career dealing with predictions about the future of warfare. Ironically, Gates is himself a victim of this myopic view of the future. In his focus on Iraq and Afghanistan, he canceled programs that he believed were not relevant to those challenges. Consequently, U.S. modernization efforts for the high-end adversary competition were supplanted by ones to confront irregular adversaries.

Indeed, military history is littered with wrong predictions. On the eve of World War I, German Chancellor Theobald von Bethmann-Hollweg said that the impending conflict would be "decisive" and a "brief storm."[3] During the interwar period, the French sought to capitalize on the lessons of the Great War. The popular view is that their efforts resulted in the sophisticated but ineffectual Maginot Line along the Franco-German border. While the defensive line largely did its job, the story is more complex. The French failed to understand the implications of mechanization, distributed command and control, and a talent-management system that relied heavily, for most of the interwar period, on short-term conscripts. Across the Atlantic, as late as 1942, U.S. Army MG John Knowles Herr pleaded with Army Chief of Staff GEN George C. Marshall—after most of Europe and large parts of Russia had fallen to the German blitzkrieg—for "the necessity of an immediate increase in horse Cavalry."[4] Before the Vietnam War, the U.S. military assumed that the next war would be a large-scale conventional or nuclear conflict with the Soviet Union in Europe. Although this was the riskiest scenario, it diverted attention from understanding how to prosecute irregular conflicts, such as the Vietnam War.[5]

It may be difficult to make specific predictions about the future of warfare, but several general tenets have proven reliable over time.[6] First, the nature of warfare has become more complex with time because of new threats coupled with the development of new technologies. Second, military organizations tend to adapt to this complexity by becoming more complex themselves. For example, advances in aviation resulted in the creation of the U.S. Air Force in 1947. Today, similar debates have emerged about distinguishing space and cyber as separate domains.[7]

Studying technology without consideration of how it might be employed in the future divorces means from ends and risks putting the proverbial cart before horse.

Given the subjectivity of predicting the nature of future conflict, some students of future conflict prefer to sidestep this endeavor entirely. Rather than technological advances being driven by guessing what the military *might* need or how and where the United States *might* fight, this school of thought reverses the causal sequence and looks at how the technological trends drive conflict. The 2015 *Air Force Future Operating Concept*, for example, noticeably avoids mentioning specific future adversaries and instead focuses on how technology will shape how the Air Force might fight in the future.[8] Judging from the views presented at the future of warfare symposium, many outside experts share this viewpoint.

Studying technology without consideration of how it might be employed in the future divorces means from ends and risks putting the proverbial cart before horse. Technology, after all, is developed to solve discrete problems, and although predicting the precise time and place of the next conflict may be as foolhardy as Gates warned, identifying the strategic problems of the future may be a more manageable task.[9] Specifically, we can at least identify five overarching trends that will help shape the who, what, where, and how of warfare in the decades to come.

## Trend 1: The Competition for Regional Hegemony Will Increase

Former Secretary of Defense Ashton Carter often argued that the United States faces four state-based threats: Russia, China, North Korea, and Iran. Although presidential administrations have since changed, this basic list of American adversaries has not.[10] With a billion-person population and the world's second-largest economy, China is a rising great power with the potential to challenge the United States on a global scale. Russia, by contrast, is a shadow of its Soviet Union heyday but still retains considerable power, particularly with neighboring states that were part of the former Soviet Union. Iran and North Korea are orders of magnitude smaller than either Russia or China but still retain considerable ability to affect events within their respective regions. As predicted by the *2015 Marine Corps Future Security Environment Forecast*, although the United States will remain the dominant global power in the future, it will have competitors—particularly on a regional level.[11]

These countries share a dissatisfaction with the current U.S.-led global order. China, for example, has territorial ambitions in the East and South China Seas that conflict with American and international legal principles of freedom of navigation, as well with the territorial claims of other states, including U.S.-treaty allies Japan and the Philippines.[12] Russia views U.S.-led North Atlantic Treaty Organization (NATO) expansion in Eastern Europe as encroaching on its traditional sphere of influence and undermining its security concerns.[13] Iran, the self-proclaimed protector of Shi'ite Muslims, opposes U.S. efforts in the region, particularly if they favor Sunni populations or Israel. Finally, North Korea's nuclear and missile programs challenge U.S. nonproliferation efforts. These regional competitions have already resulted in wars in such places as Ukraine, Georgia, Syria, and Iraq, and armed standoffs elsewhere, such as in the Korean Peninsula and the East and South China Seas.

Absent a cataclysmic event (historically rare), all four powers will continue to challenge the U.S.-led international order for decades to come. As Walter Russell Mead observed, "Chinese, Iranian, and Russian revanchism hasn't overturned the post–Cold War settlement in Eurasia yet, and may never do so, but they have converted an uncontested status quo into a contested one."[14] For the U.S. military, this means that its focus will need to shift or at least broaden from the counterterrorism and counterinsurgency fights that dominated the better part of the last two decades of conflict and toward increasing focus on state-based adversaries. As the *Summary of the 2018 National Defense Strategy* argues, "Inter-state strategic competition, not terrorism, is now the primary concern in U.S. national security."[15]

## Trend 2: Defending Ground Will Become More Challenging

The nature of "defending ground" is changing, not only in terms of the geographic location of potential conflicts but also in terms of what may define "ground" in future warfare. In addition to the changing nature of adversaries, the United States finds itself defending more ground—often in strategically difficult regions—than ever before. Starting after the Second World War, the United States developed an expansive series of security alliances in Europe, the Middle East, and Asia. While these alliances are arguably a source of strategic strength, they also commit the United States to defending states in geographically inopportune areas. As RAND Corporation research found, defending the newer NATO allies in the Baltics—let alone more-isolated countries, like Georgia—becomes problematic because of their proximity to Russia.[16]

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These same "tyranny of distance" concerns apply in other places, like East and Southeast Asia.

The increasing challenge of defending ground also applies in a more metaphorical sense when it comes to newer domains of warfare. As the number of space-faring nations multiply, so too does the number of potential threats to American space assets. The same logic applies to an even greater degree to cyber. Given the relatively few barriers to entry, potential adversaries do not even require state sponsorship to threaten American interests. Indeed, according to one of the workshop's participants, there are least 100 different cyber commands around the world today belonging to a range of state and nonstate actors. At the same time, much of the ground the United States must defend in cyberspace belongs to private-sector entities, posing legal and privacy concerns and complicating the American response.

## Trend 3: The American Qualitative and Quantitative Military Edge Will Decline

While its strategic challenges are multiplying, the American military's quantitative and qualitative edge over its adversaries is shrinking. Measured by active-duty service members, warships, and fighter aircraft, the Army, U.S. Navy, and Air Force are a fraction the size of their Cold War selves.[17] Although today's ships and planes are more capable than yesteryear's, raw size still matters. The United States faces increasing simultaneous threats in different corners of the world, and ships, planes, and troops can only be in one place at a time. Perhaps more troubling is the dulling of the American military's qualitative edge. According to a senior defense official attending the workshop, our assumptions about the inevitability of American technological superiority should be challenged. Thanks to the military drawdowns of the 1990s and later shifts in resources to pay for the counterterrorism and counterinsurgency wars of the early 2000s, weapon programs designed for near-peer adversaries stalled or stopped well short of their intended buy.[18]

By contrast, America's adversaries have not stood still and likely will continue to "reduce the [technological] gap" in the years to come.[19] For years, China has embarked on an intensive military build-up and is beginning to change the military balance in Asia. A 2015 RAND study found that, in a Taiwan scenario, China would have the advantage in air base attack and antisurface warfare against the United States and would match the United States in air supremacy, air penetration, and counter-space fights.[20] Russia also began rebuilding its military after a decade of decline in the immediate aftermath of the Cold War. As a result, Russia now has a more advanced, more professional, and ultimately more capable, albeit smaller, force.[21] Even such nonstate actors as the Islamic State of Iraq and the Levant (ISIL) now have access to advanced weapons. For example, during a single month in the Battle of Mosul, the group conducted 200 drone missions, and although these were not as sophisticated as American operations today, as one workshop participant noted, "they were science fiction to what the U.S. military had in 2001." In short, the image of the unmatched American military supremacy that first formed after the Persian Gulf War and still colors defense debates today might not capture the reality of the wars of tomorrow.

### Trend 4: The Lines Between War and Peace Will Continue to Blur

Regardless of the possible decline in America's competitive advantage, China, Russia, Iran, and North Korea might not need to resort to direct military confrontation, particularly if they can achieve their objectives through measures short of war.[22] As the *Summary of the 2018 National Defense Strategy* notes, "In competition short of armed conflict, revisionist powers and rogue regimes are using corruption, predatory economic practices, propaganda, political subversion, proxies, and the threat or use of military force to change facts on the ground."[23] All four principal state adversaries of the United States have already learned to operate in this gray zone between war and peace. In China's case, this involves building man-made islands and employing fishing boats and coast guard vessels to advance its claims in the South China Sea. Russia relies on its "little green men"—soldiers without identification—to fight in Ukraine and on cyberattacks to shape Western democracies' elections. For Iran, operating in gray zones means backing a variety of mostly Shi'ite proxy groups to attack its adversaries and advance its hold on the Middle East, while North Korea uses missile and nuclear tests to extract concessions from its Western interlocutors. As one workshop participant insightfully characterized, in the future, the "peace-war paradigm" may no longer apply. Instead, "It's always war. We're always in competition, and it's just the intensity and the nature of that competition."

In the future, this blurring the lines of war and peace will likely increase for several reasons. To begin, operating in the gray zone makes good financial sense: These operations often cost a fraction of the blood and treasure expended in a conventional conflict. Moreover, gray zone operations complicate the American and allied responses, forcing policymakers into difficult ethical, legal, and political choices of whether to escalate these crises into full-blown wars. Most importantly, recent experience proves that this form of warfare works: Russia reclaimed Crimea, while Iran posted gains in Iraq and Syria—all without the burden of large-scale conventional operations. Indeed, most successful "wars" of the future may be those that conclude without firing a shot.

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### Trend 5: The War on Terrorism Will Continue

Finally, although near-peer competitors will likely consume more attention and resources over coming decades for the reasons just mentioned, the terrorism problem that dominated conflict since the 9/11 attacks will likely continue for years, if not decades. Despite the recent gains against ISIL, the U.S. military will likely not be able to walk away from the counterterrorism mission any time soon. As terrorism expert Seth Jones argued, "Islamist extremism that al Qaeda represents will not go away soon. The ideology will survive in some form as wars in Africa, Asia, and the Middle East continue to rage."[24] Syria, Iraq, Yemen, and Libya are still in the midst of wars that have left hundreds of thousands dead and millions displaced.[25] Other Middle Eastern states—from Tunisia to Turkey—are still dealing with their domestic turmoil. To make matters worse, a broader sectarian-fueled proxy war between Iran and Saudi Arabia is slowly ratcheting up. In sum, it will be years, if not decades, before the Middle East stabilizes, and although ISIL may have been driven underground for the moment, the causes of violent extremism remain. So, while the U.S. military worries about building a force to deter and defeat state-based threats over the next several decades, it must also preserve, if not hone, the ability to pursue a global war on terrorism.

## The Future of Technology

The future of warfare sets the stage for assessing the potential contribution of emerging technology. This is especially critical, given traditional reliance on technology as a force multiplier by the United States. Yet, given the nature of defense acquisition, there is a risk of driving future technology based on current capabilities and technical feasibility rather than user needs. Technology should tie directly to operations and, in this case, the successful prosecution of warfare. It is in this context that the discussion concerning the trends in warfare outlines the user needs, also called the requirements *pull*, while the current state of the art represents the current capabilities, or technology *push*.

This section outlines the state of the art of prominent emerging technologies and explores key considerations as these technologies advance in the future. The themes that dominate the future of warfare generally map to technology in the following ways. The issues of adversaries pursuing geopolitical hegemony and of increasing indirect or fuzzy confrontation will govern technological growth at a high strategic level. The need to defend the ground most directly characterizes technology needs at a tactical level. The risk of losing a qualitative and quantitative edge emphasizes the need for technology growth in general. Finally, terrorism continues to drive technology needs, and there is a history of these needs to draw from. As one workshop attendee asked, "we have had a long time to adapt over the past 16 years, but are we ready for a faster pace?"

There is no crystal ball for what requirements will be necessary (pulled) or what technology may be developed (pushed). As one workshop participant noted, while portfolio management has always been a challenge, the goal is simply to move in the right direction. Thus, it is prudent to assess technological trends continuously and evaluate how they map to user needs and how they may help transform the role of people involved in warfare. To this end, this section is based on themes at the workshop, current literature, and subject-matter experts at RAND.

We do not intend to itemize and assess all technologies relevant to the future of warfare but rather to take the lead from the workshop and summarize prevalent topics that can support and may transform how humans engage in warfare. In that regard, the following technology topics were pervasive during the workshop:

- big data
- AI, cognitive modeling, and data analytics
- robotics
- human-machine teaming
- connectivity
- biotechnology.

In the next subsections, we discuss each of these topics. For each, we touch on how the technology is defined and on key conceptual considerations. Although thoroughly reviewing the state of the art of each topic would be beyond the scope of this work, we summarize the current state of the art, including common issues noted in the literature, as well as how the technology is used in warfighting. Finally, we note future considerations for policymakers. This includes significant risks and ways future technology may change warfare and the role of people involved in warfare in the context of the trends highlighted earlier.

## Big Data

### Definition and Key Considerations

As important and prevalent as big data is, its definition can be nebulous, depending on how one measures "big," which, in this context, is often characterized by volume, velocity, variety, veracity, and value. In general, the term *big data* represents relatively large amounts of structured or unstructured data but can also include data sharing, tracking, and ownership. De Mauro, Greco, and Grimaldi define it as "the information asset characterized by such a High Volume, Velocity and Variety to require specific Technology and Analytical Methods for its transformation into Value."[26] *Big data* refers to an increasing amount of data (and thus information) being acquired, stored, and analyzed. Big data can apply to almost all aspects of warfare, ranging from interconnected weapon systems that automatically exchange data and operate in a more coordinated fashion to the individual warfighter about whom extensive amounts of data are now gathered to indicate physical and mental performance trends.

Especially relevant to communications is not only the acquisition and archiving of data but also their consumption. In the case of warfighters, how information is absorbed and what data can be trusted are critical. Furthermore, the owner of the data is important, as well as the most effective approach to sharing it, which is especially critical for cross-service training, operations, and international military collaborations.

### State of the Art

The prevalence of big data stems from an information revolution that began in the 1990s. In fact, big data is a key aspect of a fourth industrial revolution called smart manufacturing,[27] which essentially entails acquiring, archiving, and analyzing data about interconnected manufacturing systems. This concept aligns with the effort to gather and process data about interconnected weapon systems and warfighters. As a centerpiece of this industrial revolution, in one workshop participant's terms, "data are the new oil." In fact, in just a few decades, society has moved from a machine-based society to an information-based society, and, as this process continues, we are forced to understand the nature and implications of data-driven and algorithmic systems,[28] which can range from transport vehicles to missiles.

On tactical and strategic levels, access to, ownership of, and understanding of data will continue to provide military advantages, as data are essentially information, and information has always been critical to warfare. The ability to gather, store, and process larger sets of data simply enhances the roles information has traditionally played in warfare.

Despite the growing availability of data, workshop attendees discussed the issue of whether data are trustworthy. Big data has a capability-vulnerability paradox,[29] whereby military adversaries can corrupt data through information warfare and with various forms of cyberattacks. Just as trustworthy data can be an asset for the warfighter, corrupted data can be a weapon for the adversary. To facilitate effective adoption of new technology by warfighters, it is important to ensure that data that provide underpinnings for many other technologies are valid.

In addition, for the first time, we may have too much data or information,[30] which presents a challenge for command and control. Acquiring and archiving data are not necessarily valuable in and of themselves; ultimately, humans or machines must use the data. Thus, there is a risk of providing data acquisition and data analytics without also addressing the human-factor issue of information overload, whereby too much information is presented to warfighters and inhibits effective and efficient decisionmaking.

Big data also has military implications with respect to warfighter performance and health care. There are now efforts across the services to outfit humans and their environment with interactive sensors to archive large amounts of biophysical data in real time and use them for various types of analysis.[31] Under the Air Force program Total Exposure Health, monitoring biophysical data can potentially be used not just in theater but during off-duty activities, and performance data can be aligned with additional environmental information to monitor not just the individual but that individual's interaction with the environment.[32] This program also points toward archiving information about an individual's micro–ribonucleic acid, molecules that essentially respond to various stimuli and regulate gene expression. This in turn could foster patient-specific treatments based on an individual's genetic makeup. With further extrapolation, which will be discussed the section of this Perspective on biotechnology, understanding an individual's genetics could also facilitate weapons that target individual or specific populations.

## Future Considerations

Workshop attendees agreed that, going forward, the amount of data available for use will likely increase substantially and how these data will be stored and aggregated must be considered, especially with respect to the end user. Warfighters ultimately must digest and make sense of terabytes of information, and this is not something humans do naturally. Thus, while the prospects of additional data can enhance military intelligence and operations, too much data that are not presented properly

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The issue of ownership will likely become increasingly important as human data are mined. The issue of who owns personal information gathered about a warfighter (during on- and off-duty hours) can be complex. With multiple adversaries pursuing hegemony, data ownership can become even more complex on an international level. As big data continues to be the new oil, it will be particularly relevant to state-based adversaries. It will no longer be sufficient to understand and manage our own data in the context of our own applications. We now must understand data in other regions, as well as accessibility of our data by other states. This presents a new and nebulous medium for warfare—acquisition and control of data—and can in turn blur the lines between war and peace.

## Artificial Intelligence, Cognitive Modeling, and Data Analytics

### Definition and Key Considerations

The terms *AI*, *cognitive modeling*, and *data analytics* are related; they all involve using data and often using big data to model and represent a state or a process. Nonetheless, AI is currently the most prevalent in the context of military applications and was interwoven in much of the discussions throughout the workshop. As with big data, AI often suffers from an unclear definition and, more important, misunderstanding by end users. In fact, AI can include multiple components, summarized as follows.[33] First, *perception* involves data acquisition in the same way that a human may see or hear information that is then used to make a decision. Second, *machine learning* essentially involves analyzing and learning from data. Third, AI also includes the process of *searching* data sets or information and *planning* actions. Finally, AI can include *autonomy and human interaction*. While the perception and machine-learning aspects are relatively mature, the latter two aspects are developing.

Generally, AI can be described as simulated intelligence stemming from mathematical models that make decisions. Technically, it is defined as a branch of computer science dealing with the simulation of intelligent behavior or as the capability of a machine to imitate intelligent human behavior, but even such technical definitions vary between sources.[34]

AI can overlap with the concept of big data when it includes data acquisition. In addition, the autonomy and human-interaction components of AI can overlap with robotics and human-machine teaming, which are discussed later. In a purely military setting, the term *AI* can often refer to a combat system that has the ability to make targeting decisions independently (e.g., an autonomous system),[35] but no formal, well-accepted definition of *autonomous weapons* yet exists.[36] Although DoD defines an *autonomous weapon system* as "a weapon system that, once activated, can select and engage targets without further intervention by a human operator,"[37] some argue that this definition, especially the use of the term *select*, is too ambiguous and does not distinguish between systems that act independently and autonomously and those that are preprogrammed to act automatically.[38]

All these topics can fall under the heading of data analytics, a more general category that encompasses analyzing sets of data.

Given the apparent relevance of the term, cognitive modeling can mistakenly be grouped with AI. However, cognitive modeling is more often discussed in the context of cognitive performance, modeling how people think and make decisions to understand and measure cognitive faculties rather than duplicate them. The goal of a cognitive model is to explain basic cognitive processes or how processes interact.[39]

## State of the Art

AI is dependent on underlying data. As the state of the art for big data matures, so does AI—reflecting the relationships between the two technologies. In fact, AI can help humans process the information overload that can result from big data. For example, "autonomous systems will draw on machine deep learning to operate 'at the speed of light' where humans cannot respond fast enough to events like cyberattacks, missiles flying at hypersonic speed, or electronic warfare."[40]

Although AI has been in use for many years, there has been concurrent advancement with large sets of accessible data, increased computational power, and newly developed machine-learning algorithms, and this confluence has accelerated the dissemination of machine learning such that it is broadly prevalent, even among nontechnical users. In fact, even the process of developing AI algorithms is becoming accessible to the novice user.[41] In the context of warfare, this dissemination potentially places powerful military capabilities in the hands of nonstate adversaries.

In general, the primary application for AI in warfare is automated decisionmaking and the analysis of big data. This can apply most notably to weapon systems that could potentially fire automatically, as well as scanners that can find an individual in a crowd using facial-recognition software. The applications are broad, but a few examples are described here. Project Maven is a DoD effort to use AI to improve computer vision (analysis of imagery data), which in turn would improve drone strikes.[42] Current drones use AI in some capacity to manage communications, track enemy movement, search for lost or injured service members, and survey landscapes and scenarios.[43] In the same way AI is used to provide some level of autonomy to drones, it is also used in the same way with ground-based robots, which can be used for search-and-rescue operations. Related to this application is the common use of AI for facial recognition and more broadly for analyzing and finding trends in large sets of data (big data). These data could represent satellite imagery, terrain information, or data about the status of individual warfighters.

In discussing the state of the art for AI, one must distinguish between narrow AI and general AI; each is at different levels of maturity. General AI (also called strong AI) is machine intelligence with the full range of human intelligence.[44] Alternatively, and much more common, is narrow AI (also called applied AI or weak AI), which is used to focus on one narrow task. Most researchers assume general AI is several decades away.[45] Furthermore, in the context of a thorough assessment of faulty assumptions implicit in the argument that AI may become "smarter" than humans, even general intelligence does not necessarily automatically imply the ability to solve complex problems.[46] Thinking alone does not move one from not knowing to knowing. Nonetheless, proper use of AI can help military personnel digest massive amounts of data and offload narrow and repetitive decisionmaking tasks.

As explained by a workshop participant, with respect to the use of AI in warfare, "what matters here is who can bring more cognition to the battlefield and how we apply it. Previously, we built machines stronger than humans, but now, some suggest . . . we're able to build machines that are actually smarter than humans in narrow ways, in specific tasks." While this is a critical point in the discussion about the use of AI in warfare, the idea that AI may be "smarter" than humans is a concerning and common issue. To suggest that a machine is smarter than humans necessitates a clear understanding of what it means to be smart, which is a complex concept with many different dimensions, ranging from creativity to physical coordination to social sense,[47] the spectrum of which is not captured completely, even by general AI.

## Future Considerations

The most significant consideration about the future of AI is the time frame in which general AI systems become available and can think like humans. Most researchers agree that this is decades away, but it may eventually be feasible. In a warfighting context, the most significant extension is the potential for weapon systems that can make lethal decisions independently.

Risks concerning AI do not necessarily stem from the approach in and of itself but from potential inappropriate use. The use of AI potentially places very complex capabilities in the hands of nontechnical users and thus risks inadvertent inappropriate use by adversaries and by U.S. personnel. The increased use of AI increases the risk that a poorly designed AI algorithm is integrated with a lethal system. Furthermore, AI can fall subject to "data diet vulnerability," whereby the results of an AI system are only

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as accurate (and trustworthy) as the data used to train it,[48] but the underlying data are not necessarily scrutinized by the end user. Policies for the use of AI will thus have to address industry standards, ethics, and where responsibility lies—with the user or the developer (of the underlying algorithm)—and will have to avoid moral outsourcing.[49]

Further complicating the risks surrounding AI is the trend whereby many dramatic advances in AI and autonomous machines are being made by private firms with commercial motives.[50] This can facilitate the dissemination of technology that enables autonomous weapons, which in turn presents a challenge for the U.S. Department of Commerce in controlling the export of warfare-relevant AI intellectual property. With respect to both AI and the underlying data, the trend in warfare around the need to defend ground will include defending cyberspace.

Workshop attendees agreed that the issue of managing control is related to the issue of trust, and these are two key issues to consider. AI, cognitive modeling, and data analytics all involve using data and often using big data to model and represent a state or a process. Consequently, the fundamental questions relate to the validity of the underlying mathematical models and their trustworthiness. As data analytics, including AI and cognitive modeling, become more pervasive as a tool for today's warfighter, deployment of such tools and integration into operations will depend heavily on how well they are trusted.

Another future concern regarding AI relates to the observe, orient, decide, and act (OODA) loop. With the deployment of AI and autonomous systems, the pace of war can exceed the speed at which humans can observe what is happening, conceptualize a strategy, and deliver commands. The OODA loop moves from humans to machines.[51] This will eventually raise the issue of how control is balanced between humans and machines.

The concern that the United States may be losing its qualitative and quantitative edge in warfare applies to military technology in general, but it is especially pronounced with AI, given China's focus on this evolving technology (it has been particularly aggressive in this field). China's growth as a potential technology leader has been termed a "Sputnik moment,"[52] as it is clear China presents significant technological competition. China designates AI as a transformative technology underpinning economic and military power and aims to dominate the field by 2030.[53]

In fact, "AI has become a new focal point of international competition. AI is a strategic technology that will lead the future."[54] Consequently, there is an increasing need and urgency for an AI national strategy and an improved understanding of AI technology among military personnel.

To be sure, the United States has taken some steps to start developing AI-related policy. The National Science and Technology Council (NSTC) previously released policy documents to evaluate the state of AI technology and applications, highlight policy-related questions,[55] and establish a set of objectives and priorities for federally funded AI research.[56] While this effort is an example of progress, additional work is needed with current and future AI policy. The NSTC argues that current levels of research and development spending for AI are insufficient.[57] There is an opportunity for the United States to remain competitive, but "fixing this issue requires a degree of self-awareness of the global economy surrounding AI and a drive for advancing the breadth of innovators and innovations in the country."[58]

## Robotics

### Definition and Key Considerations

Given underlying data and algorithms for processing and using data, robotics (and automation) applies trends or computational results to machines. While automation generally refers to repetitive basic tasks, robotics entails more adaptive, complex tasks, where machine learning is more prevalent. By definition, a *robot* is a machine that resembles a living creature in that it is able to move independently, or it is a device that automatically performs a task.

As workshop attendees agreed, primary questions surrounding robotics concern autonomy and the degree to which machines operate independently. How much freedom should robots and their underlying mathematical models that govern behavior have, and how much should users trust the models embedded in the robotic systems? This leads to questions of control when considering human-machine teaming and the extent to which the warfighter should or could control systems.

### State of the Art

Robotics is an especially important aspect of technology with applications to warfare, as it reflects advancement with AI, big data used to train AI, sensors, data analytics, and controls. In fact, Manufacturing USA—a network of manufacturing innovation institutes designed to address key areas for advanced development in the manufacturing sector—has recently initiated the Advanced Robotics for Manufacturing Institute.[59] This institute is supported by DoD, and it reflects a national interest. The technical thrust areas for this institute, which represent the key current areas of research and development in the field of robotics, are human-robot interaction; scheduling, learning, and control; dexterous manipulation; mobility and navigation; perception and sensing; testing, verification, and validation; and mechanism design.

A primary consideration when evaluating the state of art of robotics is what robots can and cannot do, and this assessment is often made relative to human capabilities. As Kolhatkar notes, there is a common saying in the field of robotics with regard to their capabilities: "Anything a human being can do after age five is very easy for a robot. Learn to play chess, no problem. Learn to walk, no way."[60]

A significant benefit of robotics in a military setting is that they are more expendable than humans and can be sacrificed.

Furthermore, robotics generally does not yet infringe on jobs or tasks that require emotional and social intelligence. Work with perception and classification of random objects and fine manipulation is still in the research stages but remains a goal for robotics development. Another active area of research with increasing practical applications is that of active-prosthetic (or bionics) development, which overlaps with biotechnology, specifically brain-computer interfaces.[61]

A significant benefit of robotics in a military setting is that they are more expendable than humans and can be sacrificed. This fosters their use for high-risk tasks like urban exploration and work with explosive ordnances. Robots may also be able to lighten the load for warfighters by carrying heavy loads for an individual or for a squad.

Discussions about robotics often gravitate to the topic of autonomy. In this regard, lethal autonomous weapons are perhaps the greatest current concern with respect to robotics policy, and discussions about these weapons have been held at the United Nation's Convention on Certain Conventional Weapons, which prohibits or restricts some weapons deemed to cause unjustifiable suffering.[62] U.S. policy currently requires human involvement and states that "[a]utonomous and semi-autonomous weapon systems shall be designed to allow commanders and operators to exercise appropriate levels of human judgment over the use of force."[63] Nonetheless, even within the Army, which has been relatively slow to adopt weaponized robots, use is increasing.[64] The reticence seen a decade ago is now subsiding with respect to autonomous gun-armed vehicles and robots in part because autonomous systems are becoming less expensive and more reliable.

Currently, robots can complete certain complex tasks, like landing an aircraft, with complete autonomy. However, precise repetition, such as landing the aircraft in the exact same place on a ship, can cause structural issues, and one presenter cited an example where an autonomous vehicle had to be reprogrammed to be "more error prone like humans." Regardless, much of the current work with autonomy is focused on areas of communication and target identification,[65] which can reduce the burden on the warfighter.

## Future Considerations

When considering the future of technology, key considerations for robotics often go hand in hand with autonomy and human-machine teaching (discussed in the next subsection). Relevant to military personnel and robotics specifically is the necessary attention to skill transfer and to having people shift to new jobs as robots become more pervasive. Although robotics (and AI) will likely lead to displacement of some jobs, new automation historically and routinely creates more new jobs than it displaces.[66] That is not to say that the displacement is not disruptive, but ultimately the end effect tends to be positive. Thus, as with AI, key considerations will continue to be skills assessment, alignment of skills with current and anticipated needs, and necessary corresponding training. However, in some cases, the drive for automation does not necessarily stem from desired increases in efficiency but from deficiencies in manpower. In these cases, robotics can be a welcome resource.

A significant risk with the increased fielding of lethal robots and lethal autonomous weapons is whether the general public will no longer believe that a war fought by robots is really a war—further fueling the fuzzy line between war and peace.

## Human-Machine Teaming

### Definition and Key Considerations

Human-machine teaming involves the idea of humans working or collaborating with robots. This concept is a mainstay of DoD's Third Offset Strategy,[67] which seeks to use advanced technology to overcome adversaries' recent technological gains in anti-access, area-denial systems and maintain U.S. military superiority. This integration between human and machine can apply to systems that range from exoskeletons aiding physical performance and providing ballistic protection to collaborative and collective complex problem-solving.[68] As workshop attendees noted, the proper blend of human and machine activities is an open consideration. Furthermore, the questions of autonomy and trust that apply to robotics extend to the balance between responsibility afforded to the human and the machine.

### State of the Art

Considering the role robotics plays and the extent to which humans control autonomy, there is an inevitable consideration of how humans and machine interact or team up. The military currently contends that autonomous systems should always have a human in the loop, a human with some element of meaningful control over the system,[69] but *meaningful* can be ambiguous, and clarity is critical in this context. In response to this challenge, the Defense Advanced Research Projects Agency Agile Teams program takes a systematic approach to discover, test, and demonstrate predictive and generalizable mathematical methods to enable optimized design of "agile hybrid teams"—teams of both humans and machine.[70] The program explores how to combine teams of human and machines most effectively, where the mix of human and machine and the work distribution between them change depending on the task at hand and the environment.

The idea of human-machine teaming can range from humans operating or collaborating with separate systems, such as a remotely piloted aircraft, to more-intimate integration, such as complex armor systems. U.S. Special Operations Command is currently working on a next-generation body-armor system that will enhance physical capabilities and provide improved personal protection and integrated kinetic systems.[71] In addition, the Air Force is developing a new fighter-pilot helmet that will give the user information that is contingent on the pilot's unique physical condition at the moment.[72] This helmet is one example of how software is being designed for adaptive use, providing output and feedback tailored to the user and to the immediate situation. Just as different service members have different anthropometry, they also learn and digest data in different ways, so future systems should ideally cater to these differences.

Another dimension to human-machine teaming is the idea of an autonomous wingman, where a pilot controls an unmanned jet through voice commands.[72] The Navy is also investigating this idea with the use of manned and unmanned helicopters.[73] The idea of having an unmanned system provide the eyes and ears for a manned system is easily extensible for ground systems as well.

Whether the teaming between human and machines occurs on the level of physical performance enhancement, collaboration with an autonomous system, or even brain-computer interfaces (BCIs), the critical questions concern the appropriate level of human control, and this will depend on the kind of teaming and the task being completed. There likely will be no single policy for all applications.

## Future Considerations

DoD's focus on human-machine teaming is driven not only by a desire to mitigate risks associated with unchecked machine autonomy but also by an effort to leverage inherent and unique human strengths, such as intuitive judgment and creative problem-solving. Data-based models and capabilities are limited by the underlying data, which can be expensive to gather. Creativity is not yet automated. AI is not yet able to leverage lessons learned in one scenario to solve problems in another. And robots do not yet excel at fine manipulation or emotional and social intelligence. These are areas where humans still excel, and just as machines can augment human capabilities, humans can reciprocate via human-machine teaming: "[T]he duties of tomorrow's 'pilots,' 'tank drivers,' and 'snipers' will [likely] look far different from today, but the ethos embodied in these job specialties will not change. Human judgment will always be required in combat."[75] Advancements with human-machine teaming will allow machines like planes, tanks, and robots to leverage warfighter creativity, judgment, and decisionmaking.

However, part of the human-machine team requires human operators to understand and oversee complex autonomous systems in combat, and this will place new

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Increased use of automation also has the potential to increase the pace of warfare. An accelerated tempo of operations (for both machines and people) and the OODA loop may lead to combat that is more chaotic but not necessarily more easily controlled.

burdens on the selection, training, and education of military personnel.[76] In short, the deployment of robots with increasing autonomy will continue to accelerate, so the military should start training its workforce appropriately now. In addition, as human-machine teaming becomes more prevalent, there is a need to consider the psychological and sociological effects of this teaming. Adverse effects could initially go unseen—for example, if BCIs link a warfighter to a machine or to an AI algorithm.

Increased use of automation also has the potential to increase the pace of warfare. An accelerated tempo of operations (for both machines and people) and the OODA loop may lead to combat that is more chaotic but not necessarily more easily controlled. This was a concern with the U.S. military's Second Offset Strategy, which emphasized technological superiority to offset numerical disadvantages in conventional forces. Some observers have been leery of increased combat speed and complexity that could challenge human control through pervasive automation.[77]

## Connectivity

### Definition and Key Considerations

Workshop participants noted an overarching theme of connectivity, which involves many areas of technology, from big data to human communication to robotics. Connectivity relates to how data are passed between algorithms, robots, and humans. Over the past decade, connectivity *between individuals* has expanded with the advent and dissemination of such technology as smartphones and multiplayer video games. Today, such topics as distributed virtual training, the internet of things (IoT), and smart manufacturing push forward connectivity *between systems*.[78] In the context of human-machine teaming, these topics encapsulate big data, data analytics, and robotics. In addition, because of new work in neurology, work that is linking humans with robots in a decisionmaking process,[79] connectivity can include bioengineering. To date, increased connectivity has generally been accepted as a beneficial trend, publicized primarily in the field of advanced manufacturing.

However, as connectivity begins to apply to different autonomous or semiautonomous machines and starts to link humans and machines more intimately, policymakers will have to consider what level of connectivity is beneficial and acceptable in warfare, especially considering the risks surrounding cybersecurity.

## State of the Art

As with big data, increasing efforts to integrate and connect digital systems align with and even stem from the manufacturing sector. In this context, connectivity is best represented by the IoT, which refers to the network of objects that use internet technologies to communicate; the sensors and communications technologies that allow these objects to collect useful information, to store this information, and to communicate this information; and the applications built on the results.[80] As one workshop attendee noted, there are about 9 billion things linked up to the internet, and that will soon increase to 50 billion. Advances with connectivity characterize the fourth industrial revolution—defined by a period in which technologies encompass the physical, digital, and biological sphere—and is prevalent internationally. With the deployment of 5G wireless networks, the connectivity between items and systems will accelerate, given that 5G will provide increased bandwidth to support data from various devices.[81]

DoD identifies improved readiness as a primary benefit of IoT, knowing the real-time status of materiel and weapon systems.[82] Improved readiness affects the individual warfighter by providing better understanding of the location, intent, and state of fellow squad members, thus strengthening collective operations. Essentially, underlying IoT technology can help network soldiers and improve situational awareness. Air Force Chief of Staff Gen David Goldfein has advocated the consideration of how planes, satellites, and weapons can communicate digitally. He has asked three questions about a system: Does it share? Does it connect? Does it learn?[83]

In fact, the Air Force recently canceled its Joint Surveillance Target Attack Radar System recapitalization program in favor of a more distributed battle management network.[84] The F-35, for example, is not a plane with a supercomputer; it is a supercomputer with wings.[85] It is a networked computer, fostering connectivity with many other entities. Unfortunately, as with other services and much of industry, integrating various systems has not always been a priority, and legacy efforts used proprietary standards, thus preventing electronic communication and requiring significant resources for updates. Nonetheless, the concept of IoT has significant tactical implications when considering the ability to provide warfighters access to sensors and data in urban areas.[86] Connected networks of sensors can, for example, help the military track the health or status of a city (population, infrastructure, economy, etc.) and thus execute missions more effectively.

Another area where connectivity is especially relevant with respect to people in warfare is training. Driven by the need to train during fighting and the increase in networked weapon systems, training simulators need to be connected virtually. The Air Force has led the way with live, virtual, constructive training that links live systems with physical training simulators and software-based simulations that emulate other pilots. The focus on networked training simulators and virtual training tools in general is growing across all services.

Additional applications for IoT are reliability analysis and failure prediction, perimeter defense, and intrusion detection and border patrol. Advancements with connectivity even as common as the smartphone can benefit personnel and readiness, albeit with continued cybersecurity risks.

### Future Considerations

When coupled with advancements in robotics and automation, increases in connectivity support a warfare trend toward indirect confrontation. The increasing distance between the confrontation, operators, and general public may foster more time spent in a gray zone between war and peace. As noted during the workshop, "People will be able to reach around the globe and then deliberately affect things by changing information, by sabotaging physical systems, or taking control of them." Consequently, decisionmakers and various type of actors will be further removed from the consequences of their actions. Because of this indirect confrontation, war could become too easy and too disconnected from the public and policymakers, with minimal perceived sacrifice. Of course, the increased ease with which it is possible to fight remotely may support the increasing need to defend new ground (a trend in warfare noted earlier).

Advancements with connectivity also have implications with respect to increased difficulty in defending ground. Technology is increasingly facilitating networked weapon systems and operations. There is an increasing movement toward swarm tactics; this idea ranges from a swarm of drones to a swarm-like presence of networked weapon systems in different military services. In fact, there may be some advantage for groups of warfighters to operate and approach problems with a balance of individual creativity and swarm mentality.[87]

As with big data, connectivity and IoT present a capability-vulnerability paradox. The trade-off with IoT is that, with the necessity of the internet comes associated cybersecurity risks. Although DoD has started to identify policy actions to help mitigate risks,[88] the potential risks that come with an increased exchange of and dependence on data are nonetheless substantial. The risk is not only that adversaries could acquire the data but that they could jam systems and provide deceptive data. Although increased connectivity can improve efficiency, "security is an almost unwitting victim of efficiency."[89]

## Biotechnology

### Definition and Key Considerations

The final topic relates to genetic engineering, bioengineering, and pharmaceuticals. For the purposes of this Perspective, we group these topics under the term *biotechnology*. Genetic engineering essentially involves combining desired traits, which are the result of genes that naturally exist in populations. Historically, this was followed by recombinant genetics, which can leverage genes from any form of life. Synthetic biology is a set of techniques that enables the large-scale manipulation of life. It entails the application of engineering principles to biology. With synthetic biology, the source of genetic information is no longer needed for development; sequences can be chemically synthesized.

Bioengineering is sometimes synonymous with genetic engineering, but it is typically used as a more general term and can include biomechanics, bioinformatics, and polymer science. Pharmaceuticals that are customized for specific patients represent one potential application for genetic engineering and bioengineering. Although much of the work in these areas targets individual enhancement, it can also extend to human-machine teaming, connectivity, and big data. In fact, big data is prevalent and critical for genetic sequencing, and the issues of data ownership and accessibility in this context are especially sensitive for personnel.

## State of the Art

Biotechnology is a broad area encapsulating much active research and development, with many additional potential applications to future warfare and to the people engaged in it. Genetic engineering in particular—entailing the alteration of an organism's genetic or hereditary material—can help increase food production, diagnose diseases, improve medical treatment, and produce vaccines and other useful drugs.[90] Of course, there are trade-offs. As Patra and Andrew explain, the repercussions of using a viral vector to carry a new functional gene is still unknown and could have negative impacts on the human body. Some processes involve the use of antibiotic-resistant genes, which can ultimately be lethal.[91] Finally, there are substantial ethical and social issues surrounding modifications to human genes.

Workshop attendees noted that one biotechnology application receiving substantial attention is physical and cognitive fatigue. Fatigue can be addressed by studying training approaches, diet, and various activities, but it also can be addressed with fatigue-related drugs. The use of pharmaceuticals to enhance physical performance (strength) and regulate emotion (stress management) is also being studied. Adoption of these drugs has been relatively slow because of unknown long-term effects and cultural resistance to pharmaceuticals. This latter issue stems from the idea that drug-based enhancement is akin to cheating in an academic setting, but "cheating" is not necessarily bad or immoral in war. An unfair advantage is a boon in warfare.

Another key biotechnology trend tied to human-machine teaming is work with BCI that enhances wireless data transfer between humans and machines and ultimately among humans.[92] This technology, although not currently deployed, could ultimately link capabilities and other technologies via thought. BCI could enable new approaches to performance assessment, as well as performance enhancement and training. Although research in this field is in early stages (in the lab), efforts continue toward enabling more-efficient prosthetics, wireless system control, wireless transfer of data between human brains, performance enhancements, and performance assessment.

Ultimately, this work could allow warfighters to control drones, for example, with minimal degradation in situational awareness, or to reduce the reaction time while controlling an aircraft. There is promise for capabilities that would allow commanders to monitor the cognitive workload of warfighters and make personnel decisions accordingly. Finally, BCI could foster cortically coupled AI, whereby AI algorithms are trained using human brain activity. In many respects, the warfighter's body presents a performance constraint, and, on a high level, BCI can help remove that constraint.

### Future Considerations

A provocative topic falling under biotechnology and necessitating much policy consideration is genetic testing, which is relatively close to fruition. Although it is cost prohibitive now, it may eventually be possible to identify and catalog the propensity for various injuries and diseases for every warfighter. Recording and assessing information about micro–ribonucleic acid could be used to determine what soldier might be best suited for what type of mission.[93] The topic of big data becomes especially sensitive in the context of genetics, and big (genetics-related) data has received less attention than robotics and AI. There has not yet been the Sputnik moment in this field as there has been with AI. Yet who has access to such data can have significant implications not only for the individual warfighter but also for U.S. national health care, as the United States is *relatively* unrestrictive with respect to genetic data—with the potential for personal genetic data to be analyzed outside the country.

In addition to using genetics for assessment, the field of genetics affects performance optimization. As one participant noted,

> The Chinese have produced a dog which, through genetic modification, has twice the muscle mass of a normal dog. Would the personnel system in the DoD allow a person to come in who has been genetically modified to have twice the muscle mass? . . . [W]hat if someone is on a professional football team, they do that, and then they want to join the military. Would we let that happen?

The question of controlling the use of genetic modification for performance enhancement will likely be an increasingly significant consideration. To this point, "If the connection between genetic factors, life experience, and risk-taking can be better observed, can they also be controlled? This is the question that will loom over military leaders in the decades ahead."[94]

A particularly disconcerting possibility with the future of genomics and genetics is the development of bioweapons, potentially engineered to target specific populations or even specific individuals.[95]

As noted during the workshop, biotechnology raises significant moral and social issues that must be considered sooner rather than later to facilitate its expedient use in warfare. To what extent should an individual's DNA or biology be altered? Who has access to and controls the relevant data? What unique controls are needed for managing biological data? Despite the need to answer such questions, the United States might not be protecting genomic data as carefully as it should be, and some suggest the health care industry is "notoriously vulnerable" to cyberattacks.[96] Being reactive rather than proactive in this regard could hamper efficient and ethical progress and thus mitigate the degree to which new technologies are deployed to warfighters.

Despite biotechnology's potential benefits to warfighter performance, one of the most significant challenges with it today is the lack of a systematic process for evaluating the trade-offs between immediate advantages and longer-term risks (to warfighter behavior, condition, mental health, etc.).

## Keeping Up with Advancing Technology

As technologies continue to advance, the barriers to access may diminish. The United States should expect its adversaries to acquire and use many of the same

[S]ound policy will require a well-understood and well-publicized vocabulary. In summarizing the technologies that represent the current frontier, we found that consistent and agreed-upon definitions can be elusive.

technologies that are in the hands of the U.S. military, now and in the future. Thus, maintaining a competitive advantage will be increasingly challenging. The need to keep up with technological advancements raises a number of issues.

First, sound policy will require a well-understood and well-publicized vocabulary. In summarizing the technologies that represent the current frontier, we found that consistent and agreed-upon definitions can be elusive. As technologies progress and become more commonplace among nontechnical users, developing a common vocabulary will be increasingly important.

Second, many of these technologies are interrelated, so technical development and policy decisions cannot occur in isolation.

Third, training and education will be essential to ensure that the workforce is prepared for future technological developments. In this regard, it will be prudent to be proactive, taking steps to ensure the workforce is aligned with the forthcoming technological developments, a concern that was reiterated throughout the workshop. It will be increasingly important to train per the strategy of how the United States fights but also to recognize that new technologies may substantially change the way the country fights. For example, as one workshop attendee noted, training an information technology specialist can take four to six years, but training a hacker can take six months. How can the military mimic the latter? Furthermore, emerging technology issues will be cross-disciplinary, so the new workforce will need to think and train across disciplines.

Fourth, decisions regarding human-machine control will become more central. To what extent will humans share control with one another or with machines and to what extent might they give up control completely? Answers to these questions will inform future policy and even the design of underlying systems, but often these answers may be case specific. Pursuant to the Third Offset Strategy, technology development is driving toward a merging of human and machine capabilities. Examples include use of genetic data and AI and autonomous vehicles interfacing with human brains. The focus for acquisition is not only system development but also human-systems integration.

Finally, the pace of warfare may likely accelerate as a result of new technology. As the pace of warfare increases, additional technology is needed to help warfighters digest data and make decisions at a faster rate. Warfighters want faster and more-efficient systems that are able to outsmart adversaries, but, at the same time, they want to stay in control. In addition, faster data processing by humans and faster decisionmaking can inhibit *creative* decisionmaking and problem-solving, which are critical tools in warfare. This conundrum and its effects on performance will present a formidable challenge and possibly will be the primary consideration for science and technology policy in warfare.

## The Future of Personnel Policies

The previous two sections speculate that military threats and future technologies will cause warfare to become more, rather than less, complex in the future. As the nature of warfare evolves and emerging technologies play a more prominent role in warfare, the demands on defense manpower and personnel are likely to be different from what they are today. Some attributes that are present in today's total force of defense military and civilian personnel may become less important while others may become more important.

Thus, we assume that, over time, the U.S. military will change in response to shifts in force requirements.[97] Historically, the U.S. military has shown a capacity to evolve, as evidenced by its transition to the all-volunteer force in 1973, standardization of officer career tracks, expansion of programs in support of military families, and the integration of historically disadvantaged groups into the force structure (e.g., African Americans; women; openly lesbian, gay, and bisexual personnel).

If people with different attributes are needed in the future, then adjustments will be reflected in requirements for manpower and current policies governing the full life cycle—from accession to separation and retirement—of defense human resource management. This section presents some of the ways in which military personnel policies may continue to evolve in the future.

### Evolving Personnel Requirements

In general, the workshop participants agreed that the velocity of warfare will increase in the future. Emerging technologies will increase the flow of information and the pace of battle and will force faster decisionmaking and action by human beings. Even as technology may provide greater efficiency in managing information flow, personnel will likely require specialized skills, affecting individuals across the total force of active-duty, reserve, defense civilians, and contractors in direct and indirect warfighting roles. In this context, current practices and policies related to defense human resources management will need to be reconsidered. During the workshop, participants identified the following issues as ones that need attention:

- *High-aptitude personnel*. The need for personnel of high aptitude will increase as warfare becomes more intellectualized and requires increased mental agility. Military professionals will need the knowledge and skills to use new tools and technologies. Personnel will need to process greater volumes of information and make decisions faster. Leaders will need a greater ability to "think across disciplines" in assessing complex situations and devising appropriate plans and responses. As one participant noted, "We're going to see more about an agile mind . . . and more about managing, bringing together very different types of data but making very different decisions."

- *Personnel duties and functions*. Technology will force *changes to how personnel perform basic functions and duties* in direct execution and support of warfighting activities. As technology alters how warfare is conducted, tasks performed by DoD will change, along with the knowledge, skills, and abilities required to perform warfighting and support functions.
- *Occupation types*. As required skill sets and related knowledge and abilities change, *occupations as they are currently defined should change*. Consistent with trends in the civilian world, professions will be displaced or altered in content. One workshop participant cited studies, attributed to Oxford University, McKinsey and Company, and Pricewaterhouse Coopers, predicting that between 30 to 47 percent of existing civilian occupations will be reduced or replaced in our lifetime.[98] It is not impossible to imagine that similar changes await occupations now performed by military and DoD civilian personnel.
- *Occupation structure*. Changes in how occupations will be structured and sequenced will be needed. As one workshop participant noted, "We won't be managing every specialty in terms of pyramids with a similar number of grades lock-step for E-1 to E-9." As occupations change, further changes will be needed in how education and training are provided to defense personnel. As technology advances and increases the need for more technically proficient people, continuous education will become more important. Organizational changes to the structure and operation of military education and training institutions may also be required.
- *Selection methodologies*. Methods used in assessment and selection of individuals for service would need to change. New tests and standards related to cognitive performance may be needed. The role and relative weight given to various mental and physical standards in selection will need to be reassessed. According to one workshop participant, "If you want to go to certain jobs, schools, or skill sets, you might need to have a general technological score above a certain level." Standards for physical fitness may diminish in importance for certain occupations, particularly for those functions dependent on mental agility and performed remotely.

In addition to these systemic changes in how people prepare for and perform warfighting functions, workshop attendees stated that certain overarching principles governing current systems for managing manpower and personnel would need to change. Discussion at the workshop focused on two areas:

- *The need for greater agility and flexibility in how people are managed*. Systems in place today to hire, promote, compensate, retain, and separate military and civilian personnel systems are too rigid and inflexible and are frequently characterized as "one size fits all" with little room for exceptions. In the future, it will be important to differentiate among the skills and performance across individuals and occupations with greater fidelity. Similarly, workshop participants called for more-widespread application of existing legislative authorities and of new authorities for accessing, compensating, promoting, retaining, and separating personnel, which respond rapidly to changes in demand and which are differentiated according to skill.

- *The need for a more open system*. The core idea is to open more pathways by which individuals can participate as a member of the active-duty or reserve component military or as a civilian in support of the military. A more open system would provide people with additional options than currently exist for when and how they participate and would allow for greater permeability across active, reserve, and civilian status. With emerging technologies and the rapid pace of their development in mind, workshop participants focused particular attention on the need to bring in talent from the private sector and observed that such individuals might seek to affiliate for shorter periods than a traditional enlistment term or might be more likely to affiliate under a lateral entry program, compared with today's start-at-the-bottom, work-your-way-up system.

## Implications on Future Personnel Policies

### Recruitment and Retention of Military Professionals

Workshop participants agreed that new technologies will demand new skill sets. One participant remarked that, in the future, the military will "require an aptitude for [advanced] technical things." Another participant remarked on how the military should look at "GRE [Graduate Record Examination] scores and SAT [Scholastic Assessment Test] scores for those who are trying to get into college to try to *x* out which individuals we want."

As the military adopts emerging technologies, such as big data, AI, robotics, and biotechnology, its demand for personnel with relevant technical skills will increase. But the military will not be the only employer to demand technical skills, and workshop participants were concerned about how the military can successfully compete for personnel.

Many of the skills on which the military will depend relate to a set of occupations that the U.S. Bureau of Labor Statistics (BLS) labels "computer and information-related technologies."[99] Between 2016 and 2026, the BLS projects growth in most of these occupations, ranging from 6 percent for computer network architects to 28 percent for information security analysts (see Figure 1). Given competition from civilian society for young adults with the same technical skills, the military will experience increased scarcity of skilled personnel, making it difficult to recruit and retain them over time.

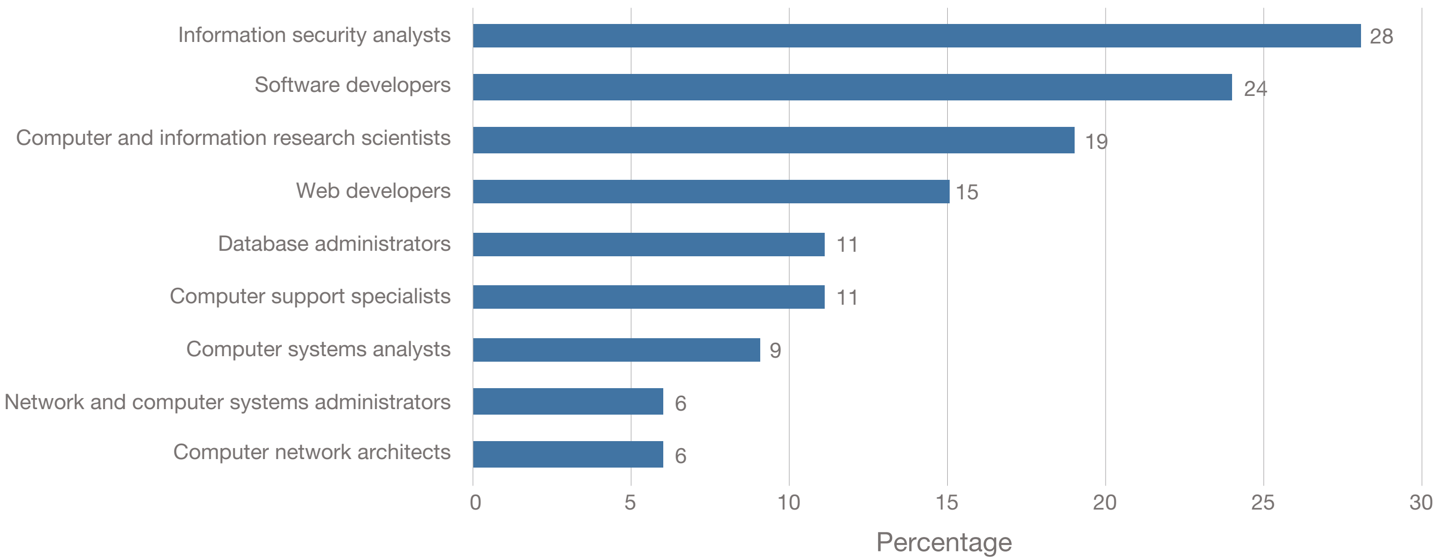
This competition for personnel with in-demand skills will force the military to become more flexible and agile in how it recruits and retains personnel. Workforce participants identified several policy changes that could facilitate such a shift.

First, there is a need for greater flexibility in physical fitness standards than what exists today. Today, the military requires that all recruits meet basic standards for physical fitness. While these standards are necessary for some occupations (e.g., special operators), they may become less relevant for others (e.g., cyber operations). As one workshop participant said, "Is an 18-year-old track star the person we really want to do cyber, or do we simply use someone who may be older, more experienced in this field, but maybe they can't run a two-miler as fast, but that doesn't matter."

Second, the military may reconsider its up-or-out promotion system, although such changes will need to be balanced against the potential for disrupting traditional military culture.[100] The current system promotes personnel based on their time in service and rarely allows for lateral entry by civilians. In recent years, some of the services have expanded their direct commissioning programs to recruit civilians with in-demand skills. For example, the Army has the Cyber Direct Commissioning Program to recruit people with skills related to computer and information-related technologies.[101] Several workshop attendees said they expect direct commissions to become more, rather than less, common in the future. One attendee noted that the first head of the Defense Intelligence Agency, Lt Gen Joseph Francis Carroll, was directly commissioned as a reservist for a few months before his promotion to general.

Third, the military may allow civilians to fill more support positions than is the case today. As one workshop participant asked, "What is a uniform requirement [for service members] versus what a civilian can or cannot do?" Why couldn't I recruit civilians at 18 years old, bring them

FIGURE 1
Job Growth for Select Occupations Related to Computer and Information Technologies, 2016–2026




SOURCE: U.S. Bureau of Labor Statistics, "Computer and Information Technology Occupations," *Occupational Outlook Handbook*, January 30, 2018.
NOTE: Data exclude computer programmers, for which the BLS estimates a decline of 7 percent from 2016 to 2026 because of outsourcing.

in, train them in the same way I train military, and make them become part of the structure by giving them a career path very similar to the military?" This question represents a long-standing debate over the degree to which the military should "civilianize" its workforce. Historically, the services lacked a consistent method for determining which military positions and functions are eligible for conversion to civilian hiring.[102] We expect this debate over military essentiality to continue in the future.

There also may be novel solutions in how contractors are used. The military has always relied on civilian contractors. For example, the Congressional Budget Office looked at historical estimates of contractor-to-military personnel ratios over time.[103] During the Revolutionary War, there was one contractor for every six service members. This ratio was one to 24 during World War I, and one to seven in World War II. In early 2008, the Congressional Budget Office estimated a one-to-one ratio of contractors and military personnel in the Iraqi theater. More recently, Air Force Space Command has considered hiring civilian contractors to fly satellites, a task historically done by airmen.[104] One should expect this trend for the military to increase in the future.

## Evolution of Career Development

The workshop attendees agreed the military may need a more flexible personnel system to manage the career development of service members and civilians. As one participant remarked, "God help us that our personnel system doesn't turn into 1,000 more career pyramids. . . . I think we have to imagine different ways that people will affiliate." In the future, new technologies may force the military to change these definitions more often. As one workshop attendee noted, "Again, our personnel system is geared toward the specialization, and it's the combination of specializations that . . . provide the flexible force."

As the military adopts new forms of technology, it follows that characteristics of career fields may change. The U.S. cavalry is a case in point. During the Revolutionary War, the Army defined its cavalry as soldiers who "served and fought on horseback."[105] With changes to technology came changes to the skills required of soldiers in the cavalry, even if the function of mobile combat arms was the same. Army tanks and jeeps replaced horses during World War II, requiring some cavalry soldiers to learn how to drive and navigate new equipment. Similarly, helicopters led to the creation of an air cavalry in the Vietnam War, resulting in new forms of specialized training. Put simply, the military tends to change the tools it uses and the division of labor (e.g., occupations, professional training, badges) based on changes in warfighter technologies. However, the general structure of units (e.g., rank) and unique characteristics of military professionalism (e.g., unit identity and military culture) typically persist as technology evolves.

In the future, the military may also change how it conducts training for some occupations, which is likely to increasingly have a cross-disciplinary focus. One participant remarked how "the future of warfare is going to [require] the department to work on not multi- but interdisciplinary solutions" to problems. Another participant predicted that as military missions become more complex, there will be needs for interdisciplinary skills. Professional military education will become key for the military to continuously train its personnel in emerging technologies. For example, the U.S. Naval

Academy has the Department of Leadership, Ethics, and Law.[106] Today, courses in this department focus on teaching midshipmen how to lead teams of humans. If the military expands the definition of *team* to include humans working with autonomous machines, then perhaps the academies will need to offer new courses in leadership of these human-machine teams.[107]

## Managing the Network of Military Systems

In the future, new technologies may force the military to change the way it manages its people. This trend has occurred before and will likely occur in the future. For example, militaries once placed thousands of soldiers into close-order formations where they waited for orders from officers to fire their muskets. The invention of rifle bullets let militaries split these large-order formations into smaller groups, where the solitary soldier depended on this primary group for support.[108]

But personnel management could change in other ways as well. Workshop participants identified a need for greater flexibility in how one conceives of managing a military of "networked systems." One participant remarked that military management will increasingly become a job of "managing systems versus doing the job yourself." Another participant noted how future military personnel system will "have someone who manages a system and a network across the whole country or globe watching things like a game with autonomous vehicles." The use of big data and connectivity could change how the military manages its personnel in various ways.

First, the military will have more rather than less data coming from these systems to analyze. As one workshop attendee noted, "We're saturating people with too much information. People have too much connectivity as well. Now you have the ability of commanders to have tons of information, but they're not [physically] there." In response to this uptick in the flow of data, militaries of the future will need more skilled labor to organize, classify, analyze, and report insights from these data streams to others. Further, AI could free the brains of service members to focus on more-complex problems instead of repetitive tasks dictated by checklists, rules, and instructions.

Second, computers and robots may evolve from mere instruments that service members use to carry out missions into partners on the battlefield. One participant predicted that "the profession that doesn't die is the robot psychologist" because the future of warfare is "going to be the interaction between people and machines as opposed to thinking about different professions." Just like research from World War II discovered the role of unit cohesion in motivating soldiers to fight,[109] future work may find that similar bonds develop between humans and machines in theater. In recent years, there have been reports of service members holding funerals for their Multi-Function Agile Remote-Controlled Robots (MARCBots) in combat,[110]while researchers have documented the emotional bonds that form between personnel and their robots in war.[111]

Third, the complexity of warfare—coupled with a flood of new data—may force military leaders to become more agile and flexible in how they collect, store, organize, and analyze new data streams to make optimal decisions. In the future, the military will need more personnel to work with these data streams and provide data-driven input during a range of conflicts (e.g., peacekeeping, gray zone conflicts, counterterrorism, conventional operations). And those who give data-driven input for decisions will have greater impact on the final decisions by their military leaders.

## Concluding Remarks

While any predictions on the future of warfare are likely fraught with errors, we began this Perspective with three key assumptions about the ways in which military organizations evolve over time. First, we assumed that the nature of military conflict will become more, rather than less, complex in the future. The United States will see more competition for regional hegemonies, declines in its military edge, blurring of lines between war and peace, and continued involvement with the war on terrorism. Second, the U.S. military will adopt new technologies as it confronts a complex array of global threats. These technologies include the rise of big data, AI, robotics, human-machine teaming, greater connectivity of the battlefield, and biotechnologies.

Third, the military may evolve in how it manages its workforce in response to the complexity of warfare and rise of new technologies. In response to these changes, we predict that the military's future personnel system will evolve by becoming more agile, flexible, and open than what exists today. And the military may become more flexible in recruiting and retaining personnel with skills in using the existing and emerging technologies that we discussed. Further, the military may consider adopting a more flexible and open system for career development that trains personnel in new skills spanning traditional academic disciplines. Finally, we expect the military to evolve toward a networked system in managing its people, processes, and new data—alongside and within the traditional military bureaucracy that exists today.

It is entirely possible that many of the conditions that led us to this speculation might not occur at all.[112] These speculations represent our analysis, for some key themes, that a small group of defense experts raised, at a single daylong workshop. What we are reasonably confident about, however, is that warfare in general will become more complex in the future and the U.S. military will continue to evolve as it has done for centuries.

## Notes

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## About This Perspective

This Perspective summarizes and synthesizes material presented and discussed at a daylong workshop held at the RAND Corporation in September 2017. During the workshop, titled "Department of Defense Personnel Policies to Address the Future of Warfare," domain experts in foresight and forecasting and advanced military technologies led a roundtable discussion among workshop participants with expertise in management of defense personnel resources.

This document draws from speaker presentations, panel and audience discussions during the workshop, and published literature to provide an overarching perspective on how policies for managing military and civilian personnel in the U.S. Department of Defense (DoD) may evolve to address future warfare environments, which are expected to be heavily influenced by advanced technologies. The authors use research from a wide range of fields (e.g., economics, engineering, military sociology, political science, psychology, public policy) to explain some of the key themes that participants raised at the workshop. Thus, this Perspective is informed speculation, instead of generalizable research, about the future of warfare.

The workshop was held on a not-for-attribution basis. Information from the discussions is attributed anonymously in compliance with the U.S. Federal Policy for the Protection of Human Subjects (also known as the Common Rule). Viewpoints expressed by participants in workshop discussions and reflected in this document do not represent official positions of DoD, the U.S. government, or the agencies or organizations with which they are affiliated.

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