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Expeditionary Operations in the Fourth Industrial Revolution

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Abstract: The Fourth Industrial Revolution is changing every aspect of life. Advances in task-specific artificial intelligence, robotics, and additive manufacturing are diffusing military power to smaller states and nonstate actors. These potential enemies will develop much deadlier weapons systems, but U.S. naval forces must still conduct expeditionary combat operations. In considering how these operations will be executed, this article discusses the types of conflicts involved and who future opponents might be; considers how the convergence of various Fourth Industrial Revolution technologies are changing the battlefield; and discusses the major implications for the Marine Corps. While relying on planning and big platforms is easier within acquisitions and logistics, the Marine Corps must rely on its core strengths: adaptability, flexibility, and responsiveness to the demands of war.

Keywords: artificial intelligence, 3D manufacturing, robotics, drones, nonstate actors, power projection, Fourth Industrial Revolution, Anti-Access/Area Denial, A2/AD, insurgents, terrorists, hybrid warfare, gray zone, nanotechnology, explosively formed projectile, mobilization, Marine Corps, joint

While the Marine Corps is often best associated with its amphibious past—from guarding Navy ships in the early republic to landings during World War II—much of its actual fighting has been expeditionary. Since the Vietnam era, the Corps has served this function, distinguish-

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ing itself from the Army by its ability to be a light, flexible force in readiness, quick to enter the fray and adapt along with the needs of the particular demands of battle. This has been especially so in the period after 11 September 2001, with Marines fighting against insurgencies in places such as Afghanistan and Iraq and working alongside international forces. It seems this is a trend that will continue, yet in the near future, expeditionary operations will become more complicated, uncertain, costly, and vulnerable.

The convergence of the technologies in the Fourth Industrial Revolution is shifting power to small states, insurgents, and even individuals. U.S. forces will go from today's happy situation of secure rear areas to an environment where the enemy will be able to strike throughout the nation's lines of communications from units in contact all the way to out of theater logistics systems. Units in contact also will face greatly increased risk from guided indirect fire systems and intelligent drones. Obviously, these increased threats will not relieve naval forces of the requirement to conduct expeditionary operations. In fact, the United States' splendid geographic isolation means the vast majority of U.S. deployments are thankfully outside of the continental United States. It is essential that the U.S. forces, and the naval team in particular, figure out how they will deal with these new threats.[1]

This article is organized into three parts. In thinking through how U.S. expeditionary forces will execute these operations, we have to start with the types of conflicts involved and who future opponents might be. After that discussion of what and who, this article will consider how the convergence of various Fourth Industrial Revolution technologies are changing the battlefield.[2] The author concludes with a discussion of the major implications for the Marine Corps. Overall, it seems that while relying on planning and big platforms is easier within the civilian and military world of acquisitions and logistics, the Marine Corps must rely on what it has done best in the past—being adaptable, flexible, and responsive to the demands of war as it is, not as anyone would like it to be.

Dealing with the Unknown

It is a virtual certainty that the United States will fight again. Unfortunately, the historical records show that U.S. national security institutions are not good at predicting the next conflict. The U.S. government actually excluded Korea as an area worth fighting for early in 1950, less than six months before it found itself in a major war there. In the early 1960s, most analysts did not believe the United States would get involved in Vietnam beyond advising. Five years later, there were more than 500,000 U.S. troops in Vietnam. In the late 1980s, almost no one was predicting Iraq would invade Kuwait, and in early 2001, no one predicted the United States would commit major forces to Afghanistan or Iraq. In

short, odds are very good that the United States will not predict the place, time, or opponent for the next fight. The 1990s serve, however, as a very specific caution against predicting a single future.[3] During that decade, the Pentagon's fascination with technology and its success in Operation Desert Storm led it to spend the entire decade preparing for a short, high-tech war. Of course, what it got in the 2000s were decade-long insurgencies. As a result, the Services were badly prepared for the wars they actually had to fight. To prepare for the future, the Corps has to consider the full range of future opponents and consider how concepts and technology will affect efforts to conduct expeditionary operations. Although *why* organizations fight each other is critical to geopolitical discussion for military planners, the *how* is more important. As always, it will be the interaction between the contestants—the *who*—that defines the why and how of the fight.

A Widening Spectrum of Conflict

Despite academic assertions to the contrary, war is not disappearing. If anything, it is increasing in frequency and duration.[4] Armed conflict will remain central to relations among states and nonstate actors. It will also remain a contest of human wills and thus the domain of uncertainty, compounded by human passions, friction, and fog. Technology will not bring clarity or brevity. Century after century, political and military leaders have embarked on wars confident that they understood the situation and would win a short and decisive war and subsequently paid the price for ignoring the true nature of war.

In contrast to the unchanging nature of war, the character of war—how it is fought—changes continually. Today, we are at the dawning of the Fourth Industrial Revolution, changing the technology of warfare dramatically. Yet despite our American love of technology, how people fight wars will remain based more on the social, economic, and political aspects of their societies. Each society will use the emerging technologies in unique ways. Further, conflict will not be based solely on those aspects of one society but the interactions of all the societies in the conflict. Thus, the conflict will not be defined by the technology but by the people using it, including state and nonstate actors.

State Actors

As most U.S. forces came out of Iraq and Afghanistan, the Department of Defense (DOD) faced a changed international security situation. When we went into Afghanistan in 2001, we had no near-peer competitor and major conventional conflict seemed a thing of the past. Today, the United States has to consider how to deal with state actors that can challenge it in a variety of ways. State actors are capable of engaging in conventional war or using surrogates. Having observed U.S. forces in Desert Storm, Enduring Freedom, and Iraqi

Freedom, states are actively seeking ways to neutralize America's demonstrated strengths. Thus, states will employ a range of approaches from conventional to subconflict gray zone techniques to overcome their disadvantages. Among state actors, China has taken the lead and has either demonstrated or is developing a wide range of capabilities that the Pentagon has lumped into the Anti-Access/Area Denial (A2/AD) arena.[5] Many of these A2/AD systems are already proliferating. Russia, Iran, and North Korea are purchasing and building systems to keep American forces at a distance. Further, as these capabilities become cheaper, smarter, and more numerous, we can be sure these states will expand their capabilities in this area, and that many will migrate to smaller states.

States will also employ surrogates to keep their own forces off the battlefield. We have seen Iran use Hezbollah and Pakistan use the Taliban to pursue their strategic interests without committing their own forces to the conflicts. More recently, the Russians made use of "little green men" as surrogates in a gray zone approach.[6] Contractors are another form of surrogate that states have used in numerous conflicts for a variety of reasons.[7] States have used even criminal organizations to execute a range of activities from cyber to propaganda to kinetic attacks. In short, states will use a wide variety of methods and resources to neutralize the United States' conventional military power as they strive to attain their strategic goals. Thus, even in a state versus state conflict, the *who* may not be easily defined. Complicating the task of preparing to meet states and their surrogates is the growing variety and capability of nonstate actors.

Nonstate Actors

As some nations employ new methods or technologies to gain advantages in asymmetric political and military situations, the world has seen a combination of state and nonstate actors working together. Nonstate actors fall into three major categories—insurgents, terrorists/superempowered small groups, and criminal organizations—who work on their own at times or ally with more powerful nation states that can provide resources or cover. Organizations of these types have been greatly empowered by the information revolution and will benefit even more from the Fourth Industrial Revolution. The United States has extensive, if not particularly successful, experience in such conflicts, yet each future conflict will provide a unique challenge based on the political, economic, and social conditions of that conflict.

Insurgents

Insurgencies are not new and will continue, but the insurgents of the twenty-first century will be driven by different goals than in the past. Such efforts will still be about self-governance but now will add a desire to change borders.

In the post-World War II era, insurgencies were primarily driven by a desire to throw off imperial power. Once the colonial powers withdrew, the primary driver became determining which local group would control the new nation. The People's Movement for the Liberation of Angola's (MPLA) long war against the National Union for the Total Independence of Angola (UNITA) is a prime example. After a multidecade conflict, the MPLA won. It now rules over a nation whose borders remain essentially the same as the colony previously controlled by the Portuguese until the 1970s.

More recently, insurgents are often fighting to redraw boundaries to align with social, cultural, or religious boundaries that preceded the colonial era. Realignment has been accomplished in places such as the former Yugoslavia and Sudan (partially). Somalia—while not de jure separated—comprises three de facto political entities today. Members of the Islamic State of Iraq and Syria (ISIS) fought hard to redraw boundaries across the region. Baluch (Iranian Plateau) and Kurd movements are fighting to create new states without regard to existing borders. The mismatches between the borders drawn by imperial powers and the desires of separated people to create or recreate single ethnic-based nations will reinforce other drivers of insurgency, especially corruption, government incapacity, failure to address minority needs, and resource scarcity.

This desire to change borders will have significant impact on U.S. counterinsurgency efforts. Current U.S. doctrine calls for supporting the host nation government against the insurgents.[8] If an insurgent movement crosses international borders, such as the Pashtuns (who straddle the Afghanistan-Pakistan border), there is no single host nation. Thus, the United States will have to work with two or more nations in most counterinsurgency efforts. The problem will come when the contending nations have irreconcilable strategic objectives. The fundamental differences between the strategic goals of Pakistan and Afghanistan, for example, have prevented effective cooperation against the Taliban insurgents. A variety of insurgent and terrorist groups based in the Pashtun regions have taken advantage of this fact.[9] We must expect this to be the norm in insurgencies that strive to redraw international borders.

We are seeing the same issue in the American conflict with ISIS. The governments of Iraq and Syria, as well as the various insurgent groups, have different strategic objectives—and each draws external support from several actors. Those outside actors—Iran, Turkey, Syria, Persian Gulf states, and the United States—all have different objectives too. Today's insurgencies are often a mix of the angry, who seek redress for a perceived injustice, and the opportunistic, who simply seek wealth. Thus, U.S. doctrine for and experience with both counterinsurgency and unconventional warfare (support to an insurgent) are inadequate to these circumstances.

Insurgencies that focus on unifying ethnic or religious identities, in short,

are attempting to build nations that transcend traditional, often Western, definitions. They are doing so both across international boundaries and within existing states. These movements present a much more complex challenge than insurgencies focused on maintaining current boundaries. Historically, such efforts at nation formation have taken decades or centuries. Achieving relative political stability in these cases will take much longer and be a more difficult process. An understanding of the long timelines must inform any decision to become involved and then guide the subsequent commitment. It also may force the planner to think in terms of containing the damage rather than in solving the problem. If history is a guide, many of these conflicts will only be solved when all sides are exhausted.

Terrorists

Unfortunately, despite the fact terrorists have caused very little actual damage, they have to be considered a separate category of threat simply because of the enormous resources the West is using to protect itself from these small groups. It is a certainty that terrorists will continue to attack in the name of various causes from a variety of locations globally. Still, while high-profile attacks such as 9/11 and Paris will continue, it is essential to keep the risk in perspective. With more than 32,000 deaths per year in auto accidents, roughly the same number of Americans die *every month* on our highways as died in the Twin Towers.[10] Since 2000, almost 200 times as many Americans have died in traffic accidents as in terrorist attacks, including 9/11. Thus, while the violent loss of life by terrorism is heinous, the U.S. response should be appropriate.[11] However, political realities ensure the United States will continued to devote a disproportionate amount of national security resources, particularly intelligence resources, to deal with the threat. The key issue for military leaders is how to meet the political demand signal without too seriously disrupting preparations for conflict.

Criminals

Criminal organizations will continue to challenge governments worldwide. These organizations take various forms, from street gangs to drug cartels to transnational criminal networks and will deal in a variety of commodities, from guns to drugs; resources, from people to counterfeit consumer items; and less tangible areas, from identity theft to cybercrime. With the exception of first-generation street gangs, these criminal organizations have a common motivation: profit. While some commentators dismiss them as a law-enforcement problem, criminal organizations have demonstrated the ability to both ally with insurgents (Columbia) and seize and rule territory within a state (Mexico). Cybercriminals are suspected of having provided the expertise for Russia's

attacks on Georgia.[12] Criminal organizations also have informally allied themselves with the United States to keep business going smoothly. Some Afghan drug cartels are closely associated with U.S.-supported Afghan officials simply because these associations allow them to continue to grow and process their products.[13] Thus, criminal organizations can have an impact on the security of the United States, and our response may well go beyond law enforcement.

Hybrid Warfare

As if these challenges were not enough, we also will see the merging of state and nonstate actors in hybrid war. With Russia's 2014 occupation of the Crimea and Eastern Ukraine, the concept of hybrid warfare became a major topic of discussion. Unfortunately, it also led to major confusion on what hybrid warfare is. Yet, in 2007, Frank Hoffman had provided a clear definition of the threat: "Hybrid threats incorporate a full range of different modes of warfare including conventional capabilities, irregular tactics and formations, terrorist acts including indiscriminate violence and coercion, and criminal disorder." Both state and nonstate actors have used this type of warfare. These "multi-modal activities can be conducted by separate units, or even by the same unit, but are generally operationally and tactically directed and coordinated within the main battlespace to achieve synergistic effects in the physical and psychological dimensions of conflict." As Hoffman notes, the "effects can be gained at all levels of war."[14] Whether used by state or nonstate actors, hybrid strategies force the defenders to deal with the full range of challenges in the same battlespace. Moreover, it can be used to obscure agency and allows state actors, regulated by international bodies and the law of war, to take action while hiding behind a virtual smokescreen. In short, the Marine Corps cannot focus on a single type of war.

Gray Zone Challenges

Recent events in the Middle East and Eastern Europe have led to a great deal of discussion about gray zone conflict. Unfortunately, it has often been lumped with hybrid war, which confuses rather than clarifies the problem. Many discussions accept the definition of gray zone as "competitive interactions among and within state and non-state actors that fall between the traditional war and peace duality."[15] This includes everything in hybrid except conventional war and so serves no useful purpose in the discussion. Further confusing the definition is the fact that this is only one of many different definitions and is overly broad since most conflicts and wars fall short of "traditional war." This article is too short to discuss the variety of definitions in detail, but the most frequently cited examples are the Russian actions in Crimea and the Ukraine. Yet, as scholars at

the Aleksanteri Institute of Finland's University of Helsinki noted, the Ukraine was highly vulnerable due to a weak government and the presence of a large number of Russians. They question whether the gray zone tactics would work more generally.[16] Like all conflicts, gray zone conflicts will be based on the social, economic, political, and technical conditions of the combatants.

Technology Converges, Power Diffuses

Having discussed the actors the United States might have to fight and the various forms of warfare that they might employ, we now transition to an exploration of the implications of the Fourth Industrial Revolution, which will significantly impact who fights, how they fight, and even where they fight. Economist and engineer Klaus Schwab states that the Fourth Industrial Revolution means the world is on "the brink of a technological revolution that will fundamentally alter the way we live, work, and relate to one another. In its scale, scope, and complexity . . . [it] will be unlike anything humankind has experienced before."[17] This revolution will alter the political, social, and economic structures of our world—and thus the character of warfare.

Technological advances are already changing the political, economic, and social structures of society, and thus how those societies apply technology to war. The convergence of revolutionary improvements in electronic miniaturization, additive manufacturing, nanotechnology, artificial intelligence, spacelike capabilities, and unmanned systems (drones) will dramatically change the character of conflict in all domains. Of particular concern, this convergence is making capabilities available to almost all states and even some nonstate actors—capabilities that were once the preserve of superpowers. These advances will continue to evolve over the next decade or two, but their effects are being felt on global battlefields today.

Electronic Miniaturization

We have watched electronic miniaturization transform almost every aspect of our personal lives. So it is not surprising that miniaturization is revolutionizing command and control and intelligence, surveillance, and reconnaissance systems, as well as bringing smart technology to smaller and smaller weapons systems. Today, even very small, cheap drones are capable of limited autonomous navigation and target selection. As 3D printing of circuit boards matures, ever cheaper and smaller computing components will be widely available and used in an increasing range of commercial products, making them easily available to small states and even nonstate actors.[18] Manufacturers have even begun printing circuits hardened against radiation that will protect the electronics against some types of directed energy weapons.[19]

Additive Manufacturing

Additive manufacturing (AM), or 3D printing, is more than 30 years old. In the last 20 years, it has been a very useful tool for rapid prototyping to allow designers to see their final product in three dimensions. In the last few years, AM has exploded. It has evolved from an interesting hobby to an industry producing a wide range of products from an ever-growing list of materials. AM is dramatically increasing the complexity of objects that people can produce while simultaneously improving speed and precision. United Parcel Service (UPS) has created a factory of 100 printers with room to increase to 1,000.[20] It accepts orders, prices them, prints them, and ships them the same day from the adjacent UPS shipping facility. Printing speeds depend greatly on the materials used, the part being printed, and the printing process employed. Yet, regardless of process, the last few years have seen steady increases in the speed of 3D printing, varying from 10 to 100 times faster. In April, Dr. Joseph DeSimone released his Carbon3D printer, which has achieved speeds 100 times faster than previous methods. DeSimone has set a goal of printing 1,000 times faster while providing higher quality than current methods.[21]

Nanotechnology

Established in 1981, nanotechnology is science, engineering, and technology conducted at the nanoscale, which is about 1 to 100 nanometers. For comparison, a sheet of newspaper is about 100,000 nanometers thick.[22] At this scale, materials act very differently and, thus, provide opportunities in chemistry, biology, physics, materials science, and engineering. For the purposes of this article, nanotechnology is advancing in two areas of particular interest for the military: energetics and materials. As early as 2002, nanoenergetics (explosives) reportedly were capable of generating twice the power of conventional explosives.[23] Since research in this field is now close hold (considered sensitive if not classified), it is difficult to say what progress has been made since then. Even if twice the power is as good as it gets, a 100-percent increase in the destructive power of any weapon is a massive increase. Continued major improvements in the power of explosives will steadily reduce delivery system requirements, which will favor smaller states in adversarial positions. Using unclassified sources, a recent book, *Nanoweapons: A Growing Threat to Humanity*, states nanoexplosives have reached between 4 and 10 times the explosive power of conventional explosives.[24] When nanoexplosives come into commercial use, they will also be available to nonstate actors.

The second area is that of nanomaterials. This field has not advanced as far as nanoenergetics, but numerous firms are applying nanomaterials to the production of batteries and to increase their storage capacities.[25] In fact, a recent accidental discovery may triple battery power storage and increase battery life

by a factor of four.[26] At the University of California, San Diego, researchers have found a cheap way to coat products with a super-thin, nonmetal material that manipulates radar waves, which has the potential to provide inexpensive stealth coatings for missiles and aircraft.[27] These improvements in energy storage, materials, and explosives will lead to increases in range, payload, and stealth for a wide variety of vehicles, to include cheap drones.

Space and Space-like Capabilities

Until recently, cost and technology requirements limited the number of nations that could venture into space. This provided a great advantage to those few countries that could do so. Not the least of these advantages was the ability to see any location on the globe. The addition of cheap, persistent space-based and air-breathing surveillance will soon provide small states and even nonstate actors access with a full suite of space and space-like capabilities. They will be able to surveil American forces from their home stations in the United States through theater hubs all the way to their frontline positions. Furthermore, they will be able to communicate with their people globally and perhaps even attack other satellites in space. The DOD has acknowledged the threat and is taking steps to protect U.S. space infrastructure.[28]

While some states, particularly China, are steadily improving their own space capabilities, the democratization of space is being driven by private companies. Several companies are deploying cube satellites, or CubeSats, today. Already CubeSats (university-class spacecraft) with basic payloads can be purchased for less than $125,000 with a lead time to build of only a few months. New Zealand's Rocket Lab is proposing to conduct weekly launches specifically for CubeSats to provide a rapid, cheap launch capability, and the Indian Space Research Organization just launched 104 satellites on a single rocket.[29] If an organization cannot afford to launch its own cheap satellites, Planet, created when Planet Labs bought Google's Terra Bella, plans to image the entire planet daily and take taskings for half-meter-resolution as well as high-definition imagery, including interpretation of what the buyer is seeing.[30] Using this service, a buyer, perhaps posing as a shipping company, could track port, airfield, road, and rail system activity in near real time. Other companies are duplicating space capabilities with systems that remain in the atmosphere. Balloons—such as those launched as a part of Project Loon (by X, formerly Google X)—and drones, such as the Global Observer drone and solar-powered follow-ons, will provide space-like communications and surveillance capabilities at much lower costs.[31]

It remains impossible to predict which technology will eventually win out. But it is fairly clear that the space capabilities formerly limited to superpowers will now be available to a wide range of customers via commercial

sources. It means that soon expeditionary forces will not be able to "disappear" at sea. Even hastily established expeditionary bases will be quickly found and imaged.

Artificial Intelligence and Drones

Two areas of artificial intelligence are of particular importance in the evolution of small, smart, and cheap weapons: navigation and target identification. In fact, widely available systems have attained limited autonomy based on these capabilities. The U.S. Global Positioning System (GPS) has proven satisfactory for basic autonomous drone applications, such as the Marine Corps Lockheed Martin/Kaman K-MAX helo-drone in Afghanistan.[32] GPS will be insufficient, however, for operations in narrow outdoor or indoor environments, dense urban areas, and areas where GPS is jammed. Academic and commercial institutions are working hard to overcome the limitations of GPS to provide truly autonomous navigation for drones. Inertial and visual navigation are advancing rapidly and are already cheap enough to use in small agricultural drones.[33] Clearly, the commercial applications for navigating in agricultural areas and inspecting buildings in urban areas can be adapted for military uses. Such a system would serve to get a drone to the target area but will not ensure it can hit a specific target. To select a specific target, there are already commercially available optical and multispectral recognition technologies in use today that allow autonomous drones to attack specific classes of targets and perhaps specific individual targets.[34] And they are cheap.

Of particular concern, autonomy means drones will be highly resistant to jamming and will be able to operate in very large numbers. They also can be programmed to wait patiently prior to launch or even proceed to the area of the target and then hide until a specified time or a specified target is identified.

Drone usage has spread widely. Many discussions about drones have focused on large, highly capable, and expensive drones, such as the General Atomics MQ-1 Predator, used primarily by the Air Force, or Northrop Grumman X-47B, used primarily by the Navy.[35] Too little discussion has considered the impact of small drones in all combat domains. While small drones can carry a limited payload, this limitation can be overcome with three approaches. First is to think in terms of *bringing the detonator*. In this case, the objective is to simply detonate the large supply of explosive material provided at the targets—aircraft, vehicles, fuel, chemical facilities, and ammo dumps. Against these targets, even a few ounces of explosives delivered directly can initiate a much larger secondary explosion or release of toxic material.

The second approach is the use of explosively formed penetrators (EFPs).[36] EFPs, weighing from as little as a few ounces to a few pounds, will allow even small drones to damage or destroy armored and protected targets. In Iraq,

Coalition forces found EFPs in a wide variety of sizes, some powerful enough to destroy a General Dynamics Land Systems M1 Abrams tank.[37] Others were small enough to fit in the hand—or on a small drone—yet still punch though one-half inch of steel using only about 30 grams (.07 pounds) of explosive.[38] And, of course, nanoexplosives can at least double the destructive power of these weapons. The primary limitation on Iraqi EFP production was the requirement for high-quality curved copper disks that form the penetrators when the charges are detonated. This type of production required a skilled machinist with high-quality machine tools. Today, additive manufacturing can print copper.[39] Anyone with a 3D printer capable of using copper will be able to print an EFP disk. Thus, we can expect small- and medium-size drones to pack a significant punch against protected targets. The improvised explosive devices of the future will not simply sit and wait. They will be intelligent, inexpensive, long-range, and active hunters.

One can argue that long-range autonomous drones will be difficult for nonstate actors to obtain for the next few years. That may be true. But today, Aerovel sells the Flexrotor drone, which has a maximum range of 3,400 km, for $200,000 or about the average operating cost of a single Lockheed Martin F-35 Lighting II or F-22 Raptor training mission.[40] For shorter-range missions, there are a large variety of commercially available cheaper drones that have a range of 20–500 km.[41] Moreover, ISIS has been employing a variety of drones in Iraq and Syria.[42]

The third approach is to employ swarms of small drones to magnify their impact. Drones will not be limited to attacking soft targets. The U.S. military is actively exploring the use of swarms for both air and naval applications.[43] These programs are consistently and rapidly increasing the number of drones they are able to employ. The recent dramatic cost reductions in each of the needed technologies will increase the number by orders of magnitude. Three years ago, researchers used old 3D techniques to print a complex drone in a single day, then added an Android phone to produce an $800 autonomous system.[44] This is less than the cost of an RPG-7 (rocket-propelled antitank grenade launcher) with one round.[45] A small factory with only 100 DiSimone Carbon 3D printers could potentially produce 10,000 such drone bodies per day. The limitation is no longer the printing but the assembly and shipment of products. The Marine Corps has to start thinking about this type of drone as expendable rounds of ammunition. How do we protect our air bases, headquarters, maintenance facilities, and supply centers in theater against potentially thousands of autonomous drones? Even if the U.S. military can protect such fixed sites, how will it protect its vehicles, in particular soft-skinned vehicles such as fuel and ammunition trucks, when they are moving?

Cheap drones also will not be limited to the air. In 2010, researchers at

Rutgers University launched an underwater "glider" drone that crossed the Atlantic Ocean unrefueled. Such drones are being used globally and cost about $100,000. In 2013, the U.S. Navy launched its own underwater glider that harvests energy from the ocean *thermocline*, or differences in water temperature at different depths. It can patrol for weeks, surfacing only as needed to report and receive new instructions.[46] In short, small-sea platforms have demonstrated the capability of achieving intercontinental range while producing very little in the way of signatures. Engineers at Michigan Technological University plan to reduce the cost of oceanic gliders to about $10,000.[47] It will not take a great deal of development to turn these into self-deploying torpedoes or smart naval mines.[48] Current versions are launched by hand from small boats or the shore. They could be modified for launch from warships and larger commercial ships.

The Implications of Convergence

The convergence of new technologies discussed above may allow these small, smart, and cheap weapons based on land, sea, or air to dominate combat in these domains. Over time, the technology has become cheaper, more reliable, and more widely employed. We are seeing this with the explosive growth in commercial drones. The Federal Aviation Administration predicts sales of unmanned aircraft to grow from 2.5 million in 2016 to 7 million units in 2020.[49] This may well be a low estimate. Commercial demand is driving costs down while dramatically increasing capabilities. Advanced manufacturing techniques will soon make them cheap enough for small companies, or even individuals, to own a large swarm of simple, autonomous, powerful drones.

Obviously, a key question is: How will forces make the transition to this new generation of weapons and, even more important, how fast? History provides numerous examples. Two demonstrated the same pattern: firearms replacing pikes in ground combat during the sixteenth century, and the modern carrier and its aircraft replacing the battleship as the key weapon for naval combat in the Pacific during WWII. In each case, the new technology started out as an experiment and was initially deployed as a novelty. As the inventors and military innovators worked together, they figured out how the new technology could assist the old—musketeers initially operated on the flanks of the Spanish *tercio*, and aircraft became the eyes of the fleet. As the technology improved, it became a partner with the old—muskets were integrated into the tercio formation, and aircraft became another striking arm of the fleet. Technology continued to improve until it replaced the existing system—muskets with fixed bayonets replaced the pikes completely, and aircraft carriers replaced battleships.

The time required for these two transitions varied greatly from more than a century for the musket to about two decades for the aircraft carrier. As Klaus

Schwab has noted, however, the Fourth Industrial Revolution is happening faster than any previous revolution; thus, we should expect the new generation of small, smart, and many to quickly replace the old generation of few and exquisite weapons.

It is useful to consider where the various technologies are on the path from assistant to partner to replacement. Clearly, the mission of long-duration surveillance in a low-threat environment has been assumed by drones. In high-threat environments, CubeSats are becoming partners in the surveillance and intelligence missions. Ballistic and cruise missiles are already full partners with strike aircraft and, in some situations, are replacing manned aircraft. Less expensive drones are beginning to appear in various conflict areas for tactical observation and even strike. For air superiority, drones are being considered as partners with the F-35 and may provide an alternative approach by destroying enemy aircraft on the ground. Each technology will develop at its own pace, but will likely replace most of our legacy systems within the next two decades.

Strategic Implications

Technological convergence will accelerate over the next decade or two. It will have direct strategic impact on the United States in four principle ways: the loss of immunity to attack, the tactical dominance of defense, the return of mass, and a requirement to mobilize.

Loss of Immunity to Attack

The United States has enjoyed immunity from attack along its lines of communications and at its intermediate staging bases. Until recently, no potential enemy had the ability to track U.S. movements in real time or the long-range strike necessary to intervene. America has already lost its monopoly on long-range, precision strikes. China and Russia have repeatedly demonstrated this capability. Soon, long-range, relatively cheap, autonomous drones will provide this capability to many states, and even insurgent or terrorist groups. These vehicles will provide the capability to strike air and sea ports of debarkation and, perhaps, embarkation. Commercial space imagery will allow small states, insurgents, and terrorists to track U.S. movements in near real time. Global secure communications will allow them to coordinate and execute actions even at intertheater ranges.

In short, the United States will no longer be able to project power with impunity. This could create major political problems in sustaining a U.S. effort, both domestically and internationally. Barring a direct attack on American soil, will the public support distant actions if they result in a significant threat to the nation's security or its economy? The small, smart, and many revolutions will allow enemies to undermine the U.S. economy. Even a few self-deploying

mines in key overseas container ports would drive up maritime insurance rates and, hence, the cost of imported and exported goods.[50]

Internationally, opponents can threaten intermediate bases. For instance, a great deal of U.S. support for Iraq flows through Kuwait. Suppose ISIS strikes an aircraft sitting at Kuwait International Airport. Is the United States prepared to provide the level of defense required to protect such targets throughout the nations that are providing facilities in the Middle East and Europe? Will it expand the protection to all key targets in those states? Will those states trust America's ability to do so? If not, will those states accept risk to their commercial assets to support U.S. actions?

Tactically Dominant Defense

While these systems create a genuine threat to all nation states, they and their descendants will provide a significant boost to anyone's defense. In state versus state war, this may create a situation similar to that between 1863 and 1917, where any person in range moving above the surface of the ground could be cheaply targeted and killed. The result was static trench warfare. Drone swarms may again make defense the tactically dominant form of warfare in ground, air, and sea domains and be able to attack the physical elements of the cyber-domain. Able to reach out thousands of miles in the surface, subsurface, and air domains these systems—augmented with cruise and ballistic missiles—may render older air and sea systems obsolete.

For their part, nonstate actors can use these systems to dramatically increase the cost of maintaining U.S. forces in a combat theater. The small size of many of these systems makes them ideal weapons for attacking U.S. airfields and base camps. Easy to hide, transport, and operate, cheap drones with even limited autonomy will require massive investment in the protection of American logistics facilities and lines of communication in a tactical environment. Proponents of directed energy weapons (e.g., lasers and microwave systems) suggest these systems will defeat such swarms and, thus, return offense to the tactical battlefield. Unfortunately, these systems are still expensive and power hungry. Moreover, they are subject to defeat by relatively inexpensive countermeasures.

While the DOD must continue to develop these systems, politicians and military planners also must be aware that they put this nation on the wrong side of cost competition with cheap drones. And like all weapons systems, directed energy weapons can be neutralized. It is imperative that these systems be tested against a thinking, reacting, simulated enemy that employs countermeasures, such as autonomy, smoke, and electromagnetic shielding. If such systems become capable of defeating thousands of drones, they also may be able to defeat the much smaller number of conventional aircraft, guided bombs, and

missiles the United States can deploy. This would reinforce the dominance of the defense.

At this point, it is impossible to tell which systems will dominate. Thus, it is essential that the DOD run rigorous experiments to understand the character of such conflicts. If the experiments show the defense will become tactically dominant, DOD will have to determine how U.S. forces can exploit this situation to achieve their inherently offensive operational and strategic missions. A key question that must be explored is whether land power—by making use of the advantages of complex terrain, unlimited magazines, massive power networks, and ever-increasing range and speed of land-based weapons—will come to dominate the air, sea, and space domains.

The Return of Mass to the Battlefield

Since the 1980s, U.S. forces have bet on precision to defeat mass.[51] Precision helped numerically smaller Coalition forces defeat Iraq's much larger army as well as initially drive al-Qaeda and the Taliban out of Afghanistan. Technological convergence, however, is pointing to the revival of mass (in terms of numbers of weapons) as a key combat multiplier. Current manufacturing techniques mean states can manufacture thousands of drones. How will our forces, which are dependent on a few, exquisite platforms—particularly air and sea platforms, such as jets and carriers—deal with the small, smart, and many? Will the United States have to respond by creating its own mass of small, smart, and many?

The Return of Mobilization

After the fall of the Soviet Union, the United States abandoned the concept of mobilization. The immediate threat had disappeared and mass mobilization was no longer seen as necessary. At the same time, the new weapons systems we were fielding, such as the Northrop Grumman B-2 Spirit Stealth Bomber and F-22, were so complex that only a single company built each; and those companies could not rapidly expand due to the special equipment and training necessary to build these systems. The painful fact is the U.S. defense industry today lacks the surge capacity to rapidly equip a mobilized population. Mobilization in World War II was possible because civilian industry could rapidly convert to military production. By 1990, the complexity of modern military weapons systems and limited capacity to produce them made rapid mobilization impossible. As Richard Danzig noted in *Driving in the Dark*, modern manufacturing has been changing this situation.[52] Additive manufacturing (AM) may radically change it. AM is inherently flexible, since the product produced depends only on the materials the printer can use, the design of the printer, and the software that is loaded. With a change of software, these printers can

go from producing commercial products to producing weapons. Thus, as AM assumes a greater role in industry, the possibility of industrial mobilization will reemerge. Successful mobilization, however, is not just about producing the weapons. The Pentagon and the Marine Corps also must be prepared to enlist and train new personnel, build them into coherent units, and then move those units and the weapons to an overseas battlefield. Professor Eliot Cohen noted successful mobilization will require significant peacetime planning, but the Pentagon is not even thinking about the issue.[53] Failure to do so means it will take that much longer to exploit the new technology to build and deploy the large number of weapons needed in a fight with an enemy who focuses on small, smart systems in very large numbers. In short, it may mean our forces are overwhelmed by numbers.

Implications for Power Projection

The implications of the Fourth Industrial Revolution for modern expeditionary operations ashore, including power projection, will vary depending on the enemy and location of the fight. Keep in mind these technologies are still in their infancies but, within a decade, will have a major impact and, within two decades, are likely to dominate the battlefield.

This article considers conflict with a near-peer competitor, a smaller nation state, an insurgency, and social disorder. The most capable near-peer competitor is obviously China. Fortunately, against China, the dominance of the defense can actually work for allied forces if the United States chooses a strategy of holding the first island chain while denying Chinese use of the waters inside the first island chain or access to the ocean beyond.[54] Land-based systems already have a wide range of advantages against attacking air and sea forces, and that advantage will grow significantly as the Fourth Industrial Revolution unfolds.

Defenders can build such systems as the U.S. Navy's experimental Low-Cost UAV Swarming Technology (LOCUST) launcher or the Chinese Harpy multiple launchers into commercial 20-foot containers. Advances in 3D printing will allow massive numbers of these systems to be produced. With the addition of a container, every commercial truck and virtually every seagoing vessel can become a weapons system. It will be impossible to find such mobile systems in the complex, cluttered terrain of the first island chain or cluttered harbors and inshore waters where smaller, ocean-going fishing boats can hide. Thus, preemption by the attacker is not an option. Reinforcing the advantage of land forces are the fact they will have much larger magazines and access to massive power infrastructure to power potential directed energy weapons when they are developed.

Naval forces will play several key roles in such a conflict. First, amphibious

forces can either seize or hold key islands near a strait. Much like the Marine defense battalions of World War II, these units, using autonomous air and sea drones supported by land-based, antiship cruise missiles, can create defended zones in the air, sea, and subsurface (e.g., Teledyne Slocum Glider-type mines) for key points in the defense. These forces could be forward deployed or move into theater to fall in on preposition assets or as part of an amphibious task force. The key is to move before the enemy can establish defenses in the area. Once ashore, the landing force must very quickly establish layered air and sea defense of the surrounding area. These forces, along with any allied forces in the first island chain, will provide anchor points for naval forces to execute additional missions, blocking penetrations of the island chain, periodically project striking power into the China Seas, and contributing to the necessary blockade of commercial traffic.

Obviously, the Corps will require considerable reorganization and reequipping to fulfill the defense battalion role. In addition, the joint force is going to have to get serious about mine warfare, both seeding and clearing. Offensively, U.S. Pacific Command is leading the effort to use relatively inexpensive target detection devices (fuzes) to turn any MK80 series low-drag general-purpose bomb body into a Quickstrike smart sea mine.[55] These air-dropped mines can quickly establish a minefield at the outbreak of hostilities. The DOD should then also invest in developing self-deploying mines based on the Slocum Glider drones. If developed, these mines could be delivered by virtually any ocean-going vessel and even be deployed from shore.

Essentially, this concept recognizes that A2/AD works both ways. The East and South China Seas will be heavily contested with the advantage going to the side operating under the cover of land-based systems. Numbers will count. Both sides will look for creative ways to increase the number of weapons systems as well as ways to clutter the tactical picture. The fact that China has almost 200,000 ocean-going fishing vessels, most large enough to carry 20-foot containers, provides an idea of the magnitude of the problem.[56] As part of a first island chain defense, the allies will have to develop the ability to deal with massive numbers of potential attackers. They have about a decade to develop and demonstrate that ability.

The situation with Iran is very different. The fact remains that the world economy runs on oil and the Middle East provides 17 million of the 97 million barrels the world consumes daily.[57] If the Iranians close the Strait of Hormuz, the world economy will crash. Currently, the United States and its allies have the capability to reopen the strait, and quickly. It is essential, however, that the Pentagon wargame the impact of Iran obtaining cheap sea, air, and subsurface drones to close the strait. How will we have to modify operational and tactical approaches? As the Iranians develop long-range precision systems, the Unit-

ed States will have to consider how it structures and protects key facilities in friendly states throughout the region. Here again Marine defense battalions could be very useful.

If the national command authority determines that U.S. forces have to land in Iran, the best option for amphibious forces may be to take to the operational offensive but tactical defensive. If we cannot quickly solve the problem of masses of smart, small weapons, then assuming the tactical defensive may be the only viable option. For example, the amphibious force could get astride a key line of communication, then dig in quickly and force the Iranians to attack. Getting dirt overhead as well as reducing unit signatures will make the amphibious forces much less vulnerable to the wide variety of smart, mobile weapons systems being developed today. In contrast, Iranian forces will be above ground and moving and, hence, vulnerable.

As noted earlier, current doctrine will not work against the insurgencies emerging from failed states across Africa and the Middle East. The United States will have to develop new political, diplomatic, strategic, and operational approaches to deal with this type of instability. Whatever approach the nation chooses, the Marine Corps will have to overcome new tactical challenges if it is going to operate in these environments. The biggest challenge will be maintaining fixed facilities and lines of communication. Even relatively small and poorly funded insurgent groups will be able to afford large numbers of autonomous weapons with ranges in excess of 40 km. They will have access to smaller numbers of systems with ranges from 500 km to the Flexrotor's 3,400 km.[58] Some will be remotely controlled and, therefore, vulnerable to electronic countermeasures, but others will be autonomous and, thus, harder to defeat.

This directly challenges one of the traditional U.S. strengths. Since the Civil War, the United States has established major supply depots at varying distances from the front lines. In counterinsurgency campaigns, we have even established platoon and company patrol bases inside enemy-dominated areas. These bases provided the lavish logistics that have characterized the American way of war. In the very near future, defending these facilities will be expensive and difficult. The Corps must continue its efforts to minimize logistics requirements even as it builds significant self-defense capabilities into its logistics units. Even when the Corps masters these challenges, it will still face the challenge of protecting high-value host nation targets. Everything from political leaders to public gatherings to economic infrastructure will be vulnerable to attack. Since the fundamental function of Marine units or advisors is to establish a secure environment for the government, protecting these types of targets will be an essential part of the mission.

Even one of the historic Marine Expeditionary Unit (MEU) tasks—non-

combatant evacuation operations—will be much more challenging. We have seen cheap drones used in Syria and Ukraine. Marine forces must expect drones in situations where different factions are fighting for control of a capital city (the driving cause of many previous evacuations). Soon all factions will acquire inexpensive drones and, thus, pose a threat to U.S. evacuations. Currently, MEUs have sufficient resources to deal with the limited threat likely from this type of enemy. Tacticians simply must add them as another planning factor. This situation, however, will change quickly and the Corps must start thinking about how a MEU can execute future missions in unstable regions.

In all cases, logistics is the key vulnerability of U.S. forces. Fixed bases, forward logistics sites, and logistics systems moving into the battlespace will be the most exposed parts of the power projection force. The Corps will have to join the other Services in figuring out how they will move forces into an area, protect them, and then support them without resorting to numerous fixed bases.

Where to from Here?

The Corps needs to experiment with and test new concepts as well as rethink its operations, tactics, and force structure. To develop and test new concepts, the Marine Corps must initiate wide-ranging research and supporting analysis as well as intensive wargames and live exercises to address key questions. Like the shift to amphibious operations, this transition should be led by the Corps' educational institutions. The Basic School led the way in experimenting with drones. The Expeditionary Warfare School, Command and Staff College, and the War College should lead the intellectual effort to understand the Fourth Industrial Revolution and its implications for expeditionary operations.

Operationally, the Corps will have to carefully consider if and when the tactical defensive will become dominant and what to do about it. Geography means the United States must be on the operational offensive to have any impact outside of the country. Thus, the Corps has to consider how to exploit the growing advantages of the tactical defense through the application of operational art. For instance, maritime prepositioning operations remain the fastest way to deploy a large, capable Marine force. How will we keep this option viable in an era when ports will be imaged several times a day and threat will arrive by air, sea, and subsurface routes? Clearly, it will require a layered defense employing all joint assets. Who pays for the development, procurement, and deployment of such a defense? How is it employed in a power projection operation? The Corps, and the joint force as a whole, will have to carefully consider the mix of prepositioned equipment (both sea and land), forward-deployed forces, and home-stationed forces in light of the changing threat environment. Amphibious forces may be uniquely suited to exploit these changes. They have the range and flexibility to seize a line of communication or a lightly defended

key enemy asset before an enemy can respond. The objective will be to force the enemy to either give up a key asset or conduct offensive operations in an effort to regain control of that asset.

Tactically, the Corps has to figure out how to protect every system in its inventory from guided rockets, artillery, missiles, and mortars and small, smart drones that are increasingly maneuverable and longer ranged. In particular, it must protect its highly vulnerable logistics elements, air bases, forward arming and refueling points (FARPs), and lines of communication from repeated swarm attacks as well as persistent individual or small group attacks. Providing sufficient overhead cover will go a long way toward protecting fixed facilities, but that still leaves the incredibly complex problem of protecting mobile assets. Tactical adaptation will not be enough. The Corps will have to work hard to reduce its logistics requirements across the board. Keep in mind that the logistics chain can be threatened throughout its length.

Fortunately, there is time to develop and implement the changes. Like all major shifts in history, the Fourth Industrial Revolution will be phased in, but it will not be an easy process with clear decision points. If the development of this new generation of weapons mirrors our past experiences, it will take place over a decade or two. The new systems will first support our legacy systems, then the legacy systems will support them, and finally the new systems will completely supplant our legacy systems. Compounding the difficulty of deciding when to shift investment is the fact that we plan to use the weapons we are buying and developing today for decades. Will manned aircraft, dominant when we started developing the F-35, be dominant or irrelevant in two decades? While an extremely difficult question to answer, this transition represents one of the critical investment decisions facing Pentagon planners. And all decisions will have to deal with the political issues integral to cancelling or reducing any program of record. Thus, organizational change will be both difficult and risky.

Ground forces, specifically Marine artillery, were the first to explore the use of drones to augment their existing systems. Today, Marine ground units are aggressively exploring how both air and ground drones—to include unmanned systems—are changing the battlefield. An element of these experiments must consider how a new generation of cheap drones can be employed as rounds of ammunition to replace traditional ground weapons systems and alter the composition of maneuver units.

Logistically, the Corps is already using the K-MAX and drones to replace manned aviation for some missions. Driverless trucks and small craft obviously have enormous potential. The Corps also has excellent initiatives for reducing the logistics burden of providing expeditionary power and water production.

Aviation faces much greater challenges. The X-47B drone shows the potential for high-end and expensive drones. And the increasing proliferation of

less expensive drones for reconnaissance, logistics, and communications links show a small part of the potential the Fourth Industrial Revolution will produce. Is the current plan of purchasing a few extremely capable platforms, such as the F-35, viable in a world where cheap, smart weapons in large numbers will actively hunt those exquisite platforms? In the November 2016 *Marine Corps Gazette,* a team of officers highlighted how badly current Marine Corps investment is skewed toward the F-35 when compared to similar investments in ground forces.[59] The article did not even take into account the fact the Corps will have to invest a great deal more to protect the F-35 bases, FARPs, and maintenance facilities against the emerging threat. Even today, relatively inexpensive drones have double the operational range of the F-35. There is little possibility of increasing the F-35's range, but vast potential for increased range in cheap drones.

Furthermore, wide-area persistent surveillance is likely to reveal the locations of F-35 bases to include distributed facilities. The Corps has bet the future of Marine aviation on an increasingly vulnerable and expensive platform that will provide little help against a rapidly evolving generation of small, smart, and cheap attackers. It needs to explore how a family of less expensive, and often autonomous, drones can assume many of the functions of Marine aviation.

Summary

The purpose of this article is to begin to frame the problem of future warfare as a basis for the numerous changes Marines must be prepared to make if they are to be ready for an uncertain future. The implications of the Fourth Industrial Revolution for the Corps are too complex to lay out in a single article. But it is clear that, whether forward deployed or deployed in a crisis, the increased vulnerability of U.S. forces to stand-off attacks will dramatically impact the U.S. force structure. The era of uncontested movement and air dominance is rapidly drawing to a close. The needed changes will be comparable to the interval between WWI and WWII, when the Corps had to completely rethink its mission, organization, and tactics. Two prime organizational traits of the U.S. Marine Corps—learning and remembering—did not, and must not, change. To learn about its possible role within the Fourth Industrial Revolution, the Corps must aggressively experiment, challenge, and test our concepts and doctrine. Fortunately, forward-thinking leaders in our Corps are pushing innovative solutions, from the introduction of cheap drones in our company-level exercises to the experimental battalion to the K-MAX supply helicopter to sea basing major combat elements. If history is an example, the hardest part will be using what the Corps learns to change its programs of record.

Just as important as learning, Marines must remember and hold onto the key cultural elements that make Marines who they are. This combination has

carried the Corps through the challenges of adapting to brigade operations in World War I, developing the amphibious techniques essential for World War II, remaining ready for the Korean War despite deep cuts across the Service, recovering from the Vietnam War, and adapting to the challenges of Iraq and Afghanistan. They can carry the twenty-first century Marine Corps into the Fourth Industrial Revolution too.

Notes

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be, but one can assume it would be more than the mere threat of potential action has had in Syria.

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